Published in final edited form as:

J Commun Disord. 2010 ; 43(5): 397–406. doi:10.1016/j.jcomdis.2010.04.012.

Children with specific language impairment show rapid, implicit learning of stress assignment rules

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Abstract

An implicit learning paradigm was used to assess children's sensitivity to syllable stress information in an artificial language. Study 1 demonstrated that preschool children, with and without specific language impairment (SLI), can generalize patterns of stress heard during a brief period of familiarization, and can also abstract underlying ordered rules by which stress patterns were assigned to syllables. In Study 2, the salience of stressed elements was acoustically enhanced. Counter to expectations, there was no evidence of learning with this manipulation for either the typically developing children or children with SLI. The results suggest that children with SLI and their typically-developing peers are sensitive to syllable stress cues to language structure. However, attempts to draw attention to these patterns by making them more salient may prompt children to use alternate learning strategies that do not lead to an implicit understanding of how stress contributes to the structure of language.

Suprasegmental information serves a variety of functions in spoken language. The emotional tone of the message is carried as much or more by suprasegmental features as by the lexical items within the sentence. Likewise, intonational variation and pauses can be used to mark clause or prepositional phrase boundaries within sentences, effectively chunking long units of continuous speech into smaller, perceptually-defined units. Suprasegmental cues also mark syllable-level, or lexical metre stress patterns, that characterize a language.

Infants appear to be highly sensitive to the stress patterns of their language (Houston, Santelmann, & Jusczyk, 2004; Mattys & Jusczyk, 2001; Nazzi, Jusczyk, & Johnson, 2000; Spring & Dale, 1977; Turk, Jusczyk, & Gerken, 1995). It has been suggested that infants 7 to 9 months prefer prosodic cues over segmental cues for determining the location of words within the ongoing acoustic speech stream. (Cutler, 1994, 1996; Jusczyk, Houston, & Newsome, 1999; Mattys, Jusczyk, Luce, & Morgan, 1999; Thiessen & Saffran, 2003). It is also the case that infants show evidence of learning and generalization of novel metrical stress patterns in an artificial language context (Gerken, 2004; Gerken & Boltt, 2008).

This sensitivity to metrical stress appears to be age-dependent. Three studies (Bahl, Plante, & Gerken, 2009; Gerken & Boltt, 2008; Guest, Dell, & Cole, 2000), each of which used the same paradigm used with infants (Gerken, 2004), have shown that typical adults perform less well than infants on a task that required learning of metrical stress. Guest et al. (2000) asked adults to listen to syllable strings in which stress patterns were assigned according to a set of ordered rules. The rules were constrained such that if a “lower-level” rule conflicted with a “higher-level” rule, the higher-level rule took precedence (see Table 1). Following a

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short period of familiarization, adults were asked to indicate whether new syllable strings were consistent with the strings heard during familiarization. Adults were able to differentiate between new strings that conformed to the pattern they had heard before, but they had difficulty abstracting the principles of the stress hierarchy. Adults in this study were only able to demonstrate principle-level generalizations when exposed to syllable strings that were longer than the ones on which they had been trained. Likewise, Bahl et al. (2009) replicated the finding of pattern-level generalization by typical adults. Their adult participants could also be induced to make principle-level generalizations if the stress pattern was acoustically enhanced by increasing the intensity of stressed items, but did not do so when stress patterns were more natural sounding. Therefore, both studies were consistent in the finding that adults recognized and generalized stress patterns like their infant counterparts. However, unlike infants, adults only demonstrated knowledge of the ordered principles under special conditions.

Two issues are raised by the current literature. First, the difference between typical infants and adults suggests a shift in learning strategy away from the use of stress assignment principles in favor of frequently occurring patterns of stressed and unstressed syllables. In this study, we use the learning paradigm of Bahl et al. (based on Guest et al., 2000) to determine whether preschool children who can be characterized as having typical language development are more similar to infants or adults in their ability to learn and generalize stress assignment principles. If typically-developing children are already past the period where prosodic principles are readily abstracted, then they will look more like the adults in the Guest et al. (2000) and Bahl et al. (2009) studies. However, if they perform more like the infants in Gerken (2004), it would suggest that preschool children can continue to discover principles about how stress is assigned in a language.

