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Processing prosodic structure by adults with language-based learning disability

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Abstract

Two experiments investigated the ability of adults with a self reported history of learning disability (hLLD) and test scores consistent with poor language relative to their peers to learn prosodic patterns of a novel language. Participants were exposed to stimuli from an artificial language and tested on items that required generalization of the stress patterns and the hierarchical principles of stress assignment that could be inferred from the input. In Study 1, the NL group successfully generalized the patterns of stress heard during familiarization, but failed to show generalization of the hierarchical principles. The hLLD group performed at chance for both types of generalization items. In Study 2, the intensity of stress elements was increased. The performance of the normal language (NL) group improved whereas the hLLD groups' performance decreased on both types of generalization items. The results indicate that NL adults are able to successfully abstract the complex hierarchical rules of stress if the prosodic cues are made sufficiently salient, but this same task is difficult for adults with hLLD.

Learning Outcomes: The reader will be able to understand: (1) the difference in the ability of hLLD and NL adults to process stress assignment in an implicit learning context and (2) that typical adults can abstract complex hierarchical rules of stress assignment when provided with strong cues.

Introduction

Infants rely heavily on and successfully employ prosodic cues for processing language structure (Gerken, 2004; Houston, Santelmann, & Jusczyk, 2004; Mattys & Jusczyk, 2001; Nazzi, Kemler Nelson, Jusczyk, & Jusczyk, 2000). This is not surprising, given that infants prefer the prosodic characteristics they experience pre-natally during early postnatal life (DeCasper & Spence, 1986). Therefore, prosodic cues are both available and used early in human development (Beach, 1991; Gleitman & Wanner, 1982; Jusczyk, 1999; Mandel, Jusczyk, & Kemler Nelson, 1994; Mandel, Kemler Nelson, & Jusczyk, 1996; Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991). There is evidence that infants and adults may use prosody differently, even for the same types of linguistic processing tasks. This difference is highlighted when competing cues to sentence structure are present in the input. For example, infants at seven to nine months appear to rely on stress cues over phonotactic

cues for word segmentation (Cutler, 1994, 1996; P. W. Jusczyk, Houston, & Newsome, 1999; Mattys, Jusczyk, Luce, & Morgan, 1999; Thiessen & Saffran, 2003).

Gerken (2004) studied infants at the age of nine-months who were exposed to an artificial language for two minutes. Infants were then tested on new sentences, some of which had the same stress pattern, or followed a hierarchy of stress assignment rules similar to the exposure language. The infants recognized the stress patterns that were consistent with what they heard previously. In addition, they showed evidence that they could infer the complex hierarchical rules.

Although infants and adults have access to the same cues to lexical and sentence structure, there is evidence that adults, at least those exposed to English, attend more to surface stress pattern than to the underlying rules for stress assignment (Guest, Dell, & Cole, 2000). Guest et al. (2000) showed that adults with intact language and cognitive abilities were able to recognize the stress patterns of an artificial language but failed to infer the hierarchical rules that governed stress assignment to sentences that were identical in length to those heard during an exposure period. This study with adults used the same stimuli as in Gerken (2004). This apparent shift in processing strategy for infants and adults may be due to any of several reasons. First, maturation may change the sensitivity to non-emotional prosodic structure. Alternatively, it may be that the prosodic pattern of the adult's native language interferes with learning the new stress patterns of the experimental language. Adults may rely on other cues that they find more reliable, based on their language processing experience. However, it appears that it is possible to shift adults away from their default strategy under certain circumstances. Guest et al. (2000) employed a second version of their experiment in which test items were two words longer than the maximum length heard during exposure to the artificial language. Under this condition, adult's responses showed application of hierarchical rules that was not previously apparent when test items length matched that of the items heard during exposure period. It is unknown whether this change made stress more salient by offering more elements over which the system of stress could be demonstrated. Alternatively, the additional words included in the test items may have caused adults to abandon representations that were possible based on the shorter sentences heard during exposure, allowing them to demonstrate sensitivity to the prosodic structure.

