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Research Article

Verb Variability and Morphosyntactic Priming With Typically Developing 2- and 3-Year-Olds

Windi C. Krok[a] and Laurence B. Leonard[b]

Purpose: This study was specifically designed to examine how verb variability and verb overlap in a morphosyntactic priming task affect typically developing children's use and generalization of auxiliary *IS*.
Method: Forty typically developing 2- to 3-year-old native English-speaking children with inconsistent auxiliary *IS* production were primed with 24 present progressive auxiliary *IS* sentences. Half of the children heard auxiliary *IS* primes with 24 unique verbs (high variability). The other half heard auxiliary *IS* primes with only 6 verbs, repeated 4 times each (low variability). In addition, half of the children heard prime–target pairs with overlapping verbs (lexical boost), whereas the other half heard prime–target pairs with nonoverlapping verbs (no lexical boost). To assess use and generalization of the targeted structure to untrained verbs, all children described probe items at baseline and 5 min and 24 hr after the priming task.
Results: Children in the high variability group demonstrated strong priming effects during the task and increased auxiliary *IS* production compared with baseline performance 5 min and 24 hr after the priming task, suggesting learning and generalization of the primed structure. Children in the low variability group showed no significant increases in auxiliary *IS* production and fell significantly below the high variability group in the 24-hr posttest. Verb overlap did not boost priming effects during the priming task or in posttest probes.
Conclusions: Typically developing children do indeed make use of lexical variability in their linguistic input to help them extract and generalize abstract grammatical rules. They can do this quite quickly, with relatively stable, robust learning occurring after a single optimally variable input session. With reduced variability, learning does not occur.

English-speaking children typically pass through a developmental stage in which they inconsistently produce tense/agreement morphemes such as auxiliary and copula *BE*, auxiliary *DO*, past tense *–ed*, and third-person singular *–s*. They may appropriately use a morpheme in one utterance (e.g., *Mommy is sleeping*) and then omit the same morpheme in the very next utterance (e.g., *The dog running*). Typically developing (TD) children tend to outgrow this stage of inconsistent production between 3 and 4 years of age.

Despite much research in this area, neither the causes of these inconsistencies nor the best methods for increasing consistent production are fully understood. One factor that does appear to contribute to children's inconsistent use of tense/agreement morphemes is the information that is present or absent in their input. When speaking with children, adults use verbs that are marked for tense/agreement (e.g., *The bunny is hopping*) as well as unmarked/nonfinite verbs (e.g., *climbing* in *Do you see the monkey climbing?*). When children first encounter a verb in an unmarked context, they may not recognize that the nonfinite clause (e.g., *the monkey climbing*) is part of a larger syntactic structure. As a result, they may incorrectly extract the nonfinite verb from the larger structure and use it as a grammatically acceptable form in new utterances (e.g., *The fireman climbing, The kitty climbing*; Finneran & Leonard, 2010; Leonard, Fey, Deevy, & Bredin-Oja, 2015; Theakston, Lieven, & Tomasello, 2003). Regardless of these early input effects, at some point, children must break away from input-dependent biases and fully integrate all new and familiar verbs into an adultlike abstract system. A better understanding of how altering different forms of input helps children move from lexically dependent constructions to a generalized

[a]Department of Speech, Language and Hearing Sciences, The George Washington University, Washington, DC
[b]Department of Audiology and Speech Sciences, Purdue University, West Lafayette, IN

Correspondence to Windi C. Krok: wkrok@email.gwu.edu

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grammatical system both immediately and over time may help us understand individual differences in rate of development and assist us in tailoring language instruction and therapy techniques for those groups of children whose development is unusually slow.

One way children appear to learn grammatical patterns from their input is by tracking statistical regularities within their language. Children and adults use transitional probabilities (i.e., the likelihood that, when one linguistic component appears in the input, another specific component will follow it) to identify word boundaries as well as grammatical patterns (Saffran, Aslin, & Newport, 1996; Saffran, Newport, & Aslin, 1996; Saffran & Wilson, 2003). Depending on the type of input they receive, children use probability cues to identify co-occurring components as either comprising a single lexical item or belonging to a part of a larger, more abstract grammatical rule.

Current research in artificial grammar learning suggests that exposure to a variety of unique exemplars of a construction helps children use statistical dependencies within a language to create abstract, generalized grammatical representations (R. Gómez & Maye, 2005; R. L. Gómez, 2002; Grunow, Spaulding, Gómez, & Plante, 2006; Plante et al., 2014; von Koss Torkildsen, Dailey, Aguilar, Gómez, & Plante, 2013). Artificial languages are composed of novel word strings containing predictable patterns such as those found in natural grammatical structures. For example, much like *is* VERB*ing* in English, an artificial grammar may have an *a*X*d* pattern, in which *d* always occurs after *a* and some intervening X. Infants and adults best learn and generalize artificial grammars to new word strings when the input contains highly varied intervening X segments (R. Gómez & Maye, 2005; R. L. Gómez, 2002; Grunow et al., 2006; von Koss Torkildsen et al., 2013). Accordingly, children should best learn a grammatical construction such as the English *is* VERB*ing* when they hear it used with multiple different verbs (e.g., *is* EAT*ing, is* JUMP*ing, is* PLAY*ing*). When more unique exemplars are present in the input, listeners are able to discover regularities within the language and learn grammatical patterns. With exposure to only a few unique exemplars, however, listeners learn strings as individual lexical items (e.g., *is* EAT*ing*) rather than components of a grammatical rule, much like children's early verb-specific productions discussed above. Increasing input variability helps children learn grammar-like structures by allowing them to focus on the components of the structure that are most stable and predictable. In artificial grammar learning studies, rule abstraction occurs best when listeners are exposed to at least 18–24 unique intervening exemplars (R. Gómez & Maye, 2005; R. L. Gómez, 2002; Grunow et al., 2006; von Koss Torkildsen et al., 2013). Presenting listeners with 12 or fewer unique exemplars, even with multiple repetitions of each, does not lead to rule abstraction.

Although artificial grammar learning studies provide insight into the processes by which children's grammatical representations develop, they do not tell us how children's productions change in response to increased variability in the input. Plante and colleagues (2014) applied suggestions from artificial grammar learning research to a more natural language learning and production task by manipulating verb variability in recasts during language treatment sessions. Children in the high variability group heard recasts of their targeted grammatical morphemes with 24 different verbs per session. Only 12 different verbs were recast per session for children in the low variability group. Children in the high variability group learned their targeted grammatical morphemes, but children in the low variability group showed no growth on any morphemes. This occurred although the children in the low variability group heard an equal number of recasts (twice per verb) as those in the high variability group.

Despite these promising results, the recast treatment sessions required a large time commitment for each child (five individual 30-min sessions per week for 6 weeks). This level of time commitment is not likely feasible for practicing clinicians. Moreover, some children required several weeks of treatment before correctly using their targeted morpheme in generalization probes. Other children never demonstrated correct use. Perhaps, using variability in a treatment technique that is more direct and focused than recasting would lead to faster learning of these morphemes.

A priming technique may serve as a useful tool for examining grammatical learning under controlled input conditions. In traditional priming tasks, speakers tend to repeat the syntactic structure of preceding examiner utterances, even in the absence of overlapping words, semantic/thematic roles, or prosodic characteristics (J. K. Bock, 1986). For example, after hearing a sentence containing a double object dative (e.g., *The student passed his friend a note*), speakers tend to repeat the same syntactic structure to describe a new, unrelated picture (e.g., *The chef baked the customers a cake*). Priming facilitates production of abstract syntactic structures in both adults and children and leads to cumulative, enduring priming effects of those structures. The cumulative and enduring nature of priming effects suggests that structural priming is a form of implicit learning, in which sentence structure mechanisms adapt in response to priming tasks (J. K. Bock, 1986; K. Bock & Griffin, 2000; Chang, Dell, & Bock, 2006; Huttenlocher, Vasilyeva, & Shimpi, 2004; Kaschak, Kutta, & Jones, 2011; Savage, Lieven, Theakston, & Tomasello, 2006; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007).