The second issue concerns whether children for whom the period of language acquisition is delayed because of a language impairment will show learning capabilities more similar to infants or to adults. There is one existing study that included learners with poor language skills. In addition to their typical adults, Bahl et al. (2009) also included a group of adults selected for a history of language-based learning disability. The clinical group in this study showed a poorer ability to learn and generalize prosodic information than their typical-language peers, even when the intensity of the stressed items was increased. Note, however, that this is a task for which infants “out-perform” adults. Therefore, it may be that younger children selected for poor language skills may show better performance than their older counterparts, particularly if their system is in a less mature state than expected for their age. However, a study by Weber, Hahne, Friedrich, and Friederici (2005) suggests that infants at risk for SLI may already show difficulty processing word-level stress cues at five months of age. Infants were repeatedly presented a CVCV nonword token, pronounced with either iambic stress (the predominant pattern heard) or trochaic stress (occurring infrequently). The at-risk infants showed a reduction of the amplitude of the mismatched negativity wave form, which is typically evoked in reaction to deviations from a frequently occurring auditory stimulus. If the group difference processing word-level prosody suggested by this wave form difference persist and translate to true behavioral differences¹, then preschool children with confirmed SLI may perform poorly on a task that requires learning a novel system of syllable-level stress assignment.

The behavioral literature does not address this issue directly. Several studies indicate children with SLI show weaker prosodic performance than their peers in both receptive and

¹Electrophysiologic differences between adults with language impairment and their normal language peers on a task that both groups could perform at high accuracy levels (Plante, Senkfor, & Van Petten, 2000). Therefore, waveform differences do not necessarily equate to performance differences.

expressive tasks (e.g., Fisher, Plante, Vance, Gerken, & Glatke 2007; Van der Meulen, Janssen, & Den Os, 1997; Wells & Peppé, 2003). However, children with SLI are not uniformly impaired across all tasks used within studies of prosodic skills (e.g., Van der Meulen et al., 1997; Wells & Peppé, 2003). It is also important to distinguish prosodic performance in terms of whether the task employed emotional or linguistic prosody, as children with SLI may perform reasonably well on tasks that involve processing emotional prosody only (Creusere, Alt, & Plante, 2004; Van der Meulen et al., 1997; Wells & Peppé, 2003). Group differences are more frequently reported for tasks involving linguistic prosody. Fisher et al. (2007) reported group differences on three variations of a task that required comparing a low-pass filtered sentence to an unfiltered target. In contrast Wells and Peppé (2003) reported differences for 9 of 16 tasks used to examine various types of prosodic processing and production. Children with SLI were significantly worse at repeating prosodic patterns, regardless of the length of the target. Receptively, group differences emerged for tasks that required detection of syllable-level stress differences (using filtered speech) or detecting stress that served pragmatic functions in isolated words or words in sentences. In contrast, performance was relatively good for tasks in which prosody was used to chunk information (e.g., fruit, salad, and milk vs. fruit salad and milk). Performance was also relatively good when participants were asked to distinguish between rising/falling pitch with filtered one-syllable words.

Importantly, the addition of word-level stress cues in language learning contexts can have positive effects. Children with SLI benefit from emphatic stress in word production, but not in word comprehension during novel word learning tasks (Ellis Weismer & Hesketh, 1993; 1998). Likewise, the addition of stress cues assisted learning of a novel grammar in an artificial language paradigm (Weinert, 1992). However, the Weinert study did not include typically-developing children, so it is not possible to know whether the level of learning represented can be regarded as “normal.” The study author indicated that, with or without stress cues, most children with SLI had difficulty learning the novel grammar.