Adults with a history of language-based learning disability (hLLD) have the same number of years of language exposure as their normal language (NL) peers. However, language skills of the former group have been compromised throughout the developmental period. It may follow that they, like younger, less linguistically sophisticated learners, may rely on prosody to analyze language structure. On the other hand, it is also possible that, like their normal language peers, their greater experience with their native language's prosody relative to children may interfere with learning a new system of stress assignment in an artificial language context. If this is the case, learning of prosodic information by hLLD adults should parallel that of typically developing adults.

This study investigates the relative sensitivity of adults with hLLD to prosodic structure. It explores the ability of participants with hLLD to extract and generalize rules governing of stress pattern assignment in an artificial language. In order to provide direct comparability to the previous studies with infants (Gerken, 2004) and adults (Guest et al., 2000), we employed the stimuli used in those studies. After a period of exposure to the novel language, participants were tested on test items that measured two levels of generalization of the stress patterns heard during training.

Study 1

Method

Participants—Thirty native English-speaking adults were recruited from undergraduate psychology classes at the University of Arizona, Tucson for the study. All subjects provided informed consent and study procedures were approved by the University's institutional review board. Participants were assigned to either a group with self reported history of language based learning disability (hLLD) or typically developing control group (NL).

The hLLD group consisted of fifteen adults (3 males, 12 females). The participants ranged in age from 18.2 to 44.5 years ($M = 27.3$ years). Several individuals in the hLLD group were receiving support services for their disabilities as part of their academic program at the time of study. This was, however, not part of the selection criteria. Fifteen participants (8 males, 7 females) in the NL group had no personal history of services for speech, language, or learning disabilities and no family history of speech, language, or learning disorder. They ranged in age from 18.8 to 23.10 years ($M = 26.1$ years). To ensure that all the participants in the hLLD group had lower language skills as compared to their peers in the control group and to ensure that no participant in the NL group had an undiagnosed disorder, we used a behavioral testing battery and procedure developed by Tomblin, Freese, and Records (1992). The battery includes the Peabody Picture Vocabulary Test—Revised (PPVT-R; Dunn & Dunn, 1981), a modified version of the Token Test (Morice & McNicol, 1985), the Written Spelling subtest of the Multilingual Aphasia Examination (Benton & Des Hamsher, 1978), and a speaking rate measured from a picture description task (Tomblin et al., 1992). The means and standard deviations of the scores are given in Table 1. The results of these tests were then subject to a discriminant analysis for participant classification on the basis of statistically weighted scores. Note that this procedure allows for highly accurate classification (Tomblin et al., 1992), even given the sometimes subtle behavioral deficits that characterize this disorder during adulthood. Participants also received the Test of Nonverbal Intelligence—Third Edition (TONI-III; Brown, Sherbenou & Johnsen, 1997) to ensure normal intelligence (standard score $> 70 + 1SEM$).

In addition, all the participants who were included in the study passed an audiometric pure tone bilateral hearing screening at 25 dB HL at 500Hz and 20 dB HL at 1000, 2000, and 4000 Hz. The two groups were matched for gender and age (hLLD: seven females and eight males, $M = 21$; NL: eight females and seven males, $M = 19$). Nine additional participants were tested but were excluded from the study because they either failed a hearing screening at the time of study or standardized testing failed to confirm either poor or normal language skills consistent with their group membership. Five participants with history of head trauma were also excluded from the study.

Materials—Six non-words that were one syllable long, namely 'do', 're', 'mi', 'fa', 'so', 'la', 'ti' and 'ton', were created for two artificial languages (Language A [LA] and Language B [LB]). Note that 'ton' is considered a "heavy" syllable because it ends with a consonant. These had been recorded by a native English speaker using Sound Edit 16 on a Power Macintosh. Using these six words, two sets of sentences were created for each language. The words within each sentence were assigned to conform to a pre-specified pattern of stress following a hierarchical set of rules for stress assignment for the language (see Table 2). One set contained items used to train the language (exposure items) and the other was reserved for use as test items. Therefore, none of the test items were heard during the exposure period, but they all followed a same hierarchical set of rules for stress assignment and were intended to test generalization of knowledge of the rules. Examples of representative exposure items and test items of version 1 and 2 are given in the Appendix.

