Clinical Linguistics & Phonetics, July 2006; 20(5): 387–399

Structural priming in children with and without specific language impairment

CAROL A. MILLER[1], & PATRICIA DEEVY[2]

[1]*The Pennsylvania State University, University Park, PA, USA, and* [2]*Purdue University, West Lafayette, IN, USA*

(Received 8 July 2004; accepted 12 November 2004)

Abstract

Primary objective: To determine if structural priming can be demonstrated in young children with and without specific language impairment (SLI).
Research design: A mixed-model design was used to compare children with SLI to two groups of typically developing (TD) children, and to compare priming conditions.
Methods and procedures: Eighteen children with SLI and 36 TD children (18 matched on age and 18 matched on MLU) participated. Children were asked to describe drawings compatible with both a transitive or an intransitive sentence structure, after being primed with one of the structures.
Results: All groups of children were more likely to produce transitive sentences when they had just heard and repeated a transitive prime. Children with SLI did not differ from the other groups.
Conclusions: Children with SLI show similar priming effects to TD children. Priming has promise as a method for investigating production factors in typical and atypical language development.

Keywords: *Syntactic priming, specific language impairment, sentence production, transitive construction*

Introduction

Some young children demonstrate significantly poorer language abilities than is expected for their age, despite having normal hearing, normal nonverbal intelligence, no evidence of socio-emotional or behavioral disorders, and no apparent neurological impairment. Children who fit this description are said to have specific language impairment (SLI). The prevalence of SLI in kindergartners has recently been estimated to be 7% (Tomblin et al., 1997). Children with SLI have deficits in several areas of language, but their difficulties with grammatical morphology, especially morphology expressing tense and agreement, have received particular attention from researchers. A number of hypotheses about the causes of SLI focus on the production of grammatical morphology (e.g., Rice, Wexler, & Cleave, 1995; Leonard, Eyer, Bedore, & Grela, 1997; Clahsen, Sonnenstuhl, Hadler, & Eisenbeiss, 2001).

Correspondence: Carol Miller, 110 Moore Building, Department of Communication Sciences and Disorders, University Park, PA 16802-3100, USA. Tel: 001 814 865 6213. Fax: 001 814 863 3759. E-mail: cam47@psu.edu

ISSN 0269-9206 print/ISSN 1464-5076 online
DOI: 10.1080/02699200500074339

Children with SLI characteristically omit morphology related to tense and agreement (in English, past tense *–ed*, copula and auxiliary *is* and *are*, third person singular present tense *–s*) to a greater degree than age-matched typically developing children (Leonard, 1998). Such omissions may be due to phonological limitations, or to a failure of grammatical knowledge (Rice et al., 1995; Clahsen et al., 2001). Another possibility is that omissions are due to a failure in the production process. That is, children have knowledge that tense and agreement are required, and know what morphemes fulfill those functions, but are not able to reliably deploy their knowledge (Bishop, 1994). In order to investigate the hypothesis that production factors play a role in SLI, it is important to understand the mechanisms involved in the production of sentences. The psycholinguistic study of adults has provided useful methods for investigating these mechanisms.

Structural priming in adults

The method of structural priming (e.g., Bock & Loebell, 1990; Bock & Griffin, 2000; Branigan, Pickering, Stewart, & McLean, 2000) has been used to investigate sentence production processes in adults. Structural (sometimes called syntactic) priming means that a person is more likely to produce a particular syntactic structure, say a passive sentence, if they have recently heard and produced a different sentence employing the same structure. Usually, participants are induced to produce primes by repeating an experimenter's model, and then the target sentence is elicited by asking participants to describe a picture that is compatible with more than one syntactic form (e.g. either active or passive). The participant is more likely to produce a passive if they have just heard and repeated a passive. Repeating the prime sentence may not be necessary; Branigan, Pickering, and Cleland (2000) found large priming effects when the participants heard, but did not repeat, the prime.

A model of sentence production such as that proposed by Bock and Levelt (1994) explains structural priming by positing stages in the production of a sentence. A message is formulated, and then lexical concepts are selected and assigned functions such as subject or object. Next, the selected constituents are assembled into a sentence frame which determines phrase structure and word order. Grammatical inflections are retrieved separately from lexical items and are attached to the sentence frame. When someone hears and repeats a sentence, a sentence frame is activated; the increased activation makes the frame more readily available for production of a new sentence.

