Novel-Word Learning in Children with Normal Hearing and Hearing Loss

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Objective: **The goal of this study was to assess performance on a novel-word learning task by normal-hearing and hearing-impaired children for words varying in form (noun versus verb), stimulus level (50 versus 60 dB SPL), and number of repetitions (4 versus 6). It was hypothesized that novel-word learning would be significantly poorer in the subjects with hearing loss, would increase with both level and repetition, and would be better for nouns than verbs.**

Design: **Twenty normal-hearing and 11 hearing-impaired children (6 to 9 yr old) participated in this study. Each child viewed a 4-minute animated slide show containing 8 novel words. The effects of hearing status, word form, repetition, and stimulus level were examined systematically. The influence of audibility, word recognition, chronological age, and lexical development also were evaluated. After hearing the story twice, children were asked to identify each word from a set of four pictures.**

Results: **Overall performance was 60% for the normal-hearing children and 41% for the children with hearing loss. Significant predictors of performance were PPVT raw scores, hearing status, stimulus level, and repetitions. The variables age, audibility, word recognition scores, and word form were not significant predictors.**

Conclusions: **Results suggest that a child's ability to learn new words can be predicted from vocabulary size, stimulus level, number of exposures, and hearing status. Further, the sensitivity to presentation level observed in this novel-word learning task suggests that this type of paradigm may be an effective tool for studying various forms of hearing aid signal processing algorithms.**

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The goal of amplification for a young child is not only to make speech audible, but also to facilitate speech and language development by helping the child to extract the rules of language. It is important to recognize that, for a young child, one would not necessarily expect to see immediate improvements in speech perception, speech production, or language skills following the introduction of amplification or a change in hearing-aid characteristics. Even for young children with normal hearing, repeated auditory experiences over time are necessary to observe marked changes in speech and language behaviors. As such, the use of objective tests (e.g., speech recognition) or subjective metrics (e.g., parent, child, teacher questionnaires) immediately following the initiation of amplification may not be a good predictor of long-term success.

To document hearing-aid efficacy, one approach would be longitudinal monitoring of specific auditory, speech, and language behaviors in an individual child to identify changes in performance that may be attributed to amplification. In addition to being labor intensive, however, it may be difficult to separate the influence of other factors (e.g., age of identification, parental involvement, rehabilitative services) from the effects of amplification. Furthermore, even if longitudinal monitoring could provide a valid measure of hearing-aid efficacy, in cases where the initial hearing-aid fitting is found to be less than optimal, valuable opportunities for speech and language development may be lost. To take advantage of technological advances, provide the best possible amplified signal for a given child, and optimize the time course of habilitation, there is a critical need for a new approach that can predict long-term performance.

A possible alternative to current methods might be a technique that has been used to study children with language disorders. It is well known that, under certain circumstances, typically developing children can acquire at least partial meaning of new words with as few as one or two exposures. This concept has been referred to as fast mapping (Carey, 1978; Dollaghan, 1985, 1987; Rice, Buhr, & Nemeth, 1990), novel-word learning (Oetting, Rice, & Swank, 1995; Rice, Buhr, & Oetting, 1992), and quick incidental learning (Rice & Woodsmall, 1988). While there are subtle distinctions between these three terms, the general idea is that children can acquire new words on the basis of a few exposures and without formal instruction. It has been suggested that this type of learning helps account for rapid word acquisition in early childhood. It is estimated that word learning begins at 1 yr of age, and that the average high school graduate has a vocabulary of approximately 60,000 words (this figure includes words con-

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structed by inflecting known words with productive morphemes), corresponding to 10 new words per day or one word every 90 waking minutes (Bloom, 2000). However, word learning does not occur at a constant rate. Three-yr-old children acquire only one to two words per day or 10 words per week, whereas older children acquire 12 to 15 words per day. When a vocabulary size of approximately 200 words is reached, it appears that children develop the skills to infer the meaning of unfamiliar words from sentence context (Evey & Merriman, 1998; Graham, Baker, & Poulin-Dubois, 1998). The acceleration in word learning (vocabulary burst) that occurs around 19 mo of age has been attributed to this shift in word-learning strategies (Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994). That is, the larger a child's receptive vocabulary, the more rapidly he or she can acquire new words (Gathercole, Hitch, Service, & Martin, 1997). The result is an exponential growth in word learning that continues until 10 to 17 yr of age (Bloom, 2000). Additional variables that appear to play a role in lexical development include the ability to map phonological representations to word meanings, working memory span, and internal verbal rehearsal (Houston, Carter, Pisoni, Kirk, & Ying, Reference Note 2).