Familiarization stimuli: The one syllable words were arranged to form sentences that were 3 and 5 words long. Two different sets of hierarchical rules were used for stress placement on the sentences for LA and LB. These rules reflected specific ways that stress could be assigned to sentences in each of these artificial languages. The rules and examples of these sentences are presented in Table 2. When rules for assigning stress were in conflict, the “higher” rule in the hierarchy took precedence. Exposure sentences contained the six words in roughly equal proportions.

Test Stimuli & Procedures: Participants were assigned to one of the two versions of the experiment on a random basis. The versions corresponded to whether a participant heard LA or LB during the exposure period. The experiment was presented via computer using Direct RT software (Jarvis, 2004). Initial instructions were given by voice presented via the computer program. After a 2-minute exposure to stimuli from either LA or LB, participants were administered test items.

Two types of test items were constructed to test two levels of generalization. The first, “Pattern items” had exactly the same stress pattern as 20% of sentences in the test item’s corresponding language (LA or LB). Pattern items for LA (Pattern A) were stressed on the 1st and 4th syllable, (e.g., ‘DO re mi TON fa’). Pattern items for LB (Pattern B) had 2nd and 5th syllables stressed (e.g., ‘re TON mi fa SO’). These test items differed from the exposure in that the position of the stressed syllable “TON” within the sentence was different than had been heard during the exposure period. Even though the position of the stressed TON was novel within the sentence of test items, this syllable’s new position permitted the sentences to retain a stress pattern heard in the familiarization stimuli, under the hierarchical rules.

The second level of generalization required participants to infer and apply principles about the stress assignment. For “Principle” items, the position of the stressed syllable TON was manipulated so as to cause constraints lower in the stress hierarchy to be ignored. For example, although the first syllable is normally stressed in LA (constraint D), the stressed syllable TON in the second position in LA would cause the first syllable to become unstressed. This is because TON must be stressed (constraint B) and two consecutive syllables cannot be stressed (constraint A). Principles A and B have precedence over principle D, resulting in an unstressed first syllable in the first position in this example. Therefore, these types of Principle items allowed us to test the hierarchy of A > D, even though the listener had never been given direct evidence that this type of sentence was acceptable.

We also note that this shift in the position of the stressed TON from the exposure to test conditions created the opportunity for listeners to over-ride the stress hierarchy in favor of a positional cue. Learners may in effect ask whether stressed TON can occur in the second position according to what they heard during the exposure period. All Principle items for LA (Principle A) had the stressed TON in the second position (e.g. ‘re TON mi FA so’). Unstressed ton but not a stressed TON occurred in this position during exposure.

Similarly, all Principle items for LB (Principle B) had the stressed TON in the penultimate position (e.g. ‘re MI fa TON sa’). Exposure items for LB had unstressed ton but not the stressed TON in the same position. Therefore, for LA and LB, the Principle test items introduce a “positional cue” that conflicted with the stress cues in LA and LB. Because these test items were taken from the previous studies by Gerken (2004) and Guest et al. (2000) that employed these stimuli, this situation would have been true for these studies as well.

All participants were tested on the Patterns and Principles items that correspond to both LA and LB. “Correct” test items for each participant were those that are consistent with the

stress hierarchy of the exposure language he or she heard. Those exposed to LA should prefer test items that conformed to the stress assignment rules of LA and vice versa. Test items were presented one at a time. The participants were instructed to press a 'yes' key if they thought the test item belonged to the language they had just heard and press a 'no' key if they believed it did not belong to that language.

There were 14 test items corresponding to each of four types of sentences (Pattern LA, Pattern LB, Principle LA and Principle LB) resulting in a total of 56 test items. The Principle test items were presented first as a block of items followed by the Pattern items. This order of presentation was adopted to eliminate the possibility of influence of Pattern items on the participants' response to Principle items. It was anticipated that hearing the Pattern items (with the same stress pattern) first might lead the participants to treat only those sentences that had the exact same stress pattern as the exposure sentences to be correct. This would cause them to respond to all Principle items, including the ones that actually belong to the exposure language, as incorrect. Within the blocks of Pattern and Principle items, individual test items were randomized.