In summary, the extant literature on sensitivity to stress by children with SLI offers an emerging, but not yet coherent picture of their abilities in this area. Production tasks typically yield lower performance for children with SLI, but performance may be confounded by the poorer memory or weaker phonological skills of these children. Receptive tasks can also be poor, particularly when filtered speech is used to test prosodic processing (Fisher et al., 2007; Wells & Peppé, 2003). However, there are indications that children with SLI do process sentence-level stress information that serves to cluster lexical items or focus attention of a specific lexical item in an utterance (Ellis Weismer & Hesketh, 1993; 1998; Wells & Peppé, 2003). It is not known whether these children are sensitive to stress assignment across syllables within a word.

In the following two experiments, we examine the ability of children with typical language and with SLI to learn and generalize a system of syllable-level stress assignment that conforms to an ordered set of rules. After a brief period of familiarization with a novel language that conforms to the rules of stress assignment, children were tested on whether they could detect similar stress patterns in new syllable strings (generalization of the stress pattern) and whether they showed evidence of abstract representation of the ordered principles (generalization of the stress principles).

Study 1

Method

Participants—The participants included 58 children, half with specific language impairment (SLI) and half who were typically developing (TD). All children were native

speakers of English. The mean age of the children with SLI (23m, 6f) was 55.5 months (range 48-64 months). Caregivers were asked to report the racial and ethnic backgrounds of participants. Thirteen of the participants with SLI were identified as white, four were African American, two were American Indian, one was Asian and one was Pacific Islander (race was not reported for eight in the SLI group). Twelve were reported to be Hispanic, seven were non-hispanic and there was no designation for ten of the participants with SLI. Their mothers' mean years of education was 13.32 years (range 9-16 years). The TD group (23m, 6f) had a mean age of 56.5 months (range 50-67 months). Twenty-one of the children were identified as white, one as American Indian, one as Asian, two as African American, and no racial identification was reported for four in the TD group. Seven of these children were reported to be Hispanic, nine as non-Hispanic, and no ethnic designation was given for thirteen. Their mothers' mean years of education was 14.63 years (range 12-17 years).

Participants were required to pass a pure-tone hearing screening at 20dB at 1000, 2000, and 4000 Hz and 30db at 500 Hz to exclude children with hearing loss at the time of study. All participants also had to receive a score of above 75 ($-2\text{ SD} + 1\text{ SEM}$) on the nonverbal scales of the *Kaufman Assessment Battery for Children – Second Edition* (K-ABC-II; Kaufman & Kaufman, 2004) to rule out mental retardation. Children in the SLI group were required to score below standard score of 87 on the *Structured Photographic Expressive Language Test – Preschool (2nd Edition)* (Dawson, Stout, Eyer, Tattersall, Fonkalsrud, & Croley, 2005). This score criterion was based on a prior validation of this test with four and five year old children that demonstrated 90.6% sensitivity and 95.6% specificity (Greenslade, Plante, & Vance, 2009). Children in the TD group had to score above 87 on this test to be included in the study. In addition, children were given the *Grammatical Understanding Subtest* of the *Test of Language Development – Primary: Third Edition* (TOLD-GU; Newcomer & Hammill, 1997). Although there is no sensitivity or specificity data for this test overall, this subtest was selected because the manual indicates language delayed children do receive lower scores (-1SD) than their peers on it. Scoring reliability for these tests averaged 98% (range 90-100%). This was obtained by live double scoring of 38% of all tests administered for the study and calculating point-to-point reliability. Test scores for children in the SLI and TD groups are reported in Table 2.

Materials and Methods—The study used materials previously used in Gerken (2004) and Bahl et al. (2009) and were modeled on those used in Guest et al. (2000). Multisyllabic nonwords were constructed from the syllables “do, re, mi, fa, so, la, ti, and ton”. Nonwords were three to five syllables long. Ton is considered the only heavy syllable in this set of syllables, since it ends in a consonant. The first seven syllables (do, re, me, fa, so, la, ti) always occurred in fixed order relative to the others of these seven syllables. The syllable “ton” occurred either in the second or penultimate position. Thus, there was no syllable order cue, except for the position of “ton” within the nonword.