Structural priming in children

The structural priming method has been adapted for use with young children (Leonard et al., 2000; Leonard et al., 2002; Savage, Lieven, Theakston, & Tomasello, 2003; Huttenlocher, Vasilyeva, & Shimpi, 2004). Savage et al. (2003) were interested in assessing the degree to which the syntactic structures produced by young children are abstract; that is, able to be used productively with a wide variety of lexical items. Savage et al. found that 6-year-olds could be primed to use active or passive sentences by structure alone, independent of the words used, whilst 3- and 4-year-olds were primed only by sentences that shared lexical items with the target sentence. The shared lexical items were simply the pronoun *it*, which could be used to describe any of the target pictures (*It pushed it*/*It got pushed by it*), as they all involved inanimate objects. Savage et al. also found a cumulative priming effect, in that more children produced a passive sentence in response to a passive prime in later trials compared to earlier trials. These results are consistent with findings in adults (Bock & Griffin, 2000; Branigan et al., 2000) that priming persists over several minutes, even when other sentences intervene.

Huttenlocher et al. (2004) investigated syntactic priming in 4- and 5-year-olds. Following examples from the adult literature (e.g., Bock & Loebell, 1990), the authors primed active vs. passive sentences, and double object vs. prepositional dative sentences. They found evidence of priming with both pairs of constructions, and showed that priming occurred even if the child did not repeat the prime sentence (Experiment 2). In their Experiment 3, Huttenlocher et al. found evidence that priming persists across several trials. They presented children with ten massed prime trials, followed by ten massed target trials. The effect of the primes persisted across the entire set of ten targets. Again, these results are consistent with findings in adults (Bock & Griffin, 2000; Branigan et al., 2000).

Leonard and colleagues (Leonard et al., 2000, 2002) adapted the structural priming paradigm to investigate the use of the grammatical morpheme auxiliary *is* by children with SLI. In these studies, the children with SLI ranged from 4 to 7 years of age and were compared to typically developing children, selected because they were variable in the use of auxiliary *is*. These children were therefore younger, ranging from 2 to 5 years of age. The studies showed that when primed with a present progressive sentence using *is* or *are*, all children increased their use of *is* in target sentences. For example, after correctly repeating a sentence such as *The witch is riding the broom*, children were more likely to produce a sentence including an auxiliary *is* in response to a picture of a fish eating a worm. Both children with SLI and typically developing children demonstrated priming effects. The dependent measure in these studies was production of a specific morpheme, unlike most priming studies, in which the dependent measure is use of a target sentence structure. However, use of the auxiliary *is* required use of an appropriate sentence structure (i.e., present progressive).

Structural priming has proven useful in the investigation of sentence production in adults, and may prove equally useful as a tool for studying production factors in the language of children, including children with language impairment. The purpose of the present study was to provide further data pertaining to the robustness of structural priming in children with and without language impairment. Savage et al. (2003) and Huttenlocher et al. (2004) demonstrated priming of active, passive, double-object, and prepositional dative structures with typically developing children. Leonard and colleagues (Leonard et al., 2000, 2002) measured morpheme production in children with and without SLI using a priming paradigm. It was presumed that increased accuracy in morpheme production was due to structural priming, but structural priming has not been directly demonstrated in children with SLI. In the present study, we filled this gap by examining priming of transitive and intransitive structures in children with and without SLI.

We chose to prime active transitive sentences and observe their production relative to intransitives using verbs that allow an optional object. A wide range of verbs allow an alternation in which the direct object may be included or omitted. This has been referred to as the "unspecified object alternation" (Levin, 1993). The omission of the object is licensed when its meaning can be inferred in some other way.

Rispoli (1992) presented an in-depth study of children's knowledge of object omission after the verb *eat*. To use this alternation felicitously with this verb, children must be sensitive to the discourse conditions under which the object is required or can be omitted.

According to Rispoli, omission is permissible when the identity of the object is unknown or completely irrelevant. Studying the transcripts of spontaneous speech for 40 children, aged 1;0 to 3;0, he found that children were aware of these discourse conditions at approximately the age of 2;3 and at an MLU of approximately 2.4. These simple sentence structures and the alternation, then, should be within the repertoire of preschoolers, so that we could expect to observe structural priming in children as young as 2.5-years-old, and in children with SLI.

The present study, designed to assess structural priming in children with SLI, addressed two main research questions:

1. Do young children demonstrate structural priming for transitive sentences?
2. Do children with SLI differ from age- and language-matched peers in the presence or absence of structural priming?