Results

The means and standard error for the rate at which participants accepted Pattern and Principle test items for the two versions are shown in Figure 1. Given that this was a two item forced choice response, the chance level of correct responses was fifty percent. There was a significant difference in the participants' performance on version 1 and version 2. Therefore, we analyzed the responses on the two language versions separately.

The responses of the two groups were analyzed using a 2 group (NL vs. hLLD) by 2 experiment version (LA vs. LB exposure) by 2 item type (correct vs. incorrect items) by 2 generalization type (Principle vs. Pattern) analysis of variance with group and version as between group effects and item and generalization type as within group effects. The ANOVA revealed a significant main effect for group, $F(1, 25) = 9.16, p < 0.005; \eta_p^2 = 0.276$, with hLLD group accepting more items overall than the NL group. A main effect of item type, $F(1, 25) = 48.29, p < 0.001; \eta_p^2 = 0.66$, indicated that items consistent with the language of exposure were accepted more often than items that were inconsistent. There was no significant main effect of generalization type ($F = 1.10, p < 0.32$) or version ($F = 3.45, p < 0.07$).

The 2-way interaction effects between generalization type and version $F(1, 25) = 24.46, p < .0001, \eta_p^2 = 0.35$ and generalization and item type $F(1, 25) = 10.93, p < .003, \eta_p^2 = 0.28$ were also significant. The generalization type by version effect is displayed graphically in Figure 2a and Figure 2b for Pattern and Principle items respectively. Results indicated that, for Pattern items, items consistent with the exposure language were preferred over items that were inconsistent for both versions. Participants' differential performance on consistent vs. inconsistent Pattern test items was evidence for recognition of stress patterns by both groups, at least to some extent.

For Principle test items, the participants preferred items of version 1 more often than those of version 2 (Figure 2b). This preference occurred independent of whether the test item was correct or incorrect for the version. Rather, participants tended to accept all the items (correct as well as incorrect) from version 1 at higher rates than version 2.

In summary, it was relatively easier for the participants to generalize to stress patterns similar to those heard during exposure than to infer hierarchical stress rules. There was no significant difference in the performance of the two groups for either type of generalization.

Study 2

In Study 1, there was an overall difference in the performance of the hLLD and the NL groups. In addition, neither group showed generalization to the inconsistent items that reflected the hierarchical stress principles. The result of Study 1 was consistent with previous findings for adults (Guest et al., 2000). We wondered whether performance could be enhanced if the stress pattern were made more salient. In other words, could adults be induced to generalize to Principle items if their attention was drawn particularly to the stress pattern of the stimuli, overriding any other aspect to which they may otherwise attend? In addition, we hypothesized that the overall performance of the hLLD group might be enhanced if the stress pattern in the input was made more salient.

Method

Participants—Twenty six native English-speaking adults were recruited from The University of Arizona, Tucson for the study. All subjects provided informed consent and study procedures were approved by the University's institutional review board. Thirteen adults (eight females and five males) had a history of language-based learning disability (hLLD) and ranged in age from 18.4 to 30.7 ($M = 26.2$). Thirteen others (seven females and six males) were adults with normal language (NL) and ranged in age from 18.3 to 26.5 ($M = 24$). The group assignment and selection criteria were the same as in Study 1. Participants' scores on the behavioral measures are given in Table 3. Five additional participants were tested but were excluded from the study because they either failed a hearing screening at the time of study or standardized testing failed to confirm either poor or normal language skills consistent with their group membership. Two participants with history of head trauma were also excluded from the study.

Materials

Familiarization materials: The materials used were modified version of those used in Study 1. The intensity level of the stressed words within the sentences was digitally enhanced to make the stress pattern more salient. The intensity of stress was increased on the stressed words by 10 db.

Test stimuli and procedures: Test stimuli and procedures were same as in Study 1.

Results

The means and standard error for the rate at which participants accepted Pattern and Principle test items for the two versions indicated no significant response differences between version 1 and 2 in this study. For this reason, we collapsed the responses to the two versions for analysis. The chance level for correct responses was fifty percent.

