Effects of Semantic and Acoustic Context on Nonword Detection in Children With Hearing Loss

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Purpose: Children with hearing loss (HL) are known to have smaller receptive vocabularies than children with normal hearing (NH). This may be due, in part, of their reduced exposure to new words and their slower rate of word learning. A necessary prerequisite to lexical development is the detection of new words in conversation. The purpose of this study was to examine the effects of HL on children’s ability to detect the presence of nonwords within sentences that varied in semantic and acoustic context.

Methods: Twenty-nine children with NH and 16 children with HL between the ages of 7 and 13 years participated. The children listened to short sentences and reported the number of nonwords detected, ranging from zero to two nonwords, in each sentence. The structure of the sentences was either meaningful or nonsensical to the children to reveal the effects of semantic context. The effects of acoustic context were revealed by presenting the sentences in quiet, steady-state noise, and in multi-talker babble.

Results: Significant effects of age (older > younger), hearing (NH > HL), and listening condition (quiet > noise and babble) were observed. Also, nonword detection was better for semantically meaningful sentences than for nonsense sentences. Error analyses revealed that the children with NH tended to underestimate the number of nonwords in meaningful sentences but not in nonsense sentences. The children with HL, however, were more likely to underestimate the number of nonwords than were the children with NH for both meaningful and nonsense sentences. These error patterns were observed in each listening condition.

Conclusions: Error patterns suggest that children with HL apply strong repair strategies during speech perception, which may limit their opportunities to learn new words.

INTRODUCTION

It has been well established that grade-school children with hearing loss (HL) have, on average, smaller receptive vocabularies than their normally hearing (NH) peers do and that their lexical deficits correspond to their degree of HL (Blamey et al. 2001; Briscoe et al. 2001; Wake et al. 2004; Kiese-Himmel 2008; Pittman 2008; Sarant et al. 2009). Specifically, lexical development tends to proceed more slowly with increasing degrees of HL. What is unclear about their slower rate of lexical development is the manner in which their peripheral deficit (i.e., HL) interferes with the cognitive processes involved in learning new words. Evidence suggests that although HL reduces a child’s ability to perceive and repeat nonsense words (an important first step in word learning) (Briscoe et al. 2001), HL does not seem to cause deficits in phonological working memory or its development (Hansson et al. 2004; Stiles et al. 2012). In fact, children with HL are able to effectively store, maintain, and retrieve information about newly learned words as well as children with NH are (Stiles et al. 2012).

The problem, then, may lie elsewhere in the word-learning process; at a point that is vulnerable to a distorted acoustic representation of a new word. Storkel and Lee (2011) proposed a model of word-learning having three sequential cognitive processes: (1) triggering, (2) configuration, and (3) engagement. Triggering involves the evaluation of a word against words already residing in the lexicon. The word is judged to be known or unknown, causing communication to continue unaffected or triggering of the remaining word-learning processes, respectively. Configuration is the process of storing lexical and semantic information about a new word in long-term memory and is followed by engagement, which is the integration of the new word with existing words. Although each of these processes may be vulnerable to the effects of HL, poor auditory perception will likely have the greatest effect on the process of triggering and result in one of two types of errors: under- or over-triggering. Under-triggering is defined here as a failure to detect the occurrence of a new word or recognize that it is unknown. For example, a child may misperceive the sentence “Did you see that black cat?” as “Did you see that black cat?” and miss the opportunity to learn about “gats” (whatever they may be). Such repair strategies are common among hearing-impaired listeners, particularly in adverse listening conditions where communication is more likely to break down. In fact, individuals with HL are known for incorrectly repairing acoustic messages, causing the flow and topic of conversation to be altered.

Over-triggering is defined as the initiation of the word-learning process when a word or series of words is misperceived as being unknown. For example, the known word “cat” may be misperceived as “gat” and cause the child to attend to the conversation differently to learn what a “gat” is. This sort of over-triggering may place items in the lexicon that do not exist within the child’s native language. For example, “cookamee” (“look at me”) and “donserly” (“dawn’s early”; from the Star Spangled Banner) are word series that were misperceived to form unique words by children known to the authors. If this sort of over-triggering occurs in children with HL, the word-learning process may be slowed because of the time it takes to disambiguate the new word from the many other words that are cluttering the child’s lexicon.