Method

Participants

A total of 54 children participated in this study. All research procedures were conducted according to institutional guidelines for the protection of human participants. Participants in the SLI group were referred by speech-language pathologists as children who could benefit from the four-week summer therapy and research program during which this study was run. Although we do not know the specific nature of the therapy they were receiving prior to participation in this program, during the program, only language areas other than syntax and morphology were targeted (e.g., vocabulary, phonology). Participants in the TD groups were recruited primarily through fliers distributed at preschools.

All children passed an oral motor screening and demonstrated the ability to produce word-final [t], [d], [s] and [z] in monomorphemic contexts. All of the children passed a hearing screening and appeared to be neurologically unimpaired. A sample of spontaneous speech of at least 100 utterances, from which MLU was computed, was obtained from each child during the course of evaluation. In these sessions, children played with toys while interacting with an examiner. The child was encouraged to initiate topics and determine the direction of conversation and the examiner asked questions or commented in order to maintain conversation. The sample was transcribed and MLU computed using the Systematic Analysis of Language Transcripts (SALT, Miller & Chapman, 2002) coding system.

The group with SLI included eighteen children: seven girls and 11 boys aged 4;3 to 6;10 (years; months). Each of these children scored at least one-and-a-half standard deviations below the mean for their age on the *Structured Photographic Expressive Language Test–II* (*SPELT–II*, Werner & Kresheck, 1983a), a test of expressive syntax and morphology. The median percentile rank was $<1^{st}$ percentile (range=$<1^{st}$ to 7^{th} percentile). Seventeen of the children had age-appropriate scores on the *Columbia Mental Maturity Scale* (*CMMS*, Burgemeister, Blum, & Lorge, 1972), a test of nonverbal intelligence. The mean standard score was 105 (SD=9, range=90–122). Because of behavioral problems on the day of testing, the remaining child, aged 4;4, was not able to attend to the *CMMS* through its completion. He was given an alternative nonverbal IQ test, the *Leiter International Performance Scale–Revised* (*Leiter–R*, Roid & Miller, 1997) and received a standard score of 98.

The first comparison group included 18 children with typical language development who were matched closely in chronological age to the children with SLI. This group will be referred to henceforth as the TD-A group. The age of each child in the group was within 3 months of the age of a child in the SLI group. The TD-A group included six girls and 12 boys ranging in age from 4;3 to 6;8. These children scored within normal limits on the *SPELT–II*, with a median rank at the 55^{th} percentile (range=20^{th} to >99^{th} percentile). They also presented with age-appropriate scores on the *CMMS* with a mean standard score of 113 (SD=10, range=92–128).

A second comparison group of 18 TD children were matched to the children with SLI on MLU in words. They will be referred to henceforth as the TD-MLU group. Children with SLI have significant problems with grammatical morphology; thus, an MLU measured in morphemes will be more affected by this limitation than an MLU measured in words. Since our dependent measure involves the production of simple sentence forms, but not grammatical morphology, matching on MLU in words provides a direct measure of the ability to produce the forms of interest in this study.

Each of the children in the TD-MLU group had an MLU that was within .30 words of that of a child in the SLI group. This group included ten girls and eight boys ranging in age from 2;8 to 4;5. Eight were old enough to be administered the *CMMS* (Mean standard score=116, SD=10, range=103–132); the remainder were administered the *Leiter–R* (Mean standard score=123, SD=10, range=103–135). Eleven of the children were between the ages of 3 and 4 and were administered the preschool version of the *SPELT* (Werner & Krescheck, 1983b) (Median rank=41^{st} percentile, range=17^{th}–64^{th}); those over 4 were administered the *SPELT–II* (Median rank=30^{th} percentile, range=19^{th}–30^{th}); the remainder who were under three were administered the U.S. standardization of the *Reynell Developmental Language Scales* (Reynell & Gruber, 1990). For the expressive portion of the test, the mean standard score was 117 (SD=14, range=102–137); for the receptive portion of the test, the mean standard score was 117 (SD=14, range=96–127) A summary of the ages and MLUs of the two groups appears in Table I.