Two sets of nonwords were constructed so that contrasting patterns of word-level stress could be assigned to words in the two stimulus sets. Syllable stress was assigned following a hierarchical set of rules so that when two rules conflicted, one rule took precedence. These rules, laid out in their hierarchy, are displayed in Table 1. Half of the children in each group were assigned to Language 1 and half to Language 2. This was presented to the child via computer using Direct RT software (Jarvis, 2004). The experiment involved a computer animation of a frog who was learning “dragon talk” (the artificial language) so she could make friends with a dragon who visits the frog's home in a pond. During a familiarization phase, the children were instructed to listen to animated frog who spoke the novel words with stress patterns generated by the rules in their assigned artificial language. At periodic intervals, the frog would catch a fly. Children were trained to press a button as fast as

possible after seeing this visual cue for the game to continue. This assured that children were attending to the program during the familiarization phase.

Children heard 139 nonword stimuli during the familiarization phase over the course of approximately seven minutes. This included the time needed for children to make button press responses during this phase. This phase was followed by a test phase. In this phase, the children were told, “The frog has been practicing dragon talk, but she makes mistakes sometimes. You can help her talk to the dragon! If the frog says is right, press the happy frog; if the frog says it wrong, press the sad frog.” Children were trained to make button press selections to indicate whether they thought practice items belonged to the “language” they had heard previously or not. They then completed 32 test items. The test items were consistent with either Language 1 or Language 2. Therefore, children familiarized with Language 1 should prefer test items consistent with Language 1 and reject those consistent with Language 2 (and vice versa). Because none of the test items were those heard during familiarization, all items can be considered generalization items. Furthermore, half of the test items involved generalization of the pattern of stress that was heard during familiarization (Pattern items) and the other half tested generalization of the hierarchical principles that must be inferred from the items heard previously (Principle items). There were seven items of each type generated for Language 1 and Language 2. Children were not reinforced for their answers to individual test items, but received periodic general reinforcers (e.g., visual tokens within the computer game) for marking their progress during the task.

Results

There was no significant difference in performance on Language 1 vs. Language 2, so this factor was collapsed for the purposes of statistical analysis. Figure 1 presents the mean rate of items accepted in the test phase of the study. The pattern of results was tested with a mixed ANOVA with a group factor (SLI vs. TD), and generalization type (Pattern items vs. Principle items), and item type (number of acceptance of Correct vs. Incorrect items) as within group factors. There was a main effect for Item Type ($F(1,56)=12.59$; $p=.0008$, $\eta_p^2=.18$). The Item Type effect was further defined using a paired t-test. Planned comparisons for Pattern Items indicated that correct generalization items were accepted more frequently than incorrect items ($t(1,57)=4.00$, $p=.0002$, $d=0.61$). The Principle Items showed a similar pattern as well ($t(1,57)=2.00$, $p=.0497$, $d=0.31$). No other main effect or interaction effect was significant.

Brief Discussion

The results indicated that both groups of children were able to generalize to new words that shared the stress pattern of items they had heard as well as items with different stress patterns that obeyed the same underlying stress principles. The latter result suggests that the performance of the young children studied here was more like infants than adults with typical language. However, the effect size associated with generalization of the ordered principle was approximately half the size of that associated with generalization of patterns. In a previous study (Bahl et al., 2009), acoustic enhancement of the stressed items (i.e., increased intensity) assisted typical adults both in terms of learning stress patterns and the underlying ordered principles. We wondered whether a stress enhancement might further facilitate the abstraction of stress principles by young children, as it did with the adults with typical language. However, it should be noted that a stress enhancement did not assist the adults whose language skills were poor and might even be interpreted as having made performance worse overall. Therefore, it may be that children with impaired language will not benefit from this manipulation. In Study 2, we tested whether an intensity enhancement would boost generalization for young children with and without poor language skills.

Study 2

Method

Participants—The participants included 32 children, half with specific language impairment (SLI) and half who were typically developing (TD). None were participants in study 1. All children were native speakers of English. The mean age of the children with SLI (12m, 4f) was 54.56 months (range 48-68 months). Their mother's mean years of education was 12.43 years (range 10-17 years). According to caregiver report, eight were identified as white, three as African American, one as Asian and one as Pacific Islander. Seven of these children were identified as Hispanic.