The responses of the two groups were analyzed using a 2 group (NL vs. hLLD) by 2 item type (correct vs. incorrect items) by 2 generalization type (Principle vs. Pattern) analysis of variance with group as a between group effect and item and generalization type as within group effects.

The ANOVA revealed a significant main effect for item type $F(1, 24) = 28.90, p < 0.001, \eta_p^2 = 0.61$, with more items consistent with exposure accepted than inconsistent items. There was no significant main effect for group $F(1, 24) = 1.39, p < 0.25$, or generalization type ($F = 1.10, p < 0.32$). The 2-way interaction effect between item and group $F(1, 24) = 7.62, p < .01, \eta_p^2 = 0.28$ was also significant indicating that the NL group accepted more correct items than incorrect items. Furthermore, there was a three way item type x generalization x group effect $F(1, 24) = 11.89, p < 0.002, \eta_p^2 = 0.31$. The NL group

accepted fewer items inconsistent with exposure than the hLLD group for both Pattern as well as Principle test items (see Figure 4).

The results suggest that enhanced stress assisted the NL group in recognizing stress patterns as well as in implicitly learning the hierarchical rules of stress assignment. However, it did not assist the hLLD group's performance on Principle test items and made their performance worse on Pattern test items than in Study 1. NL adults were significantly better on both levels of generalizations than the hLLD group when the prosodic cues were made salient.

Discussion

In Study 1, a comparison of the performance of the NL adults on Pattern vs. Principle test items replicates the results of Guest et al. (2000). They also found that normal adults were able to identify the stress patterns belonging to a novel language, but were unable to infer the hierarchical stress assignment rules for sentences of up to five words. The pattern of performance of the hLLD group in Study 1 was similar overall to that of the NL group. However, the participants of this group showed a bias towards accepting all the items in general. This reduced their overall accuracy on test items that were inconsistent with the exposure language, leading to a less differentiated response to test items. This bias may be explained by a tendency of hLLD subjects to rely on memory for individual words within the test sentence, rather recognition of the more global pattern those words formed. In the present study, all the words in the test items were phonologically identical to those heard during the exposure period, even though the stress patterns varied from exposure to test. This may have led to the increased tendency to accept items as correct, even when the phrase stress was inconsistent with the exposure set. This pattern of accepting information that is phonologically familiar has been reported previously for adults with hLLD who participated in an implicit learning task (Richardson, Harris, Plante, & Gerken, 2006).

In Study 1, neither the hLLD nor NL group showed evidence of having learned the hierarchical principles of stress that could be inferred from the exposure set. This is in contrast to the previously reported performance of infants on the same stimuli. Gerken (2004) found that children as young as nine months were able to successfully learn hierarchical as well as simple patterned forms of structural learning. A comparison of the results obtained from previous studies of typical learners (Gerken, 2004; Guest et al., 2000; Sasaki & MacWhinney, 2006; Slobin & Bever, 1982; Thiessen & Saffran, 2003) suggest that learners of different ages may concentrate on different aspects of the language input, leading to more or less focus on prosodic cues to language structure.

In Study 2, the stress was made more prominent whereas all other components of Study 1 remained unchanged. This change in stress did not alter the NL group's performance on the Pattern items, which already reflected successful learning in Study 1. Like the previous NL sample, this new group of participants was also able to recognize the Pattern items that belonged to the exposure language. In addition, their performance on the Principle items improved and more closely resembled that of the infant participants in Gerken (2004). Furthermore, the improved performance under enhanced stress conditions complements the findings of Guest et al. (2000). They showed that an alteration in the test stimuli length also led to better performance of NL adults relative to their performance on stimuli of the length used in the present study. Their results and the results of Study 2 presented here suggest that adults do not lose the ability that infants demonstrate to track hierarchical stress cues. Instead, they may be induced to track these cues under specific conditions. The difference in performance for participants in Study 1 and 2 may be due to the possibility that adults attend to multiple cues, some of which override stress cues (Thiessen & Saffran, 2003). In the current study, the hierarchical stress patterns were tested with items that also involved a change in the position of the stressed heavy syllable word "TON" within the sentence. It

may be that adults, by default, track positional cues (i.e, the position of TON in this stimulus set) over prosodic cues, but may be led to attend to the prosodic cues if they are made salient enough.