Although very few studies have directly examined learning effects in priming with children, initial results are quite promising. Savage et al. (2006) found strong support for statistical learning in priming by manipulating verb variation across prime items, similar to previous verb variability research (R. Gómez & Maye, 2005; R. L. Gómez, 2002; Plante et al., 2014). They discovered that, when verbs varied across task items, 4-year-old children maintained increased use of the passive construction in generalization probes for up to a month after prime presentations. When the same verb was used in every prime, however, the children did not show strong priming effects during the task and demonstrated no long-term learning in follow-up testing. Priming does appear to be a useful tool for inducing implicit learning and generalization of abstract syntactic structures rather than lexical dependencies in children, particularly when verbs vary across prime items.

Although most priming research has examined productions of alternative sentence structures (e.g., active vs. passive sentences), a few studies have successfully adapted the priming paradigm to increase children's morphosyntactic production, at least temporarily. Leonard and colleagues (Leonard et al., 2002, 2000) and Rissman, Legendre, and Landau (2013) found that children produce auxiliary *BE* forms (e.g., *The princess is chasing the cat*) more accurately after auxiliary primes (e.g., *The starfish is touching the rock*) than after primes or prompts with nonauxiliary sentence frames (e.g., *The plane crashed*). In these priming tasks, children also demonstrated singular/plural crossover effects in which primes containing auxiliary *ARE* increased children's use of auxiliary *IS* (Leonard et al., 2002, 2000) and primes containing auxiliary *IS* increased their use of auxiliary *ARE* (Rissman et al., 2013) in target sentences. This suggests that, at least in the immediate context, it is the "be VERBing" sentence frame that is primed, rather than a specific "is/are VERBing" structure. To date, however, no research has examined how manipulating variability during a morphosyntactic priming task affects children's learning and generalization of these structures over time.

When designing priming stimuli, it is important to carefully consider not only the type but also the arrangement of lexical items in prime and target sentences. Lexical items can differ completely within each prime–target pair, or certain lexical items can overlap, or repeat, from prime to target sentences. In a phenomenon known as the "lexical boost" effect, overlapping key content words (specifically lexical heads) between prime and target sentences can temporarily increase production of targeted syntactic structures (see Leonard, 2011, for a review). This temporary boost, which may reflect explicit memory rather than implicit learning processes, tends to fade away quickly and does not contribute to lasting learning of the targeted structure (Chang et al., 2006). Furthermore, young children, whose explicit memory processes are not yet fully developed, may not benefit at all from the lexical boost effect (Peter, Chang, Pine, Blything, & Rowland, 2015; Rowland, Chang, Ambridge, Pine, & Lieven, 2012). No research to date has examined how the lexical boost functions in morphosyntactic priming tasks with young children. An understanding of the role played by verb overlap in our priming task can have important clinical implications, especially for appropriate target word selection.

Current Study

The purpose of the current study was to examine input effects on grammatical morpheme learning in TD children in the variable production stage. This focus on typical language development and learning provides a deeper understanding of normal grammatical learning processes. It also serves as a foundation for future work examining grammatical learning in children with language impairments, who are in a similar but extended period of inconsistency. The following research questions were addressed:

How will manipulation of verb variability in the priming task affect children's auxiliary *IS* production both during and after the priming task? Variability in the input was manipulated using a morphosyntactic priming technique focusing on children's production of the auxiliary *IS* morpheme. Auxiliary *IS* was chosen as the target morpheme due to previous successful priming of this morpheme with similar-aged children (Leonard et al., 2002, 2000; Rissman et al., 2013). Morphosyntactic priming should induce implicit learning, leading to increased auxiliary *IS* use compared with baseline performance both during and after the priming task. This implicit learning should reflect generalization to a variety of unprimed verbs during posttest probes. Maximum learning and generalization should occur when children hear a variety of unique verbs during the priming phase. Therefore, half of the children heard primes in which each prime sentence used a different verb, as in the treatment study by Plante et al. (2014). Subject and object nouns also varied as much as possible across prime items. This was to allow children to focus on the stable, recurring grammatical pattern in the primes. The high variability condition was expected to induce implicit learning and generalization of the targeted morphemes, with children's use of the morphemes cumulatively increasing during the priming task and remaining elevated in posttest tasks.

The remaining children heard a prime–target sentence set that used a small number of verbs repeated several times each, similar to the low variability group in the Savage et al. (2006) and Plante et al. (2014) studies. It was expected that this condition would not lead to stronger, or perhaps any, long-term implicit learning. We did suspect, however, that performance might appear stronger during the priming task itself, as repetition of the same items could induce memorization of specific lexical strings without promoting abstraction and generalization in posttest items.

How will manipulation of lexical overlap during the priming task affect auxiliary *IS* production both during and after the priming task? We manipulated lexical overlap in the current study by exposing half of the children in the high variability group and half in the low variability group to primes whose verbs always overlapped with the target verb. The other half of the children always heard different verbs between prime and target. It was expected that, if lexical boost effects do occur in young children, their auxiliary *IS* use during the priming task itself would increase when prime and target verbs overlapped. Due to the temporary nature of the lexical boost, any advantages of the lexical overlap in the priming task itself were expected to fade away during posttests.

Will priming effects of auxiliary *IS* generalize to auxiliary *ARE* production in posttest probes? We tested children's production of auxiliary *ARE* in the baseline, 5-min, and 24-hr probes. Although previous research has demonstrated some auxiliary *IS*/*ARE* crossover effects during priming tasks themselves, the clearest outcome is priming effects of the “is VERBing” sentence structure. On the other hand, evidence suggests that *IS/ARE* may be part of the same constellation of morphemes with shared grammatical features (Rispoli, Hadley, & Holt, 2012). Because children acquire morphemes within the same constellation at similar times, increased learning of auxiliary *IS* may generalize to auxiliary *ARE* production as well.

Method

Participants

Forty TD children (21 female and 19 male) participated in this research study. All children were required to demonstrate inconsistent auxiliary *IS* production on the pretest probes or in spontaneous speech and on at least one of the test probes. Although three children scored at the floor (n = 2) or ceiling (n = 1) level on the baseline probes, these children demonstrated inconsistent auxiliary *IS* production (i.e., both inclusions and omissions) in spontaneous speech, the priming task, and at least one posttest probe. Furthermore, all participants demonstrated accuracy levels between 6.6% and 93.8% on at least one probe task. To capture a representative range of typical auxiliary *IS* development, we recruited children from the widest possible age range (age range = 27–46 months, M = 36.0 months, SD = 4.6 months). Children were recruited from a variety of urban and suburban child care centers, preschools, and parent groups in the Indianapolis and Greater Lafayette, Indiana, areas. Specific information regarding race, ethnicity, maternal education, and socioeconomic status was not collected. However, seven participants were recruited from urban child care centers known to serve families with incomes below the poverty level. Furthermore, eight children were reported by parents and preschool administrators to have regular exposure to African American English. The remainder of the participants was recruited from primarily middle to upper-middle class areas. All participants were native English speakers. One child had exposure to a second language but, per parent report, spoke primarily English at home and in day care. All participants had TD hearing, as measured by a pure-tone hearing screening at 25 dB (HL) for each ear at 500, 1000, 2000, and 4000 Hz. The children had no history of hearing loss, no active ear infections at the time of testing, and no known language or developmental delays, per parent report. All children demonstrated typically receptive vocabulary, as measured by the Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4; Dunn & Dunn, 2007; M = 106.05, SD = 9.53). All children also demonstrated age-appropriate expressive grammar skills in spontaneous interactions and during the experimental tasks. Expressive language abilities were verified with standard scores for those children old enough to be given the Structured Photographic Expressive Language Test–Preschool: Second Edition (SPELT-P:2; Dawson, Eyer, & Fonkalsrud, 2005; M = 101.59, SD = 8.50). Due to the wide age range of the participants, three children fell below the standardization age range for both the PPVT-4 (minimum age = 2;6) and the SPELT-P:2 (minimum age = 3;0). However, each of these children achieved raw scores on the PPVT-4 that would indicate typically receptive vocabulary skills for children at least 2–3 months older. Finally, all children showed the ability to produce final /s/ and /z/ in spontaneous speech as well as during probe and prime–target tasks.