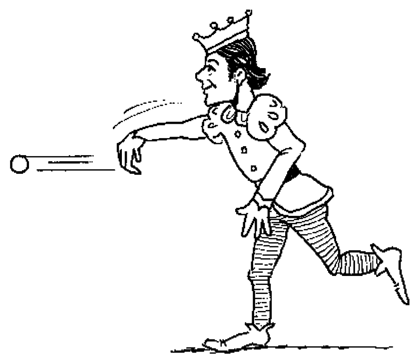
Materials

Thirty-six prime-target sentence pairs were created for the study. Black and white line drawings were created to illustrate each sentence. An example of a prime-target pair is given in Figure 1. The target sentences used 12 verbs that could be used either transitively or intransitively. For example, in describing the target picture in Figure 1, a pragmatically appropriate, grammatical response could be either "The horse is eating hay" or "The horse is eating". There were three types of primes: transitive sentences, intransitive sentences and

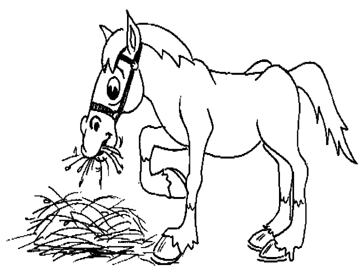
Table I. Mean ages and MLU in words for SLI and TD groups.

	SLI	TD-A	TD-MLU
Age *			
Mean (SD in mos.)	5;0 (9)	5;2 (9)	3;5 (6)
Range	4;3–6;10	4;3–6;8	2;8–4;5
MLU (words)			
Mean (SD)	4.17 (.44)	5.35 (.72)	4.16 (.41)
Range	3.44–5.08	4.36–7.52	3.17–5.03

* denoted in years; months.



Prime: The prince is throwing the ball.



Target: The horse is eating (hay).

Figure 1. Example of a prime-target pair.

non-sentence stimuli. The non-sentence primes served as controls for the sentence prime conditions. In this condition, the children were asked to simply name a set of letters, numbers, or objects, or to count a set of objects. A complete set of the materials is given in the Appendix. Although these sentences were not produced in the context of a discourse, we wanted to avoid biasing children toward omitting the object by making it appear irrelevant or by not featuring it in the picture. For all items then, a potential sentential object was shown in the picture. For example, the subject character is coloring a star in the "color" items, rather than simply shown using crayons. Because the object was present in each picture, it seemed unlikely that an effect of priming could be due to something other than the activation of a similar sentence structure by the prime.

Procedure

The pictures used in the study were presented on a laptop computer. Each child was first shown a set of pictures of the characters or animals that were used in the study's pictures. This was to familiarize them with the names and with the kinds of drawings that would be used. Most children recognized and knew the names of most characters without prompting.

After the familiarization phase, the child was told that he was going to play a "copy-cat game" in which he would repeat what the experimenter said about a picture and then say something about a picture himself. A brief practice session introduced the child to this procedure. Sitting beside the child in front of the computer, the experimenter described the first prime picture and prompted the child to repeat the sentence, if necessary. The experimenter would then advance to the target picture and prompt the child to produce a sentence, saying "And what's happening here?". If the child was reluctant to start or did not know the subject character's name, then the experimenter provided it. During the practice phase, two transitive prime-target pairs and one intransitive prime-target pair were presented; however, the targets were not optionally transitive. The point of the practice session was simply to teach the child to follow the pattern of repeating a sentence and then producing a sentence independently.

Following the practice session, one of the experimental lists was presented. The 36 prime-target pairs were divided into three lists which were blocked by condition, so that in one list, all primes were transitive sentences, in another, all were intransitive sentences, and in the third, all primes were controls. Each list presented each of the 12 target verbs once. The first list was presented at the first session; the subsequent two lists were presented on separate days. The order of presentation of the three prime lists was counterbalanced across children. The order of presentation within list was also varied for the two sentence prime lists, so that half of the children saw the list with items in one order and half saw the same set of items roughly in reverse order (the order was modified somewhat to avoid consecutive repetition of the same lexical items). Again, during the experimental lists, if the child did not readily recall the name of the subject, the experimenter would provide it. If there was an interruption after the presentation of the prime before the child could produce the target, the prime was presented again, under the assumption that priming reflects activation in short-term memory of a recently-used sentence frame. If significant time or off-task talk intervenes, presumably this will dampen the effect of the prime manipulation.

Analysis

The measure of interest in this study was the rate of transitive responses relative to intransitive responses across prime conditions. Our choice to measure the rate of transitive responses (rather than intransitives) does not imply that the priming effect will be one of facilitating transitives. The comparison to a control prime allows interpretation of the results in terms of facilitation of one structure and/or inhibition of the other.