The TD group (12m, 4f) had a mean age of 54.88 months (range 49-65 months). Their mother's mean years of education was 14.28 years (range 8-17 years). Twelve children in the TD group were identified as white, one as African American, one as Asian and there was no racial information for two children. Four of the children in the TD group were identified as Hispanic.

Participants were required to meet the same inclusion and exclusion criteria as in Study 1. Therefore, they received the same hearing screening and battery of standardized tests as reported for Study 1. Test scores for children in the SLI and TD groups for Study 2 are reported in Table 3. Point-to-point reliability for live scoring of 33% the tests was 99% (range 93-100%).

Materials and Methods—Materials and methods were identical to those of Study 1, with one exception. The intensity of each of the stressed syllables in the stimulus sets was enhanced by 10dB.

Results

As in Study 1, there was no significant difference in performance on Language 1 vs. Language 2, so this factor was collapsed for the purposes of statistical analysis. The pattern of results was once again tested with a mixed ANOVA with a group factor (SLI vs. TD), and generalization type (Pattern items vs. Principle items), and item type (Correct vs. Incorrect) as within group factors. There was a significant three-way interaction for Group $\times$ Generalization Type $\times$ Item type ($F(1,30)=5.80$, $p=.022$, $\eta_p^2=.16$). No other effect was statistically significant.

Planned comparisons for differences in item type for each of the generalization item types (Pattern Items, Principle Items) failed to detect any response patterns in which correct items were accepted more frequently than incorrect items. This was true for both the TD and SLI groups. As Figure 2 indicates, the variance that contributed to the three-way interaction occurred only because incorrect items were accepted more frequently than correct items under certain conditions (for principle items by the TD group and for pattern items for the SLI group). Since there was no evidence of learning by either group under this enhanced stress condition, we did not examine the data further for between-group differences. Furthermore, the effect sizes (d), which ranged from -0.42 to 0.24, indicated that significant effects similar to those found in Study 1 were unlikely to be obtained even with much larger sample sizes.

Discussion

The results of Study 1 demonstrated that young children, like infants, show rapid learning of word-level stress information. This result was obtained both for children with typical and for those with impaired language. Furthermore, the children showed evidence of generalizing

both the pattern of stress heard during familiarization and abstracting the underlying principles that generate patterns of stress assignment across syllables. Moreover, this result was accomplished without explicit instruction of any form and without requiring children to practice producing syllable strings that reflected the rules for stress assignment. Given the short period of exposure to the input, these young children appear remarkably adept at recognizing regularities in the input they receive and capable of conceptualizing these regularities in ways that permit generalizations that function in rule-governed ways.

The relatively good learning in Study 1 by children with SLI contrasts with previous findings of difficulty processing syllable-level prosodic cues. However, several important variables have differed for the present study and prior studies in this area. First, the stimuli were designed to mimic the arbitrary but systematic rules concerning how syllables within words are assigned stress in a language. This level of stress assignment is independent of word meaning. In prior studies where syllable stress was manipulated, it has specifically been done so to shade meaning or to serve pragmatic functions (Ellis Weismer & Hesketh, 1993; 1998; Weinert, 1992; Wells & Peppé, 2003). Although we know that children with SLI can be reasonably proficient in processing syllable-level stress cues under some circumstances (Ellis Weismer & Hesketh, 1993; 1998; Wells & Peppé, 2003), it may be the load conferred by the combination of prosodic and semantic information is more likely than not to lead to group differences than processing prosodic cues alone. Similarly, processing load may explain why these children typically perform poorly on tasks that employ low-pass filtered stimuli (Fisher et al., 2007; Wells & Peppé, 2003). Such tasks typically require a child to hold in memory one stimuli while processing a second. The added working memory load these tasks present may serve to increase the magnitude of any group difference.