Experimental Conditions

Eligible participants were pseudorandomly assigned to one of four experimental conditions (n = 10 children per condition): high variability with lexical boost, high variability without lexical boost, low variability with lexical boost, and low variability without lexical boost (see Table 1). The four conditions were designed to manipulate both verb variability and verb overlap during the priming phase. Children in all four conditions followed an identical sequence of procedures. The main difference between conditions was the organization and presentation of prime and target sentences during the priming phase of Session 2. During the priming phase, children in the high variability conditions heard prime sentences containing 24 unique verbs presented in an auxiliary *IS* sentence frame. Children in the low variability conditions heard only six unique verbs during the priming phase. Although Plante and colleagues (2014) used 12 different verbs per session in their low variability condition, the low variability condition in the current study included six verbs, each combined with several different animations. Six, rather than 12, different verbs were used to maximize the difference between high and low variability while still ensuring some degree of noun variability across items. This is also similar to one of the low variability conditions used in a previous artificial grammar learning study (Gomez, 2002). Each of the primed verbs also appeared as a target verb. In the lexical boost conditions, prime and target verbs always overlapped within an item pair (e.g., prime = *The student is washing her hands*, target = *The grandpa is washing his car*). In the no–lexical boost conditions, verbs never overlapped within prime–target pair items (e.g., prime = *The student is washing her hands*, target = *The farmer is feeding the chickens*). In all conditions, subject and object nouns also varied within individual

Table 1. Group characteristics

	Age in months	PPVT-4 standard score
	M (*SD*)	*M* (*SD*)
HiVarBoost	36.9 (4.9)	105 (11)
HiVarNoBoost	35.8 (3.9)	109.6 (8.6)
LoVarBoost	35.6 (3.9)	103 (10.9)
LoVarNoBoost	36.7 (5.9)	106.3 (7.3)

Note. PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition; HiVarBoost = high variability with lexical boost; HiVarNoBoost = high variability without lexical boost; LoVarBoost = low variability with lexical boost; LoVarNoBoost = low variability without lexical boost.

prime–target pairs. Items were arranged so that noun recurrences across primed sentences were separated by at least two intervening trials.

Stimuli

Prime–Target Sentences

Forty-eight prime–target sentence pairs (24 pairs for high variability conditions and 24 pairs for low variability conditions; see Appendixes A and B) were created using present progressive transitive verbs presented in the active voice (e.g., *The bear is eating an apple*). Subjects and objects were presented as full lexical nouns, with animate subjects and animate or inanimate objects. Prime–target sentences consisted of singular subjects only (e.g., *The girl is throwing the footballs*). Nouns were repeated across sentences, but no subject or object noun recurred after fewer than two intervening items. Most nouns and all but one of the verbs (*fly*) were selected from the MacArthur–Bates Communicative Development Inventories (Words and Gestures, Words and Sentences). To avoid transcription and scoring difficulties, no verbs beginning with /s/ or /z/ were used.

Probe Sentences

Thirty-two probe sentences (16 singular and 16 plural; see Appendix C) were created following the guidelines described above. The same 32 probe items were used with each child during baseline, 5-min, and 24-hr testing. Each probe sentence had a singular version and a plural version (e.g., *The boy is bouncing the ball, The boys are bouncing the balls*). Baseline and posttest probe sentences comprised 16 unique verbs not found in the prime–target sentence pairs. To avoid reusing prime–target verbs in the probe task, six of the probe sentence verbs (*bounce, brush, dig, ring, vacuum*, and *wave*) were not selected from the MacArthur–Bates Communicative Development Inventories. The children did not have particular difficulty using these verbs during the probe task.

Animations

Animated videos were created for each prime, target, and probe sentence using online animation tools (animaker.com and goanimate.com). Each 10-s, full-color animated video represented characters performing continuous transitive actions (e.g., *The monkey is climbing the ladder, The mom is feeding the baby*). Videos were displayed on a laptop computer with no accompanying audio.

Procedure

Session 1

Each qualifying participant participated in three 30- to 60-min experimental sessions. During the initial evaluation session, the children completed the PPVT-4, SPELT-P:2 (when age appropriate), a hearing screening, and baseline probe items. During the baseline probes, the children viewed each baseline video one at a time. While each video was playing, the experimenter provided the children with the subject noun and then prompted the child to describe "What's happening here?" Children who used sentence fragments and/or unrelated information to describe a baseline video were prompted "Tell me more" or "Look here. What's happening here?" Children who used a contracted pronoun (e.g., she's, he's, it's) instead of a lexical noun in the subject position were prompted "Look at the NOUN" or "Tell me about the NOUN. What's happening?" In the rare event that a child knew neither the noun nor the verb in a probe item, he or she was prompted "The NOUN can VERB. Tell me what's happening right now." Children were allowed no more than three trials on a single item before moving on to the next item. Children across all conditions consistently required more prompts during baseline probes than during 5-min or 24-hr probes.

Session 2

Approximately 1 week after Session 1, each child completed the priming phase of the experiment. During this phase, 24 prime–target videos and sentence pairs were presented to each child. Prime–target items were presented as a copycat game in which the child repeated the examiner's prime description of a video (e.g., *You say, The mom is feeding the baby*) and then described the target video on his or her own (e.g., *What's happening here?*). Children were not prompted to alter their repetitions or target responses during the priming phase. Prime–target pairs were presented in blocks of eight items with brief play breaks (e.g., putting stickers on a picture scene, stringing beads) between each block.

After the final prime–target block and a longer (5-min) play break, children described all 32 probe sentences a second time (5-min posttest). The posttest items were presented in the same manner as the baseline items with no primes before video descriptions.

Session 3

Twenty-four hours after the priming phase, each child described all 32 test sentences for a third and final time (24-hr posttest). The posttest items were again presented in the same manner as the baseline items with no primes before video descriptions. Due to family scheduling conflicts, three children completed the final session 48 hr after the priming phase. Any testing that had not been completed during the initial testing session was also conducted during this final session.