Responses were considered scorable if they had grammatical argument structure, even if they had errors of morphology. Although it would be interesting to look for effects of argument structure choice on the use of, for example, the auxiliary *is*, the focus of the study was on the effect of the prime sentence structure on the child's target sentence structure. In addition, it would be difficult to do a careful evaluation of a child's use or omission of the auxiliary *is* since several of the prime and target verbs began with /s/. Because of assimilation between a contracted auxiliary and the initial consonant of the main verb, we could not know reliably, for all prime and target pairs, whether the child was producing both sounds or only one. In this initial study, we chose to forgo an analysis of morphology in order to use more verbs that met the structural requirements of the design.

Occasionally, children used a verb other than the one which was targeted. For example, some used the verb *draw* in the target when the intended verb was *color*. A substitution was considered scorable if it was also optionally transitive (such as *draw*) and it was a reasonable semantic substitution. Target sentences that were eliminated as unscorable were those for which (1) either the child or examiner spoke in the period between the presentation of the prime and the production of the target; (2) the child used an obligatorily transitive or intransitive verb; (3) the child used a verb with another type of argument structure (ditransitives, verbs selecting for prepositional phrases); (4) the child's choice of verb reflected a lexical retrieval error (e.g., *run* the book instead of *read* the book). Essentially, the target had to be one for which the verb chosen allowed a choice between using a transitive or an intransitive frame. Two items per prime condition were eliminated from the analysis because they yielded fewer than four scorable responses in one or more conditions; these items used the verbs *scratch* and *spray*. Mean numbers of scorable responses and standard deviations are given in Table II. The main effect of group was significant, ($F(2, 51)=3.52$, $p=.037$), and post-hoc Fisher LSD tests showed a significant difference between the TD-A and TD-MLU groups only ($p<.02$).

Results

For each condition, children's transitive responses were counted and divided by all scorable responses to yield a proportion. Because there were not equal numbers of scorable target responses for each child, percentage of transitive targets were used; these were arc-sine transformed and entered into the statistical analysis. All means are reported as untransformed percentages.

A multivariate repeated measures analysis of variance was performed on the data with group (SLI, TD-A, TD-MLU) as a between-subjects variable and prime type (Transitive, Intransitive, Control) as a within-subjects variable. The multivariate approach was used to circumvent a violation of the sphericity assumption that can occur in an ANOVA when a repeated measure has more than two levels (Max & Onghena, 1999). Effect size is reported as R^2. Cell means and standard deviations are shown in Table III.

Table II. Mean (SD) number of scorable responses per group for each prime type.

	Group		
Prime type	SLI	TD-A	TD-MLU
Transitive	7.61 (1.58)	8.11 (1.57)	6.83 (1.69)
Intransitive	8.22 (1.35)	8.67 (.97)	7.67 (1.71)
Control	8.39 (1.42)	8.28 (1.27)	7.83 (1.62)

Table III. Mean (SD) per cent transitive responses per group for each prime type.

	Group			
Prime type	SLI	TD-A	TD-MLU	*Prime type means*
Transitive	66.1 (18.6)	66.4 (17.6)	64.6 (22.2)	*65.7 (19.2)*
Intransitive	47.0 (21.3)	45.3 (29.8)	55.8 (25.1)	*49.3 (25.6)*
Control	59.4 (20.2)	62.7 (20.2)	62.3 (20.1)	*61.5 (19.8)*
Group means	*57.5 (21.3)*	*58.1 (24.5)*	*60.9 (22.4)*	

The MANOVA revealed a significant main effect of prime type (F(2, 50)=10.76, p<.0001). R^2 for this effect was .30. The main effect of group was not significant (F(2, 51)=0.25, p>.77, R^2=.01), nor was the interaction of group and prime type (F(4, 100)=0.4, p>.80, R^2=.03). Post-hoc testing of the significant main effect of prime type revealed a significantly higher proportion of Transitive responses in the Transitive and Control prime conditions, relative to the Intransitive prime condition; the Transitive and Control conditions did not differ. Mean percent of transitive responses for the Transitive prime condition was 65.7, SD=19.2; for Intransitive prime condition, M=49.3, SD=25.6; for the Control condition, M=61.5, SD=19.8.