Although recent research has revealed much about word-learning in children with HL, many of the effects of HL on these learning processes remains to be investigated. For example, in one laboratory-based paradigm children are asked to detect and learn nonwords that are embedded within a passage that is presented in story form (implicit learning). After hearing the story a prescribed number of times, the children’s ability to identify the referent associated with each nonword is determined. Compared with children with NH, children with HL perform poorly...
on this task, suggesting that one or more of the word-learning processes was impeded by HL (Stelmachowicz et al. 2004; Pittman et al. 2005; Stelmachowicz et al. 2007). Because of the nature of the paradigm, it is possible that fewer nonwords are detected (under-triggering) by children with HL, thereby preventing the processes of configuration and engagement. However, these children may also misperceive real words or phrases in the story as unknown to them, resulting in significant over-triggering, thus limiting the number of words that they can attend to in the story. Finally, the nonwords may be triggered properly but poor auditory representations of the words compromise the configuration and engagement processes, making it difficult for the children to differentiate the new words from other words in the lexicon.

In a different word-learning paradigm, children are explicitly informed that they will learn novel words by associating them with novel objects or images through a process of trial and error (Pittman 2008, 2011a). The children’s task is to choose a referent (from a set of novel items) when a nonword is presented. The nonwords are repeated multiple times in a random fashion and the child receives reinforcement for each correct response. Ultimately, the child learns which nonword is associated with each referent, based on the feedback received during each trial. The number of exposures needed to achieve a criterion level of performance is calculated and provides an estimate of the child’s learning rate. In this explicit learning paradigm, it is expected that the word-learning processes will be triggered on every trial. Even so, children with HL require significantly more exposures than children with NH to learn a new word (Pittman 2008). Also, the presence of background noise further decreases their learning rate relative to that of children with NH (Pittman 2011a). These results suggest that the children with HL may be unable to form satisfactory acoustic representations of the nonwords such that they are able to differentiate them from each other and, perhaps, other words in the lexicon.

The nature of the interference caused by HL during the word-learning processes of triggering, configuration, and engagement is not likely to be captured in a single experimental paradigm. As a first step, the purpose of this study was to examine the effects of HL on the triggering process for unknown words. Older and younger grade-school children with NH and with HL were asked to count the number of nonwords embedded in short sentences. The sentences varied in semantic structure and were presented under various listening conditions. In addition to the effects of age and HL, error analyses were examined to reveal the types of errors made by the children as a function of sentence type and listening condition. Specifically, the proportion of errors that were due to reporting too many nonwords (over-triggering) or too few nonwords (under-triggering) was determined.

**PARTICIPANTS AND METHODS**

**Participants**

The control group for this study consisted of 29 children with NH (13 boys, 16 girls) recruited on the basis of chronological age to form two age groups: a younger group between the ages of 7 and 9 years (n = 13; mean = 8 years, 9 months; SD = 9 months; range = 7 years, 5 months to 9 years, 10 months) and an older group between the ages of 10 and 12 years (n = 16; mean = 11 years, 6 months; SD = 10 months; range = 10 years, 4 months to 12 years, 10 months). On the day of testing, all children had hearing thresholds of 15 dB HL or lower at octave frequencies between 0.25 and 8 kHz and normal middle ear status as confirmed by acoustic admittance measures.