Scoring

Each session was digitally audio-recorded using a Marantz professional solid-state recorder, Model PMD660, with an external microphone. All baseline and posttest probe items were transcribed and scored in the following manner. Children's first use of a present progressive sentence frame was selected for scoring. If, however, the child produced a contracted pronoun (e.g., *She's walking her dog*) and then, upon prompting, produced a noun phrase or uncontracted pronoun subject for the same item, the second sentence was selected for scoring and analyses. Present progressive sentence frames were scored as demonstrating correct or omitted use of auxiliary *IS*. Children's repetitions of prime sentences and prime target descriptions were scored in a similar manner, except that prompts were not provided for these items. Present progressive sentence productions that substituted appropriate noun or verb alternatives were included in the analyses provided that they accurately described the characters and actions depicted in the video. The number of unscorable probe responses decreased over time for children across all conditions ($M_1 = 3.2$, $SD_1 = 2.9$; $M_2 = 1.7$, $SD_2 = 2.5$; $M_3 = 1.4$, $SD_3 = 2.7$). A repeated-measures analysis of variance (ANOVA) indicated a significant main effect of time, $F(1, 36) = 14.33$, $p = .001$, $\eta_p^2 = .285$, and a significant interaction between time and boost, $F(1, 36) = 7.39$, $p = .010$, $\eta_p^2 = .170$, with children in the boost condition producing significantly fewer unscorable responses between baseline and 5-min probes ($p < .001$) and between baseline and 24-min probes ($p < .001$). There were no other significant main effects or interactions.

Reliability

Thirty percent of the data were transcribed and scored by a trained undergraduate coder. Agreement on sentence frame type and inclusion or omission of auxiliary *IS* was evaluated for scoring of each transcribed item. Interrater reliability was judged to be 92.8%. Any discrepancies were discussed and resolved through consensus between the examiner and the coder.

Analyses

To measure input effects of verb overlap and verb variability on children's use of auxiliary *IS* in present progressive sentences, each child's percentage of correct use in obligatory contexts (accuracy) was calculated for baseline and posttest probes, prime repetitions, and prime target descriptions. Arcsine transformations of these percentages were used in all statistical analyses. Group averages for each of the four experimental conditions were compared within and across periods. Immediate priming effects were measured by examining auxiliary *IS* accuracy during the priming task itself. Learning and generalization were measured through comparisons of auxiliary *IS* accuracy during baseline and posttest probe sessions in singular and plural contexts. To make the case that group differences were related to prime types, we first verified that all experimental groups used auxiliary *IS* equally before priming. According to baseline testing, the groups did not differ from each other in auxiliary *IS* production before the priming task, $F(3, 36) = 0.39$, $p = .76$, $\eta_p^2 = .031$. Furthermore, there was no correlation between PPVT-4 raw scores and auxiliary *IS* production at any time point (baseline: $r = -.07$, $p = .663$; 5-min: $r = .16$, $p = .322$; 24-hr: $r = .02$, $p = .890$). There was also no correlation between SPELT-P:2 raw scores of the 22 children aged 3;0 and older and auxiliary *IS* production at any time point (baseline: $r = .28$, $p = .207$; 5-min: $r = .38$, $p = .078$; 24-hr: $r = 0.34$, $p = .128$).

Results

Immediate Priming Effects

During the priming task, children in the high variability groups produced auxiliary *IS* with 72% ($SD = 32\%$) accuracy, whereas children in the low variability groups produced it with only 57% ($SD = 39\%$) accuracy. An ANOVA revealed that this difference was not statistically significant, $F(1, 36) = 1.95$, $p = .171$, $\eta_p^2 = .051$. Children in the lexical boost conditions did not use auxiliary *IS* more accurately during the priming task than children in the no–lexical boost conditions, $F(1, 36) = 0.06$, $p = .80$, $\eta_p^2 = .002$.

To identify potential cumulative learning effects during priming, high- and low-variability group differences were compared across the first and second halves of the priming task. An increase in auxiliary *IS* accuracy from the first half to the second half would suggest the presence of a cumulative learning effect during priming. A repeated-measures ANOVA revealed no significant main effect of prime half, $F(1, 36) = 0.082$, $p = .777$, $\eta_p^2 = .002$, and no interaction between prime half and variability, $F(1, 36) = 2.56$, $p = .118$, $\eta_p^2 = .063$.

Although no significant group differences were found during the priming task itself, it was expected that children would produce auxiliary *IS* more accurately after primes than they did without primes (i.e., in baseline probes). A mixed-model ANOVA revealed that overall auxiliary *IS* accuracy did increase from baseline probes to prime target descriptions, $F(1, 36) = 17.29$, $p < .001$, $\eta_p^2 = .324$, suggesting the presence of a priming effect. There was a significant interaction between priming effects and verb variability, $F(1, 36) = 5.88$, $p = .02$, $\eta_p^2 = .140$. Post hoc testing revealed that children in the high variability conditions used auxiliary *IS* more accurately after primes ($M = 72\%$, $SD = 32\%$) than in baseline probe items ($M = 50\%$, $SD = 25\%$, $p < .001$). Children in the low variability conditions, however, did not differ in their use of auxiliary *IS* after primes ($M = 57\%$, $SD = 39\%$) compared with baseline probes ($M = 53\%$, $SD = 30\%$; $p = .228$; see Figure 1).

During the priming task, children were asked to repeat each prime sentence before describing the target video. Use of auxiliary *IS* in children's prime repetitions was strongly correlated with use of auxiliary *IS* in their target descriptions ($r = .758$, $p < .001$). Ninety percent (522/581) of children's accurate productions of auxiliary *IS* in repetitions were followed by accurate productions in target descriptions. Only 32% (78/246) of repetitions with an omitted auxiliary *IS* were followed by a target description with an accurate auxiliary *IS* production.

Generalization to Probe Items

Implicit learning effects of the priming task were expected to build slowly but remain robust over time. These

Figure 1. Mean percentage correct auxiliary *IS* use for high and low variability conditions on baseline probes and prime target descriptions. Error bars represent standard error of measurement. Bars connected with an asterisk differ statistically.

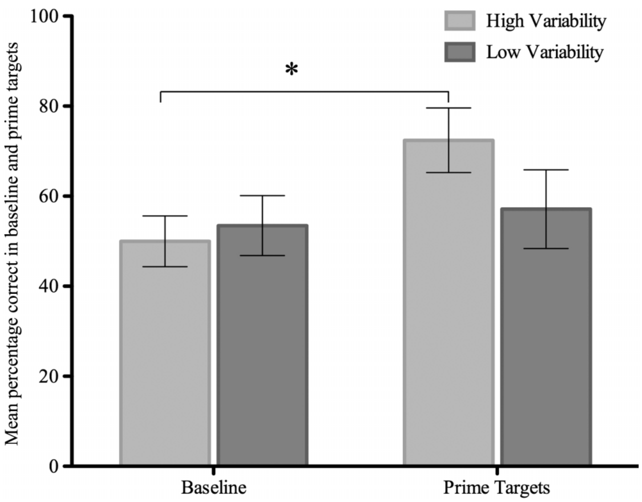
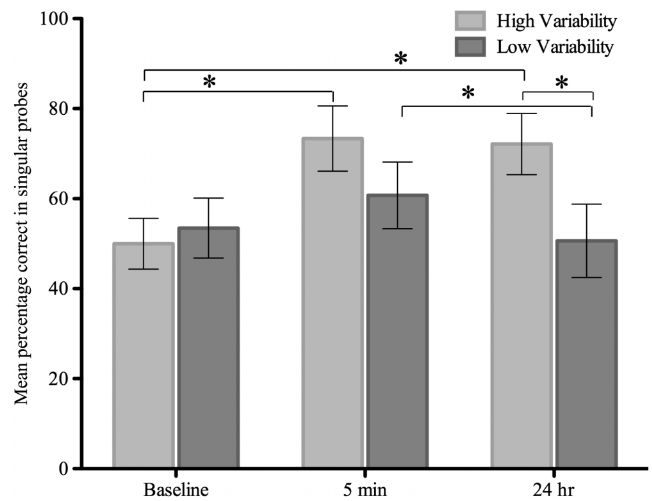