An items analysis was performed, with prime type as a between-subjects variable and group as a within-subjects variable. The results of the MANOVA showed no significant main effect of prime type (F (2, 27)=.98, p>.35, R^2=.07) and no significant main effect of group (F (2, 26)=1.94, p>.15, R^2=.13). The interaction of group and prime was not significant (F (4, 52)=1.52, p>.20, R^2=.20).

Both Savage et al. (2003) and Huttenlocher et al. (2004) found evidence for persistence of priming across multiple trials: Savage et al. by comparing trials occurring early in a session to those late in a session, and Huttenlocher et al. by massing trials. Our study was not designed to detect persistence of priming, but we examined the data for evidence of it. Five verbs (*drive, dig, drink, read, eat*) appeared in items that occupied approximately the same position in both the Transitive and Intransitive lists (see Appendix), for both orders of presentation. For each of these verbs, we computed the overall percentage of transitive targets produced; that is, the likelihood that the verb was used in a transitive sentence, collapsed across all conditions and orders of presentation. These percentages, broken down by group, are shown in Table IV. We then computed the percentage of transitive productions when each verb occurred early in a list, and compared the percentage when the verb occurred late in a list. Based on the overall means for the three prime types, it appears that the priming effect operated by inhibiting production of transitives in the Intransitive condition, relative to the Control and Transitive conditions. Therefore, if priming effects persist over multiple trials, we would expect an equal or higher percentage of transitive utterances later in the list for the Transitive condition, but a lower percentage for the Intransitive condition. Cases in which the predicted pattern was observed are in italics in Table IV. The predicted pattern was not found consistently.

Table IV. Mean per cent transitive responses for early vs. late occurrences of five verbs.

		SLI			TD-A			TD-MLU		
Verb	Prime type	Overall[a]	Early	Late	Overall[a]	Early	Late	Overall[a]	Early	Late
Drive	Transitive	75	89	87	86	100	100	80	89	98
	Intransitive		62	66		56	75		50	67
Dig	Transitive	31	*37*	*50*	44	56	56	45	44	25
	Intransitive		*44*	*14*		33	56		13	43
Drink	Transitive	59	83	67	55	67	50	79	*100*	*100*
	Intransitive		22	37		22	22		*78*	*38*
Read	Transitive	76	*100*	*100*	76	*88*	*100*	78	86	83
	Intransitive		*62*	*22*		*63*	*38*		75	50
Eat	Transitive	80	67	89	80	*78*	*86*	83	*67*	*100*
	Intransitive		67	67		*63*	*56*		*78*	*56*

Note. Italicized cells denote instances that fit the predicted pattern if priming persists over multiple trials. [a] Per cent transitive response collapsed across Transitive, Intransitive, and Control conditions.

Discussion

Our first research question was whether very young children demonstrate structural priming for transitive sentences, and it appears that they do. We found that all three groups of children produced more transitive sentences when primed with transitives. The effect may be due more to inhibition of transitives when intransitive primes are used, rather than facilitation of transitives, which seemed to be the default form for the stimuli used in this study. Transitives were produced 62% of the time in the Control condition, which is similar to the percentage of transitives in the Transitive prime condition (66%), while in the Intransitive prime condition, transitives were produced only 49% of the time.

Unlike the analysis by subjects, an analysis by items did not show a significant effect of prime type. The effect found by subjects can be interpreted as indicating that we would likely observe a main effect of prime type with a different group of subjects, while the lack of an effect by items indicates that we would not likely observe a main effect of prime type with a different set of items (Clark, 1973). This result reflects the reality that many factors affect sentence production. Our findings support the hypothesis that structural priming is one of those factors, but they also serve as a reminder that other variables are at work. These variables can only be partially controlled, especially in young children and those with language disorders. For example, some of the pictures clearly had idiosyncratic characteristics that often resulted in off-target responses (hence the elimination of *scratch* and *spray* items from the analyses). In addition, two verbs of the remaining ten (*cook* and *sweep*) elicited very low proportions of Transitive responses (31% and 19% respectively). For these items, it was hard to depict the exact "object" of the verb to be named, essentially providing a pragmatic license to omit the object. Given these floor effects, it would not be possible to see syntactic priming of an intransitive in these items. Careful selection of materials, as well as systematic replication, will be needed in order to form a complete picture of structural priming in young children.