In Study 1, the hLLD group appeared to have a non-significant preference for items that conformed to the stress rules of the items consistent to the exposure language. However, the enhanced stress in Study 2 had a different effect on the performance of the hLLD group than was expected. Their performance on the Pattern test items decreased, such that the mean responses to items that were consistent and those that were inconsistent to the exposure language hovered around chance levels. This result is counter-intuitive. It suggests that these subjects were attempting to track some cue other than prosody during the task, but were perhaps still influenced by stress cues in Study 1. When stressed was enhanced, this manipulation either failed to pull the participants' attention towards prosodic cues or caused them to actively suppress these cues in favor of some other source of information in the input. As a result, the responses to Pattern test items were even less differentiated in Study 2 than in Study 1.

A comparison of performance of both the groups in the two studies indicates that the typically developing adults are capable of employing the prosodic cues to recognize strings from a novel artificial language, but they do so only when the prosodic cues are greatly emphasized. A comparison of our results with adults to the performance of infants on the same stimuli (Gerken, 2000), suggests that a difference in learning strategy exists for adult vs. infant learners. On the other hand, adults with hLLD show some ability to match the exact stress patterns of a novel language when it is presented with typical prosodic cues; however, they do not appear to benefit from the enhancement of prosodic cues. This suggests that enhancement of stress cues in the language input is unlikely to be a viable method for improving the learning of this population.

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Appendix A. Continuing education

Test questions for 'Processing prosodic structure by adults with language-based learning disability.'

1. Performance of adults with a history of language-based learning disability (hLLD) to extract complex hierarchical rules of stress
 - a. depends on the intensity of stress
 - b. is better than that of infant learners
 - c. is like that of normal adult learners
 - d. is poorer than that of normal adult learners or infants
2. This article shows that adults with hLLD:
 - a. Can extract complex rules of stress assignment in some conditions
 - b. Cannot recognize simple stress patterns of an artificial language in any condition
 - c. Can recognize simple stress patterns of an artificial language in any condition

- d. None of the above
- 3. The ability to infer hierarchical rules of stress
 - a. is important because listeners who understand the hierarchy allows application of the rules to linguistic elements that the listener has not previously heard, allowing for good generalization.
 - b. is important because listeners use stress patterns to help them understand the meaning of what they hear.
 - c. is not important in terms of understanding how a language is structured, but can affect language meaning.
 - c. there is no advantage to understanding stress assignment in a language.
- 4. This article shows that adults with typical language development:
 - a. Can extract complex rules of stress assignment in any condition
 - b. Cannot recognize simple stress patterns of an artificial language in any condition
 - c. Can recognize simple stress patterns of an artificial language in any condition
 - d. None of the above
- 5. The article shows that manipulation of the intensity of the stimuli
 - a. served to highlight the stress patterns for hLLD adults
 - b. can yield a better recognition of stress patterns and understanding of rules of stress in typically developing adults
 - c. helped both groups recognize patters similar to what they had previously heard.
 - d. had no effect on prosodic processing for either group

Answer Key

- 1. d
- 2. d
- 3. a
- 4. c
- 5. b

Appendix B

Examples of exposure and test items.

Examples of exposure and test items	Version	
	Version 1	Version 2
Exposure items	TON ton mi TI do	mi FA so ton TON
	MI fa so LA ti	ti DO re mi FA
	DO re TON	TON ti DO

Examples of exposure and test items	Version	
	Version 1	Version 2
	TI do TON re mi TON fa so	mi fa TON so LA so la TON
Test Items		
Pattern Items	DO re mi TON fa	do TON re mi FA
	RE mi fa TON so	re TON mi fa SO
	MI fa sa TON la	mi TON fa so LA
	FA so la TON ti	fa TON so la TI
	SO la ti TON do	so TON la ti DO
	LA ti do TON re	la TON ti do RE
	TI da ra TON mi	ti TON do re MA
Principle Items	do TON re MI fa	do RE mi TON fa
	re TON mi FA so	re MI fa TON so
	mi TON fa SO la	mi FA so TON la
	fa TON so LA ti	fa SO la TON ti
	so TON la TI do	so LA ti TON do
	la TON ti DO re	la TO do TON re
	ti TON do RE mi	ti DO re TON mi

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Figure 1. Mean number of accepted Pattern and Principle items on versions 1 and 2 of the experimental task. Version 1 indicates participants heard Language A (LA) during the exposure period. Version 2 indicates participants heard Language B (LB) during the exposure period.