Figure 2. Mean percentage correct auxiliary *IS* use for high and low variability conditions on baseline, 5-min, and 24-hr singular probes. Error bars represent standard error of measurement. Bars connected with an asterisk differ statistically.



effects should be most apparent in the posttest probe items. To analyze learning of auxiliary *IS* over time, a repeated-measures ANOVA was conducted with time (baseline, 5-min posttest, and 24-hr posttest) as a within-subjects factor and verb variability (high, low) and verb overlap (boost, no boost) as between-subjects factors. There was a main effect of time, $F(1, 36) = 11.96$, $p = .001$, $\eta_p^2 = .249$, and a significant interaction between time and variability, $F(1, 36) = 13.43$, $p = .001$, $\eta_p^2 = .272$ (see Figure 2). There were no significant main effects of variability, $F(1, 36) = 1.69$, $p = .202$, $\eta_p^2 = .045$, or boost, $F(1, 36) = 0.0$, $p = .987$, $\eta_p^2 = .001$, and no significant interactions between time and boost, $F(1, 36) = 0.05$, $p = .820$, $\eta_p^2 = .001$, or time, boost, and variability, $F(1, 36) = 2.13$, $p = .153$, $\eta_p^2 = .056$.

Post hoc testing revealed that auxiliary *IS* accuracy was significantly higher in the high variability group than the low variability group in the 24-hr posttest ($p = .031$), but not during baseline ($p = .627$) or 5-min ($p = .074$) posttest probes (see Table 2). Furthermore, within the high variability group, children's accuracy increased from baseline (M = 50%, SD = 25.2%) to 5-min (M = 73%, SD = 32.4%, $p < .001$) probes and remained at an increased level 24 hr later (M = 72%, SD = 30.4%; $p < .001$). In the low variability group, accuracy slightly increased in the 5-min probes (M = 61%, SD = 33.1%) and then dropped significantly back to baseline levels (M = 54%, SD = 29.7%) 24 hr later (M = 51%, SD = 36.5%; $p = .035$). Varying verbs within the primes led to a lasting increase in auxiliary *IS* accuracy.

The children in the lexical boost conditions did not show increased accuracy on auxiliary *IS* in their target sentence descriptions during the priming task, $F(1, 36) = 0.06$, $p = .80$, $\eta_p^2 = .002$, compared with baseline productions, $F(1, 36) = 0.22$, $p = .64$, $\eta_p^2 = .006$, or during posttest probes, $F(1, 36) = 0.0$, $p = .97$, $\eta_p^2 = .000$. This factor did not interact with verb variability. Verb overlap between prime and target sentences had no immediate or lasting effects, suggesting no lexical boost effect for these young children.

Some children showed little to no increase, or a decrease, in auxiliary *IS* use over time. Most of these children demonstrated very low auxiliary *IS* in baseline probes, were in the low variability condition, or both. As shown in Table 3, the children's baseline ability levels were fairly well matched across the high and low variability groups in terms of number of children at each level. After priming, however, only four children in the high variability group, but 10 children in the low variability group, were below 50% accuracy on the 24-hr posttests. All four of the children in the high variability group, but only six of the 10 children in the low variability group, who fell below 50% accuracy on the 24-hr posttest also had baseline scores below 50%. Furthermore, of the five children who reached 100% accuracy in the 24-hr posttest, four were in the high variability group. None of these children were 100% accurate at baseline.

Due to the wide range of auxiliary *IS* accuracy at baseline, an additional repeated-measures ANOVA was run including only those children who scored between 20% and 80% on the baseline probes (14 high-variability children, 14 low-variability children). The results with this restricted range of auxiliary *IS* production were similar to those discussed above. There were significant main effects of time, $F(1, 24) = 10.02$, $p = .004$, $\eta_p^2 = .295$, and variability, $F(1, 24) = 6.93$, $p = .015$, $\eta_p^2 = .224$, and a significant interaction between time and variability, $F(1, 24) = 11.74$, $p = .002$, $\eta_p^2 = .328$. There was no significant main effect of boost, $F(1, 24) = 0.11$, $p = .74$, $\eta_p^2 = .005$, and no significant interactions between time and boost,

Table 2. Mean auxiliary *BE* accuracy over time

Group	Singular				Plural		
	Baseline	Priming	5 min	24 hr	Baseline	5 min	24 hr
HiVarBoost							
M (*SD*)	51.4 (22.4)	75.8 (31.7)	71.0 (30.3)	73.1 (32.9)	57.4 (40.7)	63.4 (46.6)	60.9 (42.5)
Min–max	18.2–78.6	9.1–100	14.3–100	14.3–100	0–100	0–100	0–100
HiVarNoBoost							
M (*SD*)	48.6 (28.9)	68.1 (34.0)	75.8 (36.0)	71.1 (29.5)	45.6 (43.1)	42.5 (42.9)	52.6 (43.6)
Min–max	6.7–81.3	0–100	12.5–100	7.1–93.8	0–100	0–100	0–100
Total	50.0 (25.1)	72.0 (32.2)	73.4 (32.4)	72.1 (30.4)	51.5 (41.3)	52.9 (44.8)	56.8 (42.1)
LoVarBoost							
M (*SD*)	57.0 (33.2)	56.4 (41.5)	57.0 (34.5)	50.5 (35.7)	53.1 (40.3)	40.6 (43.6)	41.8 (47.6)
Min–max	0–100	4.5–100	7.7–92.9	0–87.5	0–100	0–100	0–100
LoVarNoBoost							
M (*SD*)	49.9 (27.1)	59.0 (39.6)	64.4 (33.1)	50.8 (39.2)	51.4 (44.7)	57.6 (46.8)	40.3 (42.3)
Min–max	0–87.5	0–100	12.5–93.8	0–100	0–100	0–100	0–100
Total	53.5 (29.7)	57.7 (39.5)	60.8 (33.1)	50.6 (36.5)	52.2 (41.4)	49.1 (44.9)	41.0 (43.8)

Note. HiVarBoost = high variability with lexical boost; Min = minimum; max = maximum; HiVarNoBoost = high variability without lexical boost; LoVarBoost = low variability with lexical boost; LoVarNoBoost = low variability without lexical boost.

$F(1, 24) = 0.04$, $p = .846$, $\eta_p^2 = .002$, boost and variability, $F(1, 24) = 0.05$, $p = .832$, $\eta_p^2 = .002$, or time, boost, and variability, $F(1, 24) = 1.05$, $p = .316$, $\eta_p^2 = .042$.

Because the use of auxiliary *IS* with contracted pronominal subjects (*he's, she's,* and *it's*) may be routinized, thereby inflating accuracy measures in young children, an additional analysis was conducted using only responses in which children used lexical noun subjects. A repeated-measures ANOVA using time as a within-subjects factor and verb variability as a between-subjects factor again revealed a main effect of time, $F(1, 38) = 8.83$, $p = .005$, $\eta_p^2 = .189$, and a significant interaction between time and variability, $F(1, 38) = 5.93$, $p = .02$, $\eta_p^2 = .135$. Post hoc testing was conducted to determine whether the pattern of lexical-noun–only responses would match that when pronoun responses were included. Pairwise comparisons revealed similar results to those found when pronoun responses were included in the analyses. Within the high variability group, children's accuracy increased from baseline to 5-min probes and remained at an increased level 24 hr later. In the low variability group, children's accuracy did not improve from baseline to posttest probes.