The second question posed in this study was if children with SLI differed from age- and language-matched peers in the presence or absence of structural priming. There was not a significant main effect of group, and the effect size for group was small. Group membership did not interact significantly with prime type, suggesting that children with SLI were primed to the same degree as the typically developing children. Examination of the means suggests that the difference in proportion of transitive targets produced was more marked for the SLI and CA groups than for the MLU group, but this difference was not large enough to drive a significant interaction. The MLU group also had a smaller number of scorable responses. In general, it seemed that the task of describing pictures was more difficult for these three-year-olds, resulting in more variable responses. Future research should explore how age relates to the ability to describe pictures using specific types of structures.

In a follow-up analysis, we asked if there was any support for the hypothesis that structural priming persists over several trials, as was found by Savage et al. (2003) and Huttenlocher et al. (2004). Examination of the pattern of means for five verbs that could be directly compared across conditions produced little evidence to support persistence of priming. These verbs were not consistently more likely to be produced in transitive form when they occurred later in the transitive list—after the child had heard and produced more transitive primes. However, our study was not designed to test for order effects. Future research designed with order analyses in mind may yield more support for persistence of priming.

For very simple transitive and intransitive sentences, structural priming was observed in young children with and without SLI. This finding confirms that structural priming can be used to explore production mechanisms in children, including children with SLI. Future research will examine structural priming in children with SLI using more complex sentences, such as dative forms, and will investigate whether manipulation of the priming conditions affects children with SLI differently than typically-developing children; specifically, we will investigate whether children with SLI demonstrate priming if they do not repeat the prime sentence aloud, as the typically developing children did in Huttenlocher et al. (2004).

The results of the present study did not support the hypothesis that priming "builds up" over trials in an implicit learning process. However, the hypothesis continues to be of interest. Bock and Griffin (2000) and Chang, Dell, Bock, and Griffin (2000) have argued that structural priming is not the transient result of activation in the production system, but is in fact a form of implicit learning. The process that leads to increased strength of a particular sentence structure observed over the course of a few minutes in the laboratory is the same process that is involved in learning to produce sentences more generally. Bock and Griffin (2000) showed that priming effects can persist over as many as ten intervening sentences. Chang et al. (2000) demonstrated structural priming in a simple recurrent network, a connectionist model that has been used to model implicit learning.

Bock and Griffin (2000) make a distinction between learning language and learning to talk.

> …learning to talk involves learning procedures—cognitive skills—for efficiently formulating and producing utterances. What structural priming suggests is that these procedures may undergo fine-tuning in every episode of adult language production. (p. 189)

They go on to suggest that structural priming may play an important role in child language development, and that "…experience with language interacts with developing language knowledge to explain changes in how children use language" (p. 189). In the SLI literature, it remains unclear whether grammatical errors are due to limitations in grammatical knowledge, limitations in production processes, or a combination of both. The structural priming paradigm offers a promising tool for investigating how children come to be able to use their grammatical knowledge readily and flexibly.

Acknowledgements

This work was supported in part by research grant R01 00-458 from the National Institute on Deafness and Other Communication Disorders to Dr. Laurence Leonard. Thanks to Laurence Leonard and the staff of the Child Language Research Laboratory.

References

Bishop, D. V. M. (1994). Grammatical errors in specific language impairment: competence or performance limitations? *Applied Psycholinguistics*, *15*, 507–550.

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

Bock, K., & Levelt, W. (1994). Grammatical encoding. In M. Gernsbacher (Ed.), *Handbook of Psycholinguistics* (pp. 945–984). San Diego, CA: Academic Press.

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

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, *75*, B13–B25.

Branigan, H. P., Pickering, M. J., Stewart, A. J., & McLean, J. F. (2000). Syntactic priming in spoken production: Linguistic and temporal interference. *Memory and Cognition*, *28*, 1297–1302.

Burgemeister, B., Blum, L., & Lorge, I. (1972). *Columbia Mental Maturity Scale*. New York: Harcourt Brace Jovanovich.

Chang, F., Dell, G. S., Bock, K., & Griffin, Z. M. (2000). Structural priming as implicit learning: a comparison of models of sentence production. *Journal of Psycholinguistic Research*, *29*, 217–229.

Clahsen, H., Sonnenstuhl, I., Hadler, M., & Eisenbeiss, S. (2001). Morphological paradigms in language processing and language disorders. *Transactions of the Philological Society*, *99*, 247–277.

Clark, H. (1973). The language-as-fixed-effect fallacy: a critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, *12*, 335–359.