**TABLE 1.** Demographic characteristics of the children with hearing loss including sex, age, hearing thresholds as a function of frequency, type of loss, and age when hearing loss was identified and aided

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (yrs;mos)</th>
<th>Right-Ear Hearing Threshold (dB HL) as a Function of Frequency (kHz)</th>
<th>Left-Ear Hearing Threshold (dB HL) as a Function of Frequency (kHz)</th>
<th>Type of Loss</th>
<th>Age at Identification (yrs;mos)</th>
<th>Age at Amplification (yrs;mos)</th>
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C, conductive; M, mixed; N, normal; S, sensorineural; UTD, unable to determine.
The experimental group consisted of 16 children with mild to moderately severe HL (6 boys, 10 girls). As with the control group, the children were recruited on the basis of chronological age to form a younger group between the ages of 7 and 9 years (n = 6; mean = 8 years, 11 months, SD = 10 months; range = 7 years, 11 months to 9 years, 6 months) and an older group between the ages of 10 and 13 years (n = 10; mean = 10 years, 11 months; SD = 10 months; range = 10 years, 2 months to 13 years, 1 month). Independent samples t tests confirmed that the children in each hearing group (NH versus HL) did not differ with respect to age (younger: \( t[17] = -0.463, p = 0.649 \); older: \( t[24] = 1.693, p = 0.103 \)). Table 1 contains the thresholds of the children with HL in each age group at octave frequencies between 0.25 and 8 kHz. The children’s sex, chronological age, type of HL in each ear, age of identification, and age at first amplification are also provided. Figure 1 shows the average hearing thresholds (±1 SD) of the younger and older groups as a function of frequency for the right and left ears in the upper and lower panels, respectively. The data points have been jittered slightly to better display the error bars. On average, the children’s hearing sensitivity was equivalent across frequency and between ears.

On the day of testing, each child received the Peabody Picture Vocabulary Test (PPVT): IV (form B) (Dunn & Dunn 2007) to quantify his/her receptive vocabulary. Figure 2 shows the results of the PPVT as a function of chronological age for the children with NH (filled symbols) and the children with HL (open symbols). PPVT age, standard score, and raw scores are shown in the upper, middle, and lower panels, respectively. The dashed line in the top panel represents the linear relation between PPVT age and chronological age whereas the dashed lines in the middle panel represent 1 SD around the standard score of 100. A one-way analysis of variance (ANOVA) with hearing group (NH, HL) and age group (younger, older) as the between-subjects factors confirmed that PPVT standard scores were significantly different across hearing groups (\( F[1, 39] = 8.814, p = 0.005, \eta^2 = 0.184, \beta = 0.825 \)) but not across age groups (\( F[1, 39] = 2.8, p = 0.102 \)). Also, No Hearing × Age Group interaction was observed (\( F[1, 39] = 0.592, p = 0.446 \)). By way of comparison, the average standard score for the...
older group was 111 and 102 for the children with NH and the children with HL, respectively. Likewise, the average standard score for the younger children was 107 and 92 for the children with NH and the children with HL, respectively. These results are consistent with previous studies and show that the children represent their hearing and age groups well.

Stimuli
A stimulus database containing 560 sentences was created by adapting the 120 sentences used in Stelmachowicz et al. (2000) to form sentences containing one or two nonwords through single-phoneme substitutions. Each sentence contained four words. Half of the sentences in the database were both grammatically and semantically correct (referred to as meaningful), whereas the other half were grammatically correct but semantically meaningless (referred to as nonsense). The same words were used in the construction of both types of sentences. Meaningful sentences represent more familiar utterances (e.g., “Dump trucks fill holes.”), whereas nonsense sentences represent utterances that would be unfamiliar or new to a child (e.g., “Strange nails taste dark.”) (Nittrouer & Boothroyd 1990). The meaningful and nonsense sentences were modified to include nonwords by replacing a single phoneme in a word with another phoneme of similar phonotactic probability.* Sentences contained either no substitutions (e.g., Dump trucks fill holes), one substitution (e.g., Sump trucks fill holes), or two substitutions (e.g., Dump rucks fill noles). The phoneme replacement within the modified word occurred either in the initial or the final position of the word or as the second phoneme of a consonant blend. A total of 108 sentences were drawn from the larger database to create three lists of meaningful sentences and three lists of nonsense sentences. Each list contained 18 sentences with equal amounts of zero, one, and two phoneme substitutions. No sentences were duplicated in any of the lists. These sentences are provided in the (Supplemental Digital Content 1, Appendix, http://links.lww.com/EANDH/A90). The phoneme substitutions are indicated in italics.