Table 3. Number of children scoring within given accuracy ranges on auxiliary *IS* probes

Accuracy Range	Baseline		5-min posttest		24-hr posttest	
	HiVar	LoVar	HiVar	LoVar	HiVar	LoVar
< 25%	5	5	3	3	3	6
25%–49%	3	2	1	6	1	4
50%–74%	7	8	3	1	3	1
≥ 75%	5	5	13	10	13	9

Note. The numbers in each cell refer to the number of children in each condition who scored within the given accuracy range on auxiliary *IS* probes. HiVar = high variability; LoVar = low variability.

Generalization to Plural Items

To assess generalization of auxiliary forms from singular to plural contexts, an analysis of children's use of auxiliary *ARE* with plural subjects in baseline, 5-min, and 24-hr probes was conducted using a repeated-measures ANOVA. There were no effects of time, $F(1, 36) = 0.12$, $p = .727$, $\eta_p^2 = .003$, variability, $F(1, 36) = 0.22$, $p = .642$, $\eta_p^2 = .006$, or boost $F(1, 36) = 0.08$, $p = .775$, $\eta_p^2 = .002$. The interactions between time and variability, $F(1, 36) = 1.42$, $p = .241$, $\eta_p^2 = .038$, time and boost, $F(1, 36) = 0.001$, $p = .982$, $\eta_p^2 = .000$, and time, boost, and variability, $F(1, 36) = 0.22$, $p = .641$, $\eta_p^2 = .006$, were also nonsignificant. Children's plural productions remained relatively stable across all three time frames. Priming of singular auxiliary forms did not affect children's use of plural auxiliary forms in the probe tasks.

Several children used the singular auxiliary *IS* form with plural subject nouns (e.g., *The girls is walking their dogs*). There was a main effect of time, $F(1, 36) = 5.23$, $p = .028$, $\eta_p^2 = .127$, with use of auxiliary *IS* in plural contexts increasing from 2% at baseline to 8.9% in 5-min probes and 9.1% in 24-hr probes. There was also a main effect of verb variability, $F(1, 36) = 5.00$, $p = .032$, $\eta_p^2 = .122$, where children in the high variability group used auxiliary *IS* with plural subject nouns more often than those in the low variability group. There was no main effect of boost, $F(1, 36) = 0.009$, $p = .927$, $\eta_p^2 = .000$, and no significant two- or three-way interactions.

Within the high variability group, children used auxiliary *IS* in plural contexts more in posttest probes than at baseline, suggesting that singular *IS* primes did affect use of *IS* in plural contexts for these children. However, this type of intrusion error was very rare for all children. Moreover, auxiliary *IS* was used by all children in singular contexts significantly more often than in plural contexts in baseline, $F(1, 36) = 104.06$, $p < .001$, $\eta_p^2 = .743$, 5-min,

$F(1, 36) = 99.98$, $p < .001$, $\eta_p^2 = .735$, and 24-hr, $F(1, 36) = 68.58$, $p < .001$, $\eta_p^2 = .658$, probe items.

Discussion

The purpose of this research was to examine input effects of verb variability in morphosyntactic priming with 2- to 3-year-old TD children. For a more complete picture, half of the items allowed for a lexical boost. It was predicted that all children would demonstrate a temporary increase in their use of the primed structure (auxiliary *IS*) during the priming task, with potentially larger increases occurring for children in the lexical boost conditions. These temporary increases were expected to remain robust over time for children in the high verb variability conditions but fade away quickly for the children in the low verb variability conditions. All children did indeed temporarily increase their use of auxiliary *IS* production compared with baseline performance during the priming task, but only the children in the high variability conditions demonstrated statistically significant increases. The children in the high variability conditions maintained this increased use of auxiliary *IS* for at least 24 hr after the priming task, suggesting that high verb variability did facilitate children's implicit learning and generalization of the primed morpheme. The presence of verb overlap between prime and target sentences in the lexical boost conditions, however, did not affect children's auxiliary *IS* use in the priming or posttest tasks.

Verb Variability

On the basis of findings from artificial grammar learning studies, we expected that varying the verbs in present progressive primes would allow children to focus on the stable, predictable grammatical pattern in present progressive sentence frames (*is* VERB-*ing*). By also varying subject and object nouns as much as possible, we hoped to maximize the potential for children to identify the regular occurrence of the "*is* VERB-*ing*" pattern. Recognition and extraction of this abstract, rather than lexically based, pattern were expected to assist generalization to untrained verbs in probe sessions.

As predicted, manipulating verb variability in prime sentences did affect children's use of auxiliary *IS* in the posttest probes. Children who were primed with 24 unique verbs increased accurate auxiliary *IS* production in probe items 5 min later and maintained this increase for at least 24 hr. Children who were primed with only six unique verbs did not increase accurate production after priming and performed significantly worse than children in the high variability group 24 hr later. Children were only able to extract the targeted grammatical pattern (*is* VERB-*ing*) from their input and generalize it to untrained verbs when the input provided multiple unique exemplars of the pattern. Once they learned the pattern, their increased performance remained relatively stable and robust throughout the course of the experiment. These findings support previous statistical learning research using variability in artificial grammars (R. Gómez & Maye, 2005; R. L. Gómez, 2002; Grunow et al., 2006; Plante et al., 2014; von Koss Torkildsen et al., 2013).

Despite the group differences in auxiliary *IS* use found in posttest probes, there were no group differences during the priming task itself. Artificial grammar research has suggested that at least 18–24 unique exemplars are required for implicit rule learning to occur. The priming task in the current study exposed children in the high variability groups to exactly 24 different verbs, with only one item used for each verb. The priming task may have had too few items for the full extent of learning effects to be revealed during the task itself. Instead, the best evidence for learning and generalization appeared in the posttest probe items.

Children in the low variability groups were expected to learn the frequently recurring *is* VERB-*ing* exemplars in the priming input as consistent chunks of adjacent components rather than as part of an abstract, generalizable pattern. As such, the children should have used auxiliary *IS* quite accurately with the primed verbs but then struggled to generalize the grammatical pattern to untrained verbs in the probes. Surprisingly, their auxiliary *IS* accuracy never significantly increased, even during the priming task. Each unique verb did only occur four times during the priming task. The children may not have been exposed to enough repetitions to learn them as adjacent chunks. In addition, because this study used known verbs for which the children likely already had established patterns, perhaps the input was simply not sufficient to alter the children's current grammatical systems. Children in the low variability groups did show a nonsignificant increase in auxiliary *IS*, in the 5-min, but not the 24-hr, probe. This may reflect some residual short-term priming effects that faded quickly after the priming task.

The current findings support previous work by Savage et al. (2006), who found that structural priming led to long-term implicit learning of the primed structure only when verbs varied across prime items. Children receiving highly variable input in the Savage et al. study increased use of the primed structure after only five prime sentences. The children in the current study, however, required at least 24 primes before group differences began to appear. These differences are likely a result of methodological differences between the two studies. Savage et al. primed sentence structure (e.g., passives) rather than morphosyntax and used very heavy overlap on all lexical components except the verb (i.e., *It got* VERB-*ed by it*). Even in the high variability group, the children in the Savage et al. study likely learned a very limited structure that did not generalize to more lexically diverse utterances with the same structure (i.e., *The NOUN got* VERB-*ed by the NOUN*). Despite these differences, both studies support the notion that priming leads to implicit learning of abstract structures, particularly when verbs vary across prime items.

The findings are also consistent with outcomes of the grammar intervention study by Plante and colleagues (2014). The children in the Plante et al. study who heard at least 24 unique verbs in recasts during each language intervention session increased use of their targeted structures over the 6-week course of treatment. Those who heard only 12 unique verbs in recasts per intervention session, however, showed no improvement during the study. In the Plante et al. study, children who did increase target morpheme use often took up to several weeks to show any generalized learning effects, even in the high variability condition. In the current study, however, children in the high variability groups increased auxiliary *IS* accuracy after a single priming session. This increase generalized to unprimed verbs and remained stable for at least 24 hr after priming.