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

Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.

Leonard, L. B., Eyer, J. A., Bedore, L. M., & Grela, B. G. (1997). Three accounts of the grammatical morpheme difficulties of English-speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *40*, 741–753.

Leonard, L. B., Miller, C. A., Deevy, P., Rauf, L., Gerber, E., & Charest, M. (2002). Production operations and the use of nonfinite verbs by children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *45*, 744–758.

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

Levin, B. (1993). *English verb classes and alternations: a preliminary investigation*. Chicago, IL: University of Chicago Press.

Max, L., & Onghena, P. (1999). Some issues in the statistical analysis of completely randomized and repeated measures designs for speech, language, and hearing research. *Journal of Speech, Language, and Hearing Research*, *42*, 261–270.

Miller, J., & Chapman, R. (2002). *Systematic Analysis of Language Transcripts* (Version 7.0) [computer software]. Madison, WI: Language Analysis Laboratory, Waisman Center, University of Wisconsin.

Reynell, J., & Gruber, C. (1990). *Reynell Developmental Language Scales: US Edition*. Los Angeles, CA: Western Psychological Services.

Rice, M. L., Wexler, K., & Cleave, P. L. (1995). Specific language impairment as a period of extended optional infinitive. *Journal of Speech and Hearing Research*, *38*, 850–863.

Rispoli, M. (1992). Discourse and the acquisition of *eat*. *Journal of Child Language*, *19*, 581–595.

Roid, G., & Miller, L. (1997). *Leiter International Performance Scale – Revised*. Wood Dale, IL: Stoelting.

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

Tomblin, J. B., Records, N. L., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research*, *40*, 1245–1260.

Werner, E., & Kresheck, J. (1983a). *Structured Photographic Expressive Language Test–II*. DeKalb, IL: Janelle.

Werner, E., & Kresheck, J. (1983b). *Structured Photographic Expressive Language Test–Preschool*. DeKalb, IL: Janelle.

Appendix

Items used in the experiment.

Prime	Target
Order 1	
Transitive Prime list	
1. The cat's pushing the boy.	The fox is digging (a hole).
2. The man's washing the car.	Goofy's ironing (a shirt).
3. Ronald's licking the spoon.	The cow's drinking (water).
4. The turkey's chasing the cat.	The fireman's spraying (the hose).
5. The horse is throwing a ball.	The panda's eating (a leaf).
6. Mickey's tickling the dog.	The girl's scratching (her nose).
7. Bambi's watching TV.	Ronald's colouring (a star).
8. The pirate's combing his hair	The monkey's washing (his tail).
9. The witch is flying a kite.	The grinch is reading (a book).
10. The dog's licking the baby.	The horse is sweeping (the floor).
11. Barney's hugging the girl.	Mickey's cooking (the food).
12. The prince is throwing the ball.	Ernie's driving (a car).
Intransitive Prime list	
1. The dog's barking.	The bunny is driving (a car).
2. The doctor's smiling.	The bear is digging (a hole).
3. Batman's swimming.	The girl is drinking (water).
4. The lion's roaring.	Scooby's ironing (a shirt).
5. The boy's sneezing.	The horse is eating (hay).
6. The cowboy's sleeping.	Daisy's sweeping (the floor).
7. Big Bird's laughing.	The witch is cooking (the food).
8. The lady's crying.	Bambi's spraying (the hose).
9. The boy's laughing.	The mouse is reading (a book).
10. Dumbo's flying.	The farmer's washing (his hands).
11. The dolphin's splashing.	Bambi's colouring (a star).
12. The pirate's crying.	The monkey's scratching (his head).
Control list	
1. A B C D	Minnie's reading (a book).
2. 1 2 3 (Child counts elephants)	The fireman's washing (his feet).
3. 1 2 (Child counts whales)	Popeye's colouring (a star).
4. Two teddy bears.	Jasmine's spraying (the hose).
5. 1 2 3 4	The bunny's scratching (his ear).
6. Three bananas.	The tiger's eating (a cake).
7. 1 2 (Child counts butterflies)	Shaggy's sweeping (the floor).
8. 1 2 (Child counts kangaroos)	Minnie's cooking (the food).
9. L M N O	Donald's driving (a car).
10. Houses.	T-Rex is digging (a hole).
11. 1 2 (Child counts clowns)	The kitty's drinking (milk).
12. 3 4 5 6	Jasmine's ironing (a shirt).