Stimuli were spoken by a female talker with a standard American English dialect. Recordings were made at a sampling rate of 22.05 kHz, using a microphone (AKG, C535EB) with a flat frequency response to 10 kHz. The words were edited using a digital audio editor (Adobe, Audition) to equate them for root-mean-square level and to create single audio files. Some semantic information was preserved in that small portions of each conversation (a few words) could be selectively followed. Both the high- and low-predictability sentences were presented in each of the listening conditions for a total of six test conditions. The signal-to-noise ratio for this experiment was +6 dB.

Presentation Levels
All stimuli were routed binaurally through earphones (Sennheiser, 25D) having a flat frequency response to 10 kHz. For the children with NH, the stimuli were presented at an overall level of 65 dB SPL, which is consistent with average conversational speech. To accommodate the elevated thresholds of each child with HL, the stimuli were frequency shaped according to the desired sensation level prescription procedure (DSL V5.0A). This algorithm provides amplification targets for average conversational speech (Scollie et al. 2005). The targets were derived using age-appropriate real-ear-to-coupler differences and a speech-weighted input level of conversational speech (65 dB SPL). Because the stimuli were presented via supra-aural, rather than insert-earphones, target levels were

Listening Conditions
Sentences were presented in three listening conditions: in quiet, in steady-state noise, and in multi-talker babble. The steady-state noise served as an energetic masker to the low-level acoustic properties of the speech stimuli and thereby increased the perceptual difficulty of the task. This masker consisted of broadband, random noise shaped to match the long-term spectrum of the multi-talker babble. The multi-talker babble, in addition to being an energetic masker, provided an additional semantic masker that was expected to compete with the context of the speech stimuli. It contained conversations of six men and six women recorded separately and then mixed together into a single audio file. Some semantic information was preserved in that small portions of each conversation (a few words) could be selectively followed. Both the high- and low-predictability sentences were presented in each of the listening conditions for a total of six test conditions. The signal-to-noise ratio for this experiment was +6 dB.

\*Phonotactic probability is a computational method for determining the frequency with which a phoneme or blend of phonemes occur in the initial, medial, or final position of a word within a given language (Vitevitch & Luce 2004).
approximated by measuring the 1/3 octave bands levels developed in a 6-cm³ coupler.

Nonword-Detection Task
The children’s task was to count the number of words in each sentence that were not real. The children interacted with a computer game that promoted attentive listening through reinforcement. On each trial, a sentence was randomly selected and presented. The child selected one of four buttons located at the bottom of the computer screen. The buttons displayed the numbers 0, 1, 2, and 3 and represented the number of nonwords the child detected in each sentence. Although the maximum number of nonwords in any sentence was two, the option to choose three nonwords was provided as a foil to detect instances of over-triggering. Reinforcement for accurate selections was provided via a video game displayed in the upper portion of the screen (e.g., a piece of a puzzle appeared after each correct response). Reinforcement was not provided for incorrect responses. Although the temporal parameters of the experiment were controlled via the custom software, the children’s responses were self-paced. That is, a stimulus file was presented (3000-msec duration), the children responded at their own pace (15-sec response window), reinforcement was provided when appropriate, and then the next stimulus was presented after a short delay (1000 msec).

Procedure
All testing was conducted in a sound-treated booth in the presence of two examiners. One examiner managed the experimental equipment and monitored the child’s performance. The other examiner familiarized the child with the game and monitored his/her behavior during testing.

The following instructions were given to the child before beginning the task:

You are going to hear short sentences. Each sentence has four words. Some sentences make sense but others are silly. Some sentences have words that aren’t real. Your job is to count the words in each sentence that are not real and select that number on the screen. If you counted correctly, the game on the screen will play. If you didn’t, nothing will happen. Listen carefully because you will only hear each sentence once.

Each child practiced with the examiner using a one-page screenshot of the computer monitor. The examiner asked the child, “How many words are not real in this sentence? ‘Pick up that foom.’” The child was then instructed to point to the correct number. The examiner then asked “How many words are not real in this sentence?” “Clean out the car.” If the child indicated that there were no nonwords in the sentence by pointing to the number zero, the experimental testing began. None of the children required additional practice before proceeding.