Two major differences between the Plante et al. (2014) treatment study and the current study may explain why the children in this study increased use of the targeted grammatical structure so much more quickly than those in the treatment study by Plante et al. First, whereas the children in the Plante et al. study all presented with language impairments, the children in the current study all demonstrated typical language development. Children with language impairments often display reduced statistical learning abilities (Evans, Saffran, & Robe-Torres, 2009; Tomblin, Mainela-Arnold, & Zhang, 2007). Weaknesses in the ability to efficiently use statistical regularities to extract grammatical patterns should lead to extended learning trajectories for children with language impairments, even under optimal input conditions.

Methodological differences may also have led to extended learning times for children in the Plante et al. (2014) study compared with children in the current study. Plante et al. used a fairly child-initiated treatment approach using play and spontaneous conversation. Informative input was always provided in the form of recasts of children's own utterances. Generalization probes were also conducted in a play-based, conversational manner. The current study, on the other hand, provided input to children in a much more direct manner. Although the training was not explicit in nature, the task was focused solely on the target structure. The children received a short, intense training session that was very adult-directed. The probes were also very structured and did not measure use in spontaneous conversation. The children in the current study may also have required several training sessions before fully generalizing learning to unstructured conversational settings. Conversely, this more structured training session may have resulted in faster generalization of the grammatical rule to all types of contexts. Perhaps with more focused input, children would require fewer treatment sessions before reaching treatment goals.

Lexical Overlap

Overlapping prime and target verbs did not result in an increased use of auxiliary *IS* during the priming phase, indicating the absence of a lexical boost effect. Although Savage, Lieven, Theaskston, and Tomasello (2003) found that high lexical overlap in prime–target pairs was required for priming to occur in young children, the overlaps in their stimuli were very different than those in the current research. Whereas lexical overlap in the current study was defined as verb repetition across prime–target pairs, Savage et al. defined overlap as repetition of every lexical element except the verb. This led to a very restricted set of prime–target sentences (i.e., *It got VERBed by it*) in the Savage et al. study that did not follow the traditional definition of lexical boost. Previous priming research that did use a more traditional definition of lexical boost—defined as verb overlap—found no lexical boost effects in young children (Peter et al., 2015; Rowland et al., 2012).

The absence of a lexical boost effect in the current and previous research with young children supports the belief that the temporary boost provided by verb overlap in adult priming results from a separate, explicit memory process that is unrelated to implicit learning mechanisms (Chang et al., 2006; Chang, Janciauskas, & Fitz, 2012). Young children's immature explicit memory abilities do not allow for effective use of verb overlap cues in their target productions. In the current study, children in the lexical boost conditions did reuse the prime verbs in most of their target productions. Explicit memory of the prime verbs may have been sufficient to help children in the lexical boost conditions select the correct verb for their target responses. It did not, however, increase their use of the primed morpheme.

Generalization to Plural Contexts

Learning that occurred in singular present progressive contexts did not generalize to plural contexts. Lack of group findings may be due to the high variation in baseline levels between subjects in all groups. Children's plural auxiliary use often did not match their singular auxiliary use at baseline. At baseline, several children were already at ceiling on the plural probes, whereas several others had 0% accuracy. Changes at these extreme levels of performance were difficult to assess. Some individual children did increase their auxiliary *ARE* accuracy by up to as much as 66% from baseline throughout the course of the experiment.

We may have seen stronger singular to plural crossover effects if we had measured children's plural production during the priming task itself. Previous research has shown that primes containing auxiliary *ARE* increase children's use of auxiliary *IS* in target sentences (Leonard et al., 2002, 2000) and primes containing auxiliary *IS* increase their use of auxiliary *ARE* (Rissman et al., 2013). These crossover effects may be somewhat short-lived in young children and thus not appear in delayed testing contexts.

We also noted that, after priming, children in the high, but not the low, variability groups increased their use of auxiliary *IS* on plural probe items (e.g., *The boys is brushing their teeth*). These intrusion errors often occurred on the first several plural probe items per session and then faded away. This likely reflects the strong priming of *IS* experienced by children in the high variability group. Plural probes always occurred after singular probes, likely leading to even stronger *IS* priming for those children with increased accuracy on the singular posttest probes. Despite the increase, such intrusion errors accounted for a very small proportion of total responses. Moreover, all children used auxiliary *IS* significantly more often with singular subjects than with plural subjects.

Future Directions

The primary purpose of this study was to examine the role of input in typical morphosyntactic development. It also helped establish a foundation for future research with children with language impairments. Children and adults with specific language impairment (SLI) have reduced statistical learning abilities (Evans et al., 2009; Tomblin et al., 2007), which may help explain their morphosyntactic weaknesses. As mentioned earlier, the children with SLI in the Plante et al. (2014) study were quite slow to learn their targeted forms. This may have been a result of task type or simply due to the children's weak statistical learning abilities. Future research should examine how children with SLI respond to highly variable input in more direct tasks such as the one used in the current study in conjunction with the more child-centered approach used by Plante et al. and how this affects generalization to spontaneous language contexts. If increasing verb variability in more direct tasks does assist morphosyntactic learning in children with SLI, clinicians could very easily adapt the task to a traditional school-based therapy setting. School-based speech-language pathologists often see children only a few times per week for 20–30 min per session. This type of task could be incorporated into quick interactive games and story book activities that would fit in well with a clinician's schedule. Parents could also be taught to use verb variability in similar quick home-based activities. It may be most beneficial to include both direct and indirect therapy components in treatment, exposing children to increased verb variability in priming-type activities to induce quick implicit learning of the targeted form and recast therapy to promote further generalization (see Eisenberg, 2013).

The priming task used in this research is similar to a commonly used clinical approach known as focused stimulation. During focused stimulation activities, clinicians provide children with multiple examples of preselected targets during contextually meaningful activities, such as play or shared book reading (see Ellis Weismer, Venker, & Robertson, 2017, for a review). Focused stimulation differs from priming in that, although children's spontaneous productions of target forms are acknowledged by the clinician, children are not required to provide responses during the activity. The priming task used in this research prompted children to provide both prime repetitions and target descriptions after each prime sentence, but the accuracy of children's auxiliary *IS* use was never acknowledged by the examiners. However, given the frequent use of focused stimulation activities by clinicians and its similarities to priming activities, future research should examine the effects of increased verb variability on children's morphosyntactic productions after focused stimulation tasks.

Future research should also examine individual statistical learning differences among children. Even under optimal conditions, a few of the TD children in the current study showed little to no increase in auxiliary *IS* use. These were mostly the children who demonstrated the lowest auxiliary *IS* use in baseline probes. These children simply may not have been developmentally "ready" to learn the structure at the time of the experiment. They may not have had enough positive exposures to the structure to make adequate use of variability in the input. They may also have had poor statistical learning abilities, which would suggest that these children were potentially at risk for developing language impairments. Follow-up testing with these children or future longitudinal testing to identify potentially at-risk children could assist in early identification efforts.

Limitations

One major limitation to these findings is that children's spontaneous language was not sampled before and after the priming task. Our probe tasks were very structured and used the same items during each session. Some of the growth demonstrated by children may have been related to familiarity with the task and items. Spontaneous language samples would have provided a true understanding of the extent of children's learning and generalization of the primed structures. Nevertheless, we did see group differences related to verb variability alone, and we expect that language samples would have shown similar, if not quite as strong, effects of increased verb variability.