The finding of good ability to learn stress assignment rules in the present study also stands in contrast to the results obtained in studies of adult learners that employed highly similar (Guest et al., 2000; Gerken & Boltt, 2008) or identical stimuli (Bahl et al., 2009). Adults, unlike these young children, showed poor ability to generalize ordered stress assignment principles. This suggests a developmental shift, occurring at some time during the childhood years, in which English-speaking learners move away from using stress assignment principles toward expecting stress to occur in particular lexical positions (e.g., first syllable). This ability does not appear to be lost, however. Adults with typical language could be induced to use stress cues if these cues were highlighted sufficiently either by enhancing the stress acoustically (Bahl et al., 2009) or by disallowing a lexical position cue by hearing longer words at test than in familiarization (Guest et al., 2000). It may be that by adulthood, a learner's accumulated experience with the stress assignment rules of his own language makes him or her less receptive to stress cues that differ from it. This is consistent with the proposed role of linguistic experience in narrowing the types of linguistic contrasts that have been learned in other artificial language paradigms (Gerken & Boltt, 2008).

Unlike previous results for adults with typical language skills, the acoustical enhancement of stress in Study 2 did not yield better learning for typically-developing children. This was also true for children with SLI, a result that does parallel the findings of Bahl et al. (2009) for adults with poor language skills. We speculate that the enhanced stress may have been interpreted as emphatic stress for these learners. We know from other work (Ellis Weismer & Hesketh, 1993; 1998; Weinert, 1992) that children with language impairment are sensitive to and benefit from the use of emphatic stress. In these studies, emphatic stress was applied to individual elements (e.g., lexical items) that were to be learned. It may be that when stress was acoustically enhanced, learners interpreted it as a cue to focus attention on the stressed items within each string, rather than on the overall pattern of stress assignment across the syllable string. Since the individual items are not informative in this paradigm, treating stress as a cue to the importance of individual syllable forms would not enhance learning.

This result suggests that word-level stress may be a functional cue for young children under normal circumstances, but attempts to artificially highlight this cue may inadvertently cause children to shift to a different learning strategy. We note that enhanced acoustic cues to stress was a useful cue for the typical language adults in Bahl et al. (2009). This suggests that the pattern shown by both typically-developing children and children with SLI is fundamentally different than learning strategies that are applied in the context of a normally-functioning and mature learning system.

Acknowledgments

Preparation of this work was supported by National Institute on Deafness and Other Communication Disorders (NIDCD) grant # R01DC04726.

References

- Bahl M, Plante E, Gerken LA. Processing prosodic structure by adults with language-based learning disability. *Journal of Communication Disorders* 2009;42:313–323. [PubMed: 19324365]
- Bortolini U, Leonard LB. Phonology and grammatical morphology in specific language impairment: Accounting for individual variation in English and Italian. *Applied Psycholinguistics* 1996;17:85–104.
- Cutler A. Segmentation problem, rhythmic solutions. *Lingua* 1994;92:81–104.
- Cutler, A. Prosody and the word boundary problem. In: Morgan, JL.; Demuth, K., editors. *Signal to syntax: Bootstrapping from speech to grammar in early acquisition*. Mahwah, NJ: Erlbaum; 1996.
- Dawson, JL.; Stout, C.; Eyer, JA.; Tattersall, P.; Fonkalsrud, J.; Croley, K. *Structured Photographic Expressive Language Test: Third Edition*. DeKalb, IL: Janelle Publications; 2003.
- Ellis Weismer S, Hesketh L. The impact of emphatic stress on novel word learning by children with specific language impairment. *Journal of Speech, Language, and Hearing Research* 1998;41:1444–1458.
- Ellis Weismer S, Hesketh L. The influence of prosodic and gestural cues on novel word acquisition by children with specific language impairment. *Journal of Speech & Hearing Research* 1993;36:1013–1025. [PubMed: 8246467]
- Fisher J, Plante E, Vance R, Gerken LA, Glatke TJ. Do children and adults with language impairment recognize prosodic cues? *Journal of Speech, Language, Hearing Research* 2007;50:746–758.
- Gerken LA. Nine-month-olds extract structural principles required for natural language. *Cognition* 2004;93:B89–B96. [PubMed: 15178379]
- Gerken L. A metrical template account of children's weak syllable omissions from multisyllabic words. *Journal of Child Language* 1994a;21:565–584. [PubMed: 7852473]
- Gerken L. Young children's representation of prosodic phonology: Evidence from English-speakers' weak syllable productions. *Journal of Memory and Language* 1994b;33:19–38.
- Gerken L, Bolt A. Three exemplars allow at least some linguistic generalizations: Implications for generalization mechanisms and constraints. *Language Learning and Development* 2008;4:228–248.
- Greenslade KJ, Plante E, Vance R. The Diagnostic Accuracy and Construct validity of the Structured Photographic Expressive Language Test – Preschool: Second Edition (SPELT-P2). *Language, Speech, and Hearing Services in Schools* 2009;40:150–160.
- Guest DJ, Dell GS, Cole JS. Violable Constraints in Language Production: Testing the Transitivity Assumption of Optimality Theory. *Journal of Memory and Language* 2000;42:272–299.
- Houston DM, Santelmann LM, Jusczyk PW. English-learning infants' segmentation of trisyllabic words from fluent speech. *Language and Cognitive Processes* 2004;19:97–136.
- Jarvis, BG. *DirectRT Research Software (Version 2004)* [Computer software]. New York: Empirisoft; 2004.
- Jusczyk PW, Houston DM, Newsome M. The beginnings of word segmentation in English learning infants. *Cognitive Psychology* 1999;39:159–207. [PubMed: 10631011]