Figure 2a.

Figure 2b.

Figure 2.

a. Mean number of accepted Pattern items that were consistent or inconsistent with the language of exposure on versions 1 and 2 of the experimental task. Version 1 indicates participants heard Language A (LA) during the exposure period. Version 2 indicates participants heard Language B (LB) during the exposure period. *b.* Mean number of accepted Principle items that were consistent or inconsistent with the language of exposure on versions 1 and 2 of the experimental task. Version 1 indicates participants heard Language A (LA) during the exposure period. Version 2 indicates participants heard Language B (LB) during the exposure period.

Figure 3.
Mean number of accepted Pattern and Principle items that were consistent or inconsistent with the language of exposure for the hLLD and NL group.

Table 1

Means and standard deviations of hLLD and NL groups on behavioral measures.

Behavioral Measures	hLLD		NL	
	M	SD	M	SD
^a PPVT-R (standard score)	96.13	14.5	102.4	13.8
^b Modified Token Test (raw score)	32.46	6.33	39.78	3.64
^c Speaking Rate (Words per minute)	112.03	10.28	9.64	2.64
^d Spelling (raw score) *	6.06	3.69	145.39	16.38
^a TONI	103.6	15.5	108.5	15.5
^a Letter Word Identification	94	10.5	103.7	8.22
^a Reading Fluency	94.6	9.85	110.7	9.63
^a Passage Comprehension	96.1	8	103.7	12
^a Word Attack	87.2	8.59	97.2	9.46

^a Reported as standard score ($\bar{X} = 100$, $SD = 15$)^b Modified Token Test is reported as raw score out of a total of 44^c Speaking Rate is reported as words per minute^d Spelling is reported as raw score out of a total of 10, From the Multilingual Aphasia Battery

Table 2

Hierarchy for stress assignment in the two experimental languages.

	Language version	
	Language A	Language B
Hierarchy	A > B > C1 > D1	A > B > C2 > D2
Rules	A: Two consecutive words cannot be stressed	A: Two consecutive words cannot be stressed;
	B: Words composed of a heavy syllable, i.e., ending with a consonant, are always stressed;	B: Words composed of a heavy syllable, i.e., ending with a consonant, are always stressed;
	C1: The <u>penultimate</u> word should be stressed;	C2: The <u>second</u> word should be stressed;
	D1: Alternating words starting from the <u>left</u> should be stressed.	D2: Alternating words starting from the <u>right</u> should be stressed.
Examples	'DO re mi FA so'	'do re TON mi FA'
	'DO re TON mi fa'	'do RE mi ton TON'

Note. Capitalized letters indicates a stressed syllable.

Table 3

Means and standard deviations of hLLD and NL groups on behavioral measures.

Behavioral Measures	hLLD		NL	
	M	SD	M	SD
^a PPVT-R (standard score)	91.23	16.9	108.38	9.02
^b Modified Token Test (raw score)	32.46	4.33	41.23	1.96
^c Speaking Rate (Words per minute)	118.5	16.7	146.11	41.29
^d Spelling (raw score) *	7.23	3.85	10.6	2.4
^a TONI	89.7	33.5	116	14.6
^a Letter Word Identification	92.9	14.4	108.7	14.6
^a Reading Fluency	90.1	15.8	109.5	11.3
^a Passage Comprehension	89.6	28.3	108.7	10.6
^a Word Attack	78.6	24.6	104.7	6.4

^aReported as standard score ($\bar{X} = 100$, $SD = 15$)^bModified Token Test is reported as raw score out of a total of 44^cSpeaking Rate is reported as words per minute^dSpelling is reported as raw score out of a total of 10, From the Multilingual Aphasia Battery