Word lists and sentence type were presented in a counterbalanced fashion across listening conditions. Testing lasted approximately 3 min per listening condition for a total test time of approximately 18 min (3 Listening Conditions × 2 Sentence Types × 3 Min). Children were provided with breaks as necessary and were paid for their participation according to the procedures outlined by the Institutional Review Board at Arizona State University.

RESULTS
The data were first analyzed to confirm the effects of age and HL. Values of proportion correct were arcsine transformed before analyses. Average performance in proportion is shown as a function of age group in Figure 3 and as a function of hearing group in Figure 4. The results for the meaningful and nonsense sentences are shown in the upper and lower panels of both figures, respectively. The parameter in each panel is listening condition. The shaded sections of each bar represent proportion correct (solid section), proportion of errors caused by under-triggering (hatched section), and proportion of errors caused by over-triggering (open section).

In terms of correct detection (solid section), the younger children performed more poorly than did the older children (Fig. 3) and the children with HL performed more poorly than did the children with NH (Fig. 4). Also, performance was poorer for the nonsense sentences than for the meaningful sentences. The data were submitted to a repeated measures ANOVA with hearing group (NH, HL) and age group (younger, older) as the between-subjects factors and listening condition (quiet, noise, babble) and sentence type (nonsense, meaningful) as the within-subjects factors. Significant main effects of hearing ($F[1, 37] = 18.66, p < 0.001, \eta^2 = 0.335, \beta = 0.988$), age ($F[1, 37] = 6.451, p = 0.015, \eta^2 = 0.148, \beta = 0.696$), and sentence type ($F[1, 37] = 16.395, p < 0.001, \eta^2 = 0.307, \beta = 0.976$) were observed but not for listening condition ($F[2, 74] = 1.544, p = 0.22$). No significant interactions were revealed except for Listening Condition × Age Group ($F[2, 74] =$
be observed in Figure 3. The interaction can be seen as the older children were able to detect the nonwords more accurately in the quiet listening condition. This interaction was also significant for overall performance, with a main effect of listening condition suggesting that nonword detection was affected by the type of condition. However, the significant interaction indicates that nonword detection was affected by the combination of condition and age group. For example, the children with HL made nearly twice as many errors due to under-triggering than the children with NH.

The proportion of each type of error was arcsine transformed and subjected to repeated measures ANOVA with hearing group (NH, HL) and age group (younger, older) as the between-subjects factors and listening condition (quiet, noise, babble), sentence type (nonsense, meaningful), and type of error (over, under) as the within-subjects factors. Consistent with the results for overall performance, significant main effects of hearing, age group, and sentence type were observed. Additionally, a significant interaction was found between listening condition and age group, indicating that the older children were more likely to make under-triggering errors than the younger children.

The children’s errors were then examined to determine whether they were equally likely to misperceive real words (over-trigger) and nonwords (under-trigger) or whether they tended to make more of one type of error. For each incorrect trial, the number of nonwords reported by the child was compared to the number of nonwords contained in the sentence in that trial. Differences were categorized as being either greater than (over-trigger) or less than (under-trigger) the correct number of nonwords. Figures 3 and 4 show the proportion of each type of error that occurred in each listening condition. Both age groups (Fig. 3) made more errors because of under-triggering for the meaningful sentences (upper panel) but equally as many under- and over-triggering errors for the nonsense sentences. A similar pattern of errors is seen for the NH and HL groups (Fig. 4) with the exception that the children with HL made nearly twice as many errors due to under-triggering than the children with NH.