- Mattys SL, Jusczyk PW. Do infants segment words or recurring contiguous patterns? *Journal of Experimental Psychology: Human Perception and Performance* 2001;27:644–655. [PubMed: 11424651]
- Mattys SL, Jusczyk PW, Luce PA, Morgan JL. Phonotactic and prosodic effects on word segmentation in infants. *Cognitive Psychology* 1999;38:465–494. [PubMed: 10334878]
- McGregor KK, Leonard LB. Subject pronoun and article omissions in the speech of children with specific language impairment: A phonological interpretations. *Journal of Speech and Hearing Research* 1994;37:171–181. [PubMed: 8170122]
- Nazzi T, Jusczyk PW, Johnson EK. Language Discrimination by English-Learning 5-Month-Olds: Effects of Rhythm and Familiarity. *Journal of Memory and Language* 2000;43:1–19.
- Newcomer, PL.; Hammill, DD. *The Test of Language Development – Primary*. 3rd. Austin, TX: Pro-Ed; 1997.
- Plante E, Van Petten C, Senkfor AJ. Electrophysiological dissociation between verbal and nonverbal semantic processing in learning disabled adults. *Neuropsychologia* 2000;38:1669–1684. [PubMed: 11099725]
- Samuelsson C, Nettelbladt U. Prosodic problems in Swedish children with language impairment: Towards a classification of subgroups. *International Journal of Language & Communication Disorders* 2004;39:325–344. [PubMed: 15204444]
- Samuelsson C, Scooco C, Nettelbladt U. Towards assessment of prosodic abilities in Swedish children with Language Impairment. *Logopedics Phoniatrics Vocology* 2003;28:156–166.
- Thiessen ED, Saffran JR. When cues collide: Use of stress and statistical cues to word boundaries by 7- to 9-month-old infants. *Developmental Psychology* 2003;39:706–716. [PubMed: 12859124]
- Turk A, Jusczyk P, Gerken L. Do English-learning infants use syllable weight to determine stress? *Language and Speech* 1995;38:143–158. [PubMed: 8867758]
- Spring DR, Dale PS. Discrimination of linguistic stress in early infancy. *Journal of Speech and Hearing Research* 1977;20:224–232. [PubMed: 895094]
- van der Meulen S, Janssen P, Os E. Prosodic abilities in children with specific language impairment. *Journal of Communication Disorders* 1997;30:155–170. [PubMed: 9160237]
- Weber C, Hahne A, Friedrich M, Friederici A. Reduced stress pattern discrimination in 5-month-olds as a marker of risk for later language impairment: Neurophysiological evidence. *Cognitive Brain Research* 2005;25:180–187. [PubMed: 15951161]
- Wells B, Peppé S. Intonation Abilities of Children With Speech and Language Impairments. *Journal of Speech, Language, and Hearing Research* 2003;46:5–20.
- Weinert S. Deficits in acquiring language structure: The importance of using prosodic cues. *Applied Cognitive Psychology* 1992;6:545–571.