Another major limitation was the wide variation in children's abilities at baseline. Although average baseline scores were matched across groups, the children within each group demonstrated anywhere from very minimal to nearly perfect use of auxiliary *IS*. Stronger effects would likely have been found if the children had all fallen within a more restricted ability range, particularly in their use of auxiliary *ARE* in plural contexts. Again, though, group effects were still evident in singular contexts both in the presence of a very wide range of abilities represented across children and when children with very high or low baseline levels were excluded from the analyses.

Finally, some of the younger participants fell below the normative age ranges for the standardized language tests used in this research. These tests were primarily selected to ensure all participants demonstrated age-appropriate language abilities. PPVT-4 raw scores for children below the normative age range were equivalent to those expected for children at least 2 to 3 months older, suggesting abilities above the expected range. However, standardized testing that included the full age range of our participants may have allowed for a more complete examination of individual differences.

Conclusions

The results of this study suggest that TD children do indeed make use of lexical variability in their linguistic input to help them extract and generalize abstract grammatical rules. They can do this quite quickly, with relatively stable, robust learning occurring after a single optimally variable input session. With reduced variability, though, learning does not occur, even in the short term. There is also no evidence of learning effects resulting from lexical overlap between children's input and their targeted output. Priming tasks can serve as useful tools for inducing implicit learning of abstract grammatical patterns, particularly when the primes are optimally designed. Priming-type tasks can be easily adapted for use in home and clinical language stimulation activities. The findings of this research with TD children may help direct future examinations of precisely how input affects learning in children with language impairments, specifically those with reduced statistical learning abilities.

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Appendix A

High-Variability Prime and Target Sentences

	Target sentences	
Prime sentences	**With lexical boost**	**Without lexical boost**
The firefighter is drawing a boat.	The girl is drawing a flower.	The doctor is reading a book.
The bear is eating the apples.	The bunny is eating the carrot.	The elf is kissing the snowman.
The girl is throwing the footballs.	The boy is throwing the snowballs.	The nurse is pushing the wheelchair.
The mom is feeding the baby.	The farmer is feeding the chickens.	The penguin is taking a bath.
The soldier is carrying the dishes.	The mom is carrying the box.	The girl is hugging the teddy bear.
The alien is flying a spaceship.	The pig is flying the helicopter.	The grandpa is washing his car.
The shark is biting the boat.	The dog is biting the shoe.	The boy is throwing the snowballs.
The horse is pulling the sleigh.	The witch is pulling the refrigerator.	The elephant is drinking the water.
The astronaut is hitting the rocket.	Superman is hitting the door.	The bird is driving the car.
The girl is building a snowman.	The boy is building a sandcastle.	The bunny is playing the drums.
The mummy is chasing his hat.	The policeman is chasing the robber.	The lady is cutting the vegetables.
The monkey is climbing the tree.	The cat is climbing the ladder.	The man is cooking the hotdogs.
The grandma is riding a motorcycle.	The cowboy is riding a horse.	The bunny is eating the carrot.
The king is playing the guitar.	The bunny is playing the drums.	The dog is biting the shoe.
The cow is driving the truck.	The turkey is driving the car.	The boy is building the sandcastle.
The pilgrim is cutting the wood.	The lady is cutting the vegetables.	The pig is flying the helicopter.
The policeman is drinking his coffee.	The elephant is drinking the water.	The witch is pulling the refrigerator.
The chef is cooking the pizza.	The dad is cooking the hotdogs.	Superman is hitting the door.
The leprechaun is reading the paper.	The doctor is reading a book.	The girl is drawing a flower.
The princess is kissing the dog.	The elf is kissing the snowman.	The cat is climbing the ladder.
The astronaut is pushing the rock.	The nurse is pushing the wheelchair.	The cowboy is riding the horse.
The turtle is taking a shower.	The penguin is taking a bath.	The woman is carrying the box.
The boy is hugging a tree.	The girl is hugging the teddy bear.	The policeman is chasing the robber.
The student is washing her hands.	The grandpa is washing his car.	The farmer is feeding the chickens.

Appendix B

Low-Variability Prime and Target Sentences

	Target sentences	
Prime sentences	With lexical boost	Without lexical boost
The princess is kissing the dog.	The elf is kissing the snowman.	The policeman is pushing the cart.
The horse is pulling the sleigh.	The witch is pulling the refrigerator.	The alligator is riding the boat.
The moose is eating the corn.	The doctor is eating the popcorn.	The elf is kissing the snowman.
The spaceman is hitting the rocket.	Superman is hitting the door.	The mom is pushing the stroller.
The fireman is pushing the bucket.	The policeman is pushing the cart.	The doctor is eating the popcorn.
The turtle is riding the escalator.	The lady is riding the elephant.	The boy is hitting the tree.
The bear is eating the apples.	The bunny is eating the carrot.	The man is kissing the dinosaur.
The chef is pulling the stove.	The girl is pulling the suitcase.	The lady is riding the elephant.
The monster is kissing the cat.	The man is kissing the dinosaur.	The horse is eating the grass.
The soldier is riding the bike.	The cowboy is riding the horse.	The doctor is hitting the chair.
The farmer is pushing the tractor.	Santa is pushing the snowman.	The reindeer is pulling the present.
The gorilla is hitting his chest.	The boy is hitting the tree.	The bunny is eating the carrot.
The pirate is kissing the parrot.	The king is kissing the teddy bear.	The nurse is pushing the wheelchair.
The alien is pulling the spaceship.	The reindeer is pulling the present.	The girl is hitting the bed.
The panda is eating the leaves.	The boy is eating the hamburger.	The cowboy is riding the horse.
The pilot is hitting the airplane.	The girl is hitting the bed.	The witch is pulling the refrigerator.
The astronaut is pushing the rock.	The nurse is pushing the wheelchair.	The king is kissing the teddy bear.
The grandma is riding the motorcycle.	The alligator is riding the boat.	The shark is pulling the boat.
The dog is eating his food.	The horse is eating the grass.	The girl is riding the bus.
The football player is pulling the footballs.	The shark is pulling the boat.	Santa is pushing the snowman.
The leprechaun is kissing the squirrel.	The bunny is kissing the baby.	Superman is hitting the door.
The mouse is riding the train.	The girl is riding the bus.	The boy is eating the hamburger.
The cow is pushing the hay.	The mom is pushing the stroller.	The rabbit is kissing the dinosaur.
The student is hitting the books.	The doctor is hitting the chair.	The girl is pulling the suitcase.

Appendix C

Probe Task Sentences

Singular sentences	Plural sentences
The boy is bouncing the ball.	The boys are bouncing the balls.
The man is painting the fence.	The men are painting the fence.
The worker is fixing the car.	The workers are fixing the cars.
The boy is brushing his teeth.	The boys are brushing their teeth.
The girl is opening the presents.	The girls are opening the presents.
Santa is ringing the bell.	The Santas are ringing the bells.
The pirate is waving the sword.	The pirates are waving the swords.
The dog is licking the pumpkin.	The dogs are licking the pumpkins.
The girl is taking pictures.	The girls are taking pictures.
The mom is vacuuming the rug.	The moms are vacuuming the rug.
The man is tickling the cat.	The men are tickling the cats.
The bunny is holding the balloons.	The bunnies are holding the balloons.
The dog is digging a hole.	The dogs are digging the holes.
The girl is walking her dog.	The girls are walking their dogs.
The boy is kicking the balls.	The boys are kicking the balls.
The policeman is picking the flowers.	The policemen are picking the flowers.