The proportion of each type of error was arcsine transformed and subjected to repeated measures ANOVA with hearing group (NH, HL) and age group (younger, older) as the between-subjects factors and listening condition (quiet, noise, babble), sentence type (nonsense, meaningful), and type of error (over, under) as the within-subjects factors. Consistent with the results for overall performance, significant main effects of hearing (F[1, 39] = 5.96, p < 0.001, η² = 0.29, β = 0.973), age group (F[1, 39] = 4.894, p = 0.033, η² = 0.111, β = 0.578) and sentence type (F[1, 39] = 9.068, p = 0.005, η² = 0.189, β = 0.836) were observed as well as a lack of a Hearing × Age Group interaction (F[1, 39] = 0.012, p = 0.914). Of interest here is the significant main effect of error type (F[1, 39] = 27.21, p < 0.001, η² = 0.411, β = 0.999) and Error Type × Hearing Group interaction (F[1, 39] = 7.15, p = 0.011, η² = 0.155, β = 0.741). Post hoc analyses revealed that the children with HL made significantly more errors due to under-triggering than the children with NH.

The lack of an Error Type × Age Group interaction (F[1, 39] = 0.872, p = 0.356) suggests that these error patterns were the same for both age groups.

**Lexical Constraints**

It was also of interest to relate the children’s performance on the nonword-detection task to their receptive vocabularies as measured with the PPVT. As the children evaluated the words in each sentence, they had to compare them with the words residing in their lexicons. It was expected that the ability to detect nonwords would be directly related to the size of the receptive vocabulary such that children with smaller vocabularies would perform more poorly. Figure 5 shows performance for the nonword-detection task as a function of the PPVT raw score for the children with NH (filled symbols) and the children with HL (open symbols). The results for the meaningful and nonsense sentences are shown in the left and right panels and the quiet, noise, and babble conditions are shown in the upper, middle, and lower panels, respectively. The Pearson correlation coefficient and the linear relation between nonword detection and PPVT are provided in each panel. Significant correlations at the p < 0.05 level are indicated by an asterisk. In all but one condition (meaningful sentences presented in noise) there was a significant relation between the children’s ability to detect the nonwords and their PPVT raw scores. However, these correlations became insignificant when age was partialed out of the analyses. The results indicate that nonword detection was influenced, in large part, by constraints stemming from the size of the receptive vocabulary, which is closely related to the children’s chronological age.

**Hearing History**

A final analysis involved the relation between the children’s ability to detect the nonwords and their history of HL and use of amplification. It was expected that performance would be related to the age at which the HL was identified and the age...
at which the children were provided with amplification. Partial correlations controlling for the children’s chronological age revealed no significant relation between the children’s hearing history and their performance for either type of sentence in any of the listening conditions, nor were significant correlations observed for either type of error under these same conditions \( (p > 0.05) \).

**DISCUSSION**

The purpose of this study was to examine the effects of HL on the initial stage of word learning, which is triggered when an unknown word is detected. Older and younger grade-school children with NH and with HL counted the number of nonwords contained in meaningful and nonsense sentences presented in quiet, noise, and multi-talker babble. To perform well, the children had to perceive correctly the phonetic content of each word in the sentence, compare each word with those in their lexicon, identify any words that were not known, and retain the nonwords detected for a short time in working memory. It should be noted that this detection task is different from more traditional detection tasks in which the listener indicates the presence or absence of a simple stimulus within one or more presentation intervals. It should also be noted that because the children with NH served as the control group for this task, any under- or over-triggering that they demonstrated was the result of the stimuli and listening conditions rather than a deficit in word learning. Therefore, the performance of the children with NH was considered normal and served as the basis for determining the effects of HL on nonword detection.

The overall performance of the older children was better than that of the younger children and the performance of the children with NH was better than that of the children with HL. The lack of an Age × Hearing Group interaction suggests that the younger children with HL were at no particular disadvantage when detecting the nonwords. Likewise, the lack of a significant main effect of listening condition suggests that the +6 dB signal-to-noise ratio was not challenging enough to cause performance to decrease relative to the quiet listening condition. However, the expected decrease in noise was observed in the older children, but this does not explain why the younger children were not affected in a similar fashion. In fact, one would expect that the degrading effects of noise would be more pronounced in the younger children. Instead, their nonword detection was the same in each listening condition, suggesting that the presence of noise did not increase the difficulty of the task. Although these results suggest that children’s detection of nonwords may improve with age in quiet, the advantage of age is lost in the presence of acoustic competitors. In practical terms, noisy classrooms may not be ideal places for learning new words at any age.