Figure 1.
Rate of acceptance of Study 1 items testing generalization of stress patterns (Pattern Correct Items vs. Pattern Incorrect) and generalization of the ordered stress principles (Principle Correct vs. Principle Incorrect).

Figure 2.
Rate of acceptance of Study 2 items testing generalization of stress patterns (Pattern Correct vs. Pattern Incorrect) and generalization of the ordered stress principles (Principle Correct vs. Principle Incorrect).

Table 1

Ordered rules for stress assignment. Higher numbered rules take precedence over lower numbered rules. Syllable strings ranged from 3 to 5 syllables. Capital letters indicate stressed syllables in the strings.

Language 1	Example	Language 2	Example
1) Starting with the first syllable and working <u>start-to-end</u> within the nonword, alternating syllables should be stressed.	1) DO-re-TON	1) Starting from the last syllable and working <u>end-to-start</u> within the nonword, alternating syllables.	1) TON-fa-SO
2) The <u>penultimate</u> syllable should be stressed.	2) TI-de-re-MI-fa	2) The <u>second</u> syllable should be stressed.	2) fa-SO-la-ti DO
3) Heavy syllables, i.e., ending with a consonant, are always stressed.	3) do-TON-re-MI fa *	3) Heavy syllables, i.e., ending with a consonant, are always stressed.	3) do-RE-mi-TON-fa *
4) Two consecutive syllables cannot be stressed.	4) TON-ton-re-MI-fa	4) Two consecutive syllables cannot be stressed.	4) la-TI-do-ton-TON
Familiarization	DO-re-me-FA-so TON-fa-so TON-ton-so-LA-ti LA-ti-TON	Familiarization	mi-FA-so-la-TI la-TI-do-ton-TON Re-me-TON so-LA-ti-do-RE
Pattern Test Item	DO-re-mi-TON-fa	Pattern Test Item	ti-TON-do-re-MA
Principle Test Item	ti-TON-do-RE -mi	Principle Test Item	ti-DO-re-TON-mi

Pattern Test Items match the pattern heard in the familiarization set, but with different syllables.

Principle Test Items reflect stress patterns never heard during familiarization, but could be inferred from the input.

* Items excluded from familiarization to test generalization of principles of stress assignment

Table 2

Standardized test scores for the participants of Study 1.

	TD		SLI	
	Mean	SD	Mean	SD
K-ABC	108.34	10.48	97.38	13.00
SPELT-P2	107.03	9.37	70.45	13.27
TOLD-GU	10.72	2.37	8.52	2.64

Note. The K-ABC, and SPELT-P2 scores are based on a mean of 100 and SD of 15. The TOLD-GU is based on a mean of 10 and a SD of 3. K-ABC-II: *Kaufman Assessment Battery for Children – Second Edition* (Kaufman & Kaufman, 2004), SPELT-P2: *Structured Photographic Expressive Language Test – Preschool (2nd Edition)* (Dawson et al., 2005), TOLD-GU: *Grammatical Understanding subtest of the Test of Language Development – Primary: Third Edition* (Newcomer & Hammill, 1997).

Table 3

Standardized test scores for the participants of Study 2.

	TD		SLI	
	Mean	SD	Mean	SD
K-ABC	105.63	11.10	99.44	14.85
SPELT-P2	110.69	7.99	69.88	9.90
TOLD-GU	9.94	1.53	8.00	2.80

Note. The K-ABC and SPELT-P2 scores are based on a mean of 100 and SD of 15. The TOLD-GU is based on a mean of 10 and a SD of 3. K-ABC-II: *Kaufman Assessment Battery for Children – Second Edition* (Kaufman & Kaufman, 2004), SPELT-P2: *Structured Photographic Expressive Language Test – Preschool* (2nd Edition) (Dawson et al., 2005), TOLD-GU: *Grammatical Understanding subtest of the Test of Language Development – Primary: Third Edition* (Newcomer & Hammill, 1997).