Because young children are immersed in the process of learning new words and adults hear unfamiliar words less frequently, children's ability to learn new words in a fast mapping paradigm is much better than that of adults (Newport, 1990). Common examples of this type of word learning can be found in storytelling and television viewing, where after only a single exposure, children may have sufficient knowledge to recognize a new word.

Various experimental paradigms have been developed to determine the conditions under which novel-word learning occurs and to compare the novel-word learning abilities of typically developing children with those of children with specific language impairments. One paradigm uses a videotape in which novel or unfamiliar words are introduced as part of a story. After viewing the story, the children are asked to identify specific words from a group of pictures or to produce the word upon presentation of a picture. This paradigm has been used with older children and, to a limited degree, with children as young as 3 yr of age (Rice & Woodsmall, 1988).

In typically developing children, the number of exposures required to learn a new word depends upon a number of factors. Childers and Tomasello (2002) investigated how the frequency and timing of exposure to new words in a novel-word learning paradigm influenced both comprehension and production for 2-yr-old children with normal hearing. They found that distributed exposure (spacing the introduction of new words over several days) was better than massed exposure (repeated exposures on a single day) for both comprehension and production.

The manner of presentation is also important. It has been shown, for example, that morphosyntactic cues, such as the word ending –ing, can facilitate the recognition of verbs (Eyer, Leonard, Bedore, McGregor, Anderson, & Viescas, 2002). That is, previous knowledge of language rules can help a child determine whether an unfamiliar word refers to an object or an associated action. Word form (e.g., noun, verb, adjective) also can influence the pattern of learning. Typically developing children learn nouns at a faster rate than verbs, presumably because nouns usually have an obvious visual referent (Gentner, 1982; Maratsos, 1991). Some studies have shown that young children (3½ to 5½ yr) acquire nouns more easily than verbs in a novel-word learning paradigm (Eyer et al., 2002; Rice et al., 1990) while others have found a verb advantage (Horohov & Oetting, in press; Rice, Oetting, Marquis, Bode, & Pae, 1994). Finally, the rate of word learning in this type of paradigm is influenced by the task used to assess word acquisition. In general, comprehension precedes production by several months and it has been shown that young children can comprehend two to three times as many words as they can produce. Childers and Tomasello (2002) found that this holds for novel-word learning as well.

There have been many studies comparing typically developing and language-delayed children, but only one study has compared children with normal-hearing with children with mild-moderate hearing loss (Gilbertson & Kamhi, 1995). Although the groups were matched for receptive vocabulary, the hearing-impaired children required significantly more trials to acquire the novel words. Consistent with previous studies relating word learning and lexicon, performance of the hearing-impaired group was highly correlated with their scores on the Peabody Picture Vocabulary test. Additional analyses, however, showed a bi-modal distribution of performance within the hearing-impaired group. Ten of the 20 hearing-impaired children exhibited significantly poorer performance than the remaining 10 hearing-impaired children or the normal-hearing children. Because these children performed poorly on measures of language as well, it was concluded that they also had language impairments. However, it is possible that variations in audibility of the test stimuli may have been responsible for this bimodal distribution of performance within the audiologically diverse hearing-impaired group. Because the electroacoustic performance of the hearing aids worn by these children was not assessed prior to

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testing (only a simple listening check was performed), it is not possible to determine whether some of these children performed poorly due to inappropriately fitted or malfunctioning hearing aids. In addition, variations in signal audibility may have occurred due to the live-voice presentation of the novel words.

In general, previous results suggest that lexical development under naturalistic circumstances may be predicted from the results of a novel-word learning paradigm. Thus, novel-word learning under controlled conditions may be useful in exploring the efficacy of various forms of amplification (e.g., two different noise-reduction schemes) in a single test session. Because limited novel-word learning data are available from children with hearing loss, however, it is unclear how various input manipulations and research design features may influence results. The primary goal of this study was to compare novel-word learning in normal-hearing and hearing-impaired children. A secondary goal was to determine how the learning rate for novel words is affected by a relatively simple manipulation in acoustic input (stimulus level). The final goal was to examine the effects of word form (nouns versus verbs) and number of word repetitions to provide guidelines for the development of optimum test parameters in subsequent studies. Other factors that may influence novel word learning (e.g., language age, speech perception, audibility) also were examined in this study. We hypothesized that overall word learning would be significantly poorer in the subjects with hearing loss and that performance would be positively correlated with language ability for both groups. In addition, we hypothesized that word learning would increase with number of exposures, that nouns would be retained at a higher rate than verbs, and that word retention would increase with stimulus level.

METHOD

Participants

Thirty-one children participated in this study. The normal-hearing group consisted of 20 children (10 girls and 10 boys) with an age range of 6 yr 3 mo to 9 yr 10 mo (mean = 7.9 yr, SD = 1.2). These children had hearing thresholds ≤ 20 dB at octave frequencies from 0.25 through 8.0 kHz. The hearing-impaired group consisted of 11 children (five girls and six boys) with an age range of 6 yr 9 mo to 9 yr 11 mo (mean = 7.7 yr, SD = 1.3). All of the hearing-impaired children had bilateral sensorineural hearing losses and were aided binaurally. Mean pure-tone thresholds (in dB HL) for the left and right ears of each child are shown in Figure 1.

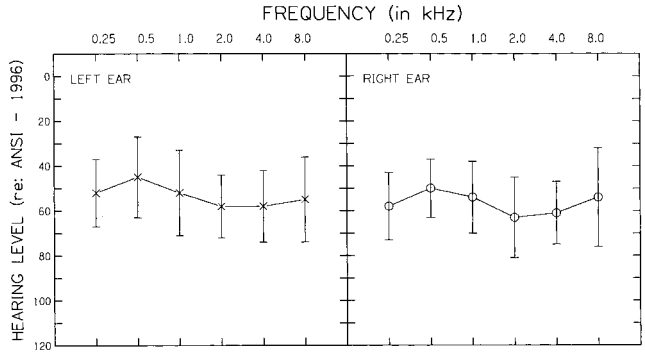

Figure 1. Mean thresholds (in dB HL) as a function of frequency for the left (left panel) and right (right panel) ears of the 11 children with hearing loss. Error bars denote ±1 SD.

Additional audiological and amplification information for these subjects is shown in Table 1. The group is somewhat heterogeneous with respect to age of identification and the age at which hearing aids were first fitted. Because these children were at least 6 yr of age at the time of the study, all of them were born prior to the initiation of universal newborn screening in their state of residence. This may have been a contributing factor to the relatively late mean age of identification (3 yr, 9 mo) and the fact that only 3 of the 11 children were diagnosed with hearing loss by 2 yr of age. On average, these children had been wearing hearing aids for 3 yr, 1 mo (with a range of 8 mo to 5 yr, 11 mo). At the time of the study, seven of the children were wearing hearing aids with wide dynamic range compression and four were wearing aids with compression limiting. In all cases, the hearing aids were fitted using the Desired Sensation Level fitting algorithm (DSL i/o version 4.1) (Cornelisse, Seewald, & Jamieson, 1994). Only two children (Subjects 4 and 6) were thought to have progressive hearing losses.

Development of the Word-Learning Paradigm

The word-learning paradigm consisted of a 4-minute animated slide show (Microsoft Powerpoint, 2000) developed specifically for this study. The story, titled *Edward's Special Toy*, was about a young boy who imagined himself creating new and innovative toys, and was narrated by an adult male. An example of one slide is shown in the Appendix. Eight novel words describing the toys (four nouns and four verbs) were introduced in the story. To assess the effect of repeated exposures, half of the words were repeated twice and half were repeated three times in each story. To assess the effect of stimulus level (audibility), half of the words were presented at 50 dB SPL and half were presented at

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TABLE 1. Audiological information and amplification characteristics for the 11 hearing-impaired children.

Subject	Age at Test (yr:mo)	PTA (right)	PTA (left)	Age of ID (yr:mo)	Age Aided (yr:mo)	Circuit
1	6:1	53	45	1:0	1:2	WDRC
2	9:9	58	53	6:5	6:5	CL
3	6:1	88	85	2:8	2:8	CL
4	8:3	45	30	3:5	3:5	WDRC
5	6:4	65	55	0:0	0:5	CL
6	8:8	45	47	4:8	4:9	WDRC
7	6:7	55	57	2:0	2:0	CL
8	8:9	43	37	4:8	4:8	WDRC
9	6:8	37	37	6:0	6:0	WDRC
10	8:8	55	55	6:6	6:10	WDRC
11	7:8	67	65	3:9	3:10	WDRC
Mean	7:7	56	51	3:9	3:10	
SD	1:4	14	15	2:2	2:2	

WDRC = wide dynamic range compression; CL = compression limiting.

TABLE 2. Name, presentation level, and number of repititions for each novel noun and verb.

Nouns

Name	nankle [næŋk!]	waser [wɔsɚ]	orport [orport]	seddert [sɛdɚt]	[foil]	[foil]
Level	60	50	60	50	X	X
Repetitions	2	2	3	3	X	X

Verbs

Name	brillis [brɪlɪs]	mayboo [mebu]	wiffle [wɪf!]	bealer [bilɚ]	[foil]	[foil]
Level	60	50	60	50	X	X
Repetitions	2	2	3	3	X	X

60 dB SPL. Table 2 provides these details for the eight words. The nouns were simply represented by their respective pictures and were introduced as part of the story, (e.g., "Orports change colors when you talk to them."). The verbs were animations applied to a common object (e.g., bathtub, teddy bear) and were referred to by name during the story. Four additional novel words (two objects, two actions) appeared in the story, but were not given names. These items were used as foils in the novel-word identification test.

Procedures

Prior to the novel-word learning task, all children were given the Peabody Picture Vocabulary Test (PPVT-III, Form B) to estimate lexical development (Dunn & Dunn, 1997). For the PPVT, the hearing-impaired children wore their personal hearing aids at their normal settings. Every child exhibited a language age within ±2 SD of the published normative values for his or her age (Dunn & Dunn, 1997). A recorded version (male talker) of the Phonetically Balanced Kindergarten (PBK-50) test (Haskins, Reference Note 1) was administered in the sound field at both 50 and 60 dB SPL and scored by whole words. These tests were included to determine whether novel-word learning could be predicted from lexical development and/or speech recognition.

For the word-learning task and the PBK-50 tests, the hearing-impaired children were aided binaurally with programmable hearing aids (Phonak Piconet P2AZ). These hearing aids were fitted using DSL i/o (Cornelisse et al., 1994), but were set to operate linearly for 50 and 60 dB SPL input signals. By applying equal gain at these two levels, both the normal-hearing and hearing-impaired participants would experience a 10 dB difference in the level of speech for the novel words presented at 50 and 60 dB SPL. The last column in Table 1 shows the type of hearing aid circuit the children had been accustomed to wearing. In theory, the compression limiting circuits were most similar to the linear circuits used in this experiment.

Probe-tube microphone measures (Audioscan RM-500) of gain and output were obtained to document aided audibility of the novel words for these subjects. Specifically, the sensation level of the story was calculated in 17 1/3 octave bands from 200 to 8000 Hz for each ear independently. It was assumed that children wearing binaural hearing aids would use the most audible information available to them. Thus, audibility calculations were based on the highest sensation level at each frequency, regardless

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of ear. The following formula was used to calculate a binaural aided audibility index (AAI_{bin}):

$$AAI_{bin} = \frac{1}{30}\sum_{i=1}^{17}(SL_{bin})W_i$$

Where SL_{bin} is the maximum sensation level at each frequency, W represents the importance function for short passages (ANSI S3.5–1997), and the 1/30 multiplier constrains the sum of the weighted SLs to a 30 dB range.

For the novel-word learning task, each child was seated one meter from a computer monitor and loudspeaker, which was placed at a 0° azimuth. The instructions were: "We want you to watch and listen to a story. You will hear it twice and afterwards, we will ask you some questions." The overall level of the story was set at an rms level of 60 dB SPL, but within the story, half of the novel words were presented at 50 dB SPL and half were presented at 60 dB SPL. After hearing the story once, the PBK-50 test was administered after which the children viewed the story a second time. The novel-word identification task also was administered in the sound field with the child seated in the same position as during the story. This test consisted of 40 trials (5 repetitions of each novel word) in a four-alternative, forced-choice format without feedback. For each test item, the four choices consisted of the correct word, a foil of the same form (verb or noun), a foil of opposite form, and one of the extra four foils. The target verbs were animated as in the story except that the associated picture was never a noun from the story. The child's task was to indicate which panel (1 through 4) contained the word that was presented.

RESULTS AND DISCUSSION

One of the normal-hearing children had unusually low scores on the novel-word learning task despite good performance on the PBK-50 word lists and a language age that exceeded her chronological age. This particular child was restless and inattentive during the experiment and, as a result, her data were excluded from the analyses.

For both groups, data were collapsed across word form, number of repetitions, and presentation level to obtain an overall score (in percent) on the novel-word identification test. Overall performance was 60% for the normal-hearing children and 41% for the children with hearing loss. Although the mean differences in word identification were relatively small, the range of performance within each group differed substantially. Scores ranged from 33 to 90% for the normal-hearing children and from 25 to 53% for the hearing-impaired children.

The three panels in Figure 2 show the mean scores on the novel-word identification task as a function of presentation level, word form, and number of repetitions. The hatched and solid bars represent the normal-hearing and hearing-impaired subjects, respectively. Both groups demonstrated an increase in word identification as a function of presentation level. The pattern of word identification across level (50 to 60 dB SPL) increased by 14% for the normal-hearing children and 17% for the hearing-impaired. The middle panel in Figure 2 shows the effect of word form on novel-word identification. For the subjects with normal hearing, mean performance for the nouns and verbs was similar. For the children with hearing loss, however, mean performance for the nouns was 10% poorer than the verbs. The right panel shows novel-

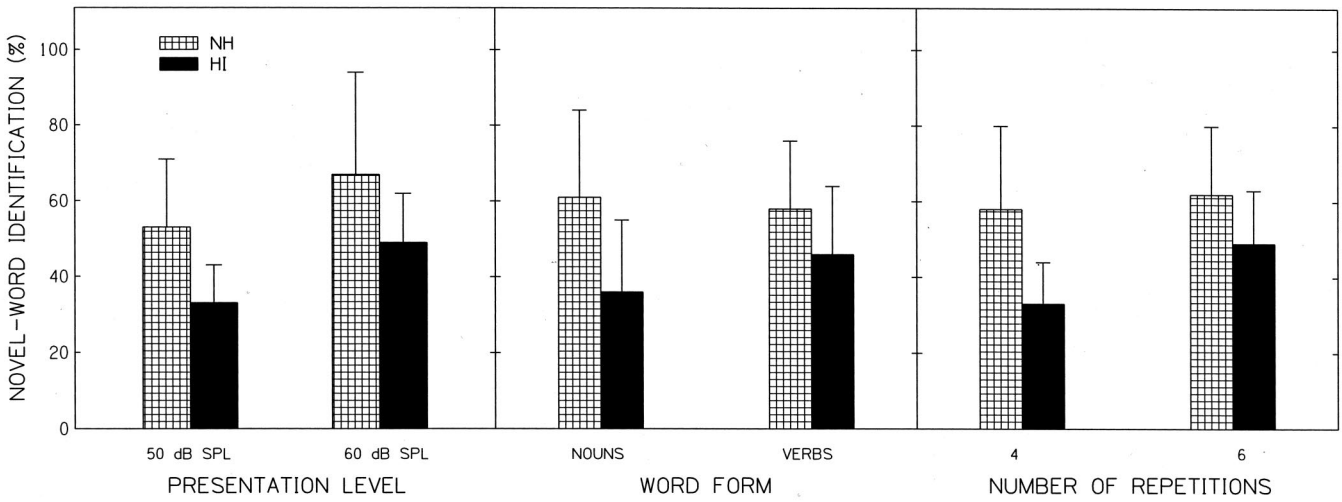

Figure 2. Novel-word identification (%) for the normal-hearing and hearing-impaired children for presentation level (left panel), word form (middle panel), and number of repetitions (right panel). Error bars denote +1 SD.

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word identification as a function of number of repetitions for both groups. Recall that specific novel words within the story were presented either two or three times each. Because the story was heard twice in a single session, however, the numbers of repetitions were actually four and six. The normal-hearing children showed a small (4%) increase in word identification from four to six repetitions. In contrast, the hearing-impaired children showed a marked benefit from more repetitions with a mean increase in word identification of 16%.

The ability to learn novel words may be related to word recognition proficiency and/or to the audibility of speech. Figure 3 illustrates the effect of presentation level on performance for the PBK-50 word lists for both groups of children. For the normal-hearing children, mean performance was high (92 and 97%) at both 50 and 60 dB HL. This was expected because both presentation levels were high enough to expect ceiling effects for listeners with normal hearing. For the hearing-impaired listeners, AAI_{bin} values at 50 and 60 dB SPL were 0.71 and 0.87, respectively, and their speech recognition scores were considerably poorer (50% and 67%) than the normal-hearing listeners. This 17% difference in mean performance suggests that, even with well-fitted linear hearing aids, performance for soft conversational speech (50 dB SPL) appears to be on the changing portion of the performance-intensity function for these listeners.

Because the children in this study ranged from 6 to 9 yr of age, it is possible that chronological age

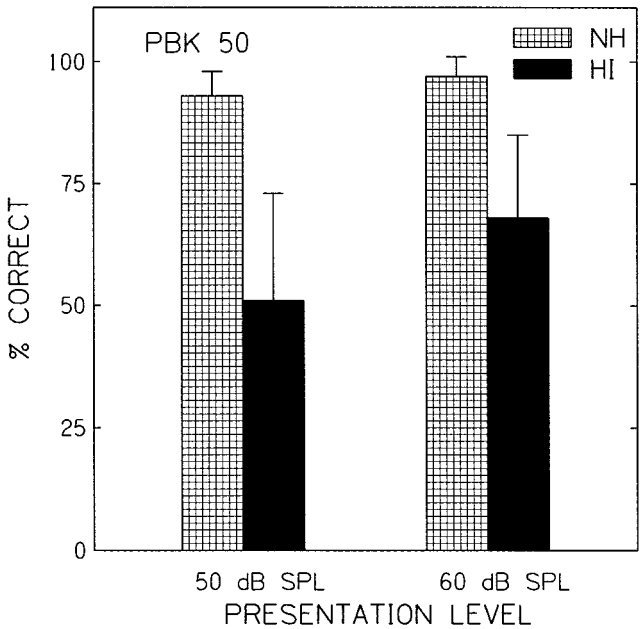

Figure 3. Mean PBK-50 performance (%) by presentation level for the normal-hearing (NH) and hearing-impaired (HI) groups. Error bars denote +1 SD.

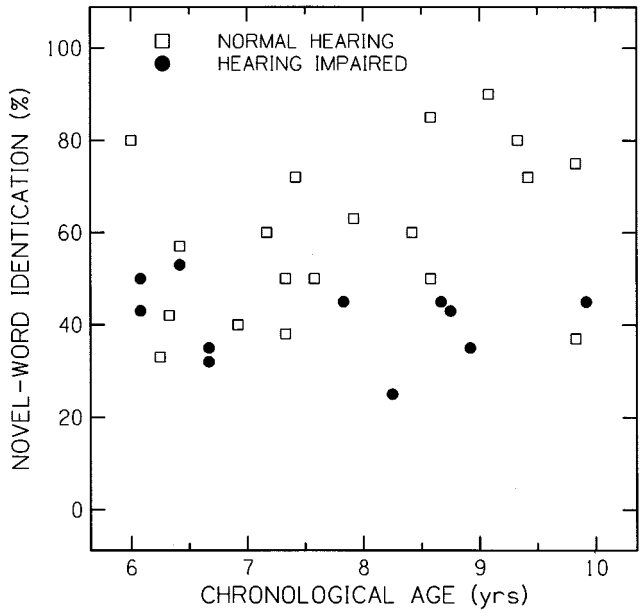

Figure 4. Novel-word identification (%) as a function of chronological age (in yr) for the normal-hearing (open squares) and hearing-impaired children (filled circles).

may also contribute to novel-word learning. Figure 4 shows the relation between the percentage of novel words identified (collapsed across form, level, and repetition) and chronological age for the normal-hearing (open squares) and hearing-impaired children (filled circles). The range of performance for the children with normal hearing is greater than that of the children with hearing loss. In general, the normal-hearing listeners exhibited a slight increase in novel-word identification as a function of age, while there was no such trend for the children with hearing loss. Figure 5 shows novel-word identification as a function of the PPVT raw score for both groups. The normal-hearing children show an increase in performance as the PPVT raw score increased. No such trend is observed for the children with hearing loss. Furthermore, these children demonstrate a narrow range of scores for both novel-word identification and the PPVT.

The relation between each child's PPVT raw score and age is shown in Figure 6 for the normal-hearing (open squares) and hearing-impaired (closed circles) children. Linear regression equations were fitted to the data for each group. These results are consistent with previous studies confirming delayed lexical development in children with hearing loss (Blamey et al., 2001). However, the steeper slope for the hearing-impaired data suggests that these delays may be overcome as these children age.

To determine the relation between novel-word learning and the variables age, group, level, repetitions, form, PPVT raw scores, word recognition, and

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