Finally, it was expected that the children would be better able to detect the nonwords in the nonsense sentences due to the lack of semantic context that might promote repair strategies. Instead, both groups of children were better able to detect the nonwords in the meaningful sentences. The poorer performance of all groups (NH, HL, older, younger) for the nonsense sentences was caused by over-triggering, indicating that the lack of context caused the children to misperceive real words as nonwords. This benefit of semantic context is consistent with research regarding children’s speech perception (Elliott 1979; Boothroyd & Nittouer 1988; Stelmachowicz et al. 2000) and suggests that context also supports children’s ability to identify words that are unknown to them.

Of particular interest was the nature of the errors made by the children when they failed to detect the nonwords in the sentences. Error analyses revealed that the children with NH were more likely to under-trigger when listening to the meaningful sentences, suggesting that their perception of the nonwords was such that they did not consider them to be inconsistent with known words. Their under- versus over-triggering errors were more balanced for the nonsense sentences, suggesting that the absence of semantic context promotes both types of errors. This is consistent with their poorer overall performance for these sentences and the benefit that context provides to the detection of new words. However, the errors for the children with HL revealed that although their rate of over-triggering increased when listening to the nonsense sentences, their tendency to under-trigger increased significantly more. This is not consistent with the expectation that they would be more likely to over-trigger because of their poorer speech perception and smaller receptive vocabularies. One possible explanation is that they underestimated the number of nonwords in each sentence due to a lack of confidence in their ability to perceive speech. However, to apply such a strategy the children would have had to ignore, in large part, the reinforcement provided to them and, more importantly, such a strategy would have resulted in fewer instances of over-triggering, which was not the case. In fact, their rate of over-triggering was the same as that of the children with NH. Another possibility is that the children with HL were not able to detect more than one nonword in a sentence. That is, once a nonword was identified, their attention to other words in the sentence was impeded. But again, that would have required the children to ignore the reinforcement and would have resulted in fewer instances of under-triggering, which again was not the case. A more likely explanation is that the children with HL applied strong repair strategies to both the meaningful and nonsense sentences. Further research is necessary to determine the strength of these strategies and their effect on children’s ability to learn new information.

It is also interesting to note that an increased rate of under-triggering was responsible for the older children’s decrease in performance in the steady-state noise and in the noisy listening conditions. That is, the noise caused them to consider more nonwords to be known words. This contradicts the notion that noise interferes with speech perception and causes the words to be unrecognizable. Perhaps this listening strategy develops during childhood as a way to communicate in difficult listening environments because it is more successful than those that would reject utterances that do not fit within narrow parameters of recognition. If so, this might explain the higher rate of under-triggering by the children with HL relative to the children with NH. Their broader experience with distorted acoustic representations may have encouraged the use of broader word-recognition criteria, resulting in significantly more under-triggering.

Finally, the lack of correlation between the children’s performance and their hearing history is not unusual for this age group. Pittman (2011a, b) and others have reported no relationship between hearing history and a number of auditory
perception tasks when children reach grade school. This may be because of the wide range of early and late onset etiologies of HL and progressive HL in this age group. It is also possible that the factors relating hearing history and auditory task performance in infants and young children (Moeller 2000) are somewhat transitory such that other factors become significant in older children. Thus, it is not surprising that the hearing history of older children with HL is not captured well by the simple parameters of age at identification and amplification. A comprehensive examination of children’s hearing history gathered in a longitudinal fashion may better reveal factors that bear significantly on children’s lexical development.

Implications
The results of the present study suggest that the smaller receptive vocabularies of children with HL may be caused, in part, by their inability to detect new words in conversation. Regardless of the cause of children’s tendency to under-trigger, these results indicate that their learning processes are not triggering properly. Therefore, improving the ability of hearing-impaired children to detect nonwords will no doubt provide them with more opportunities to learn new words. The degree to which a child’s strategies can be shaped to be more like those of his/her normal-hearing peers through amplification or early intervention is unknown and a matter of further research.

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The authors declare no conflicts of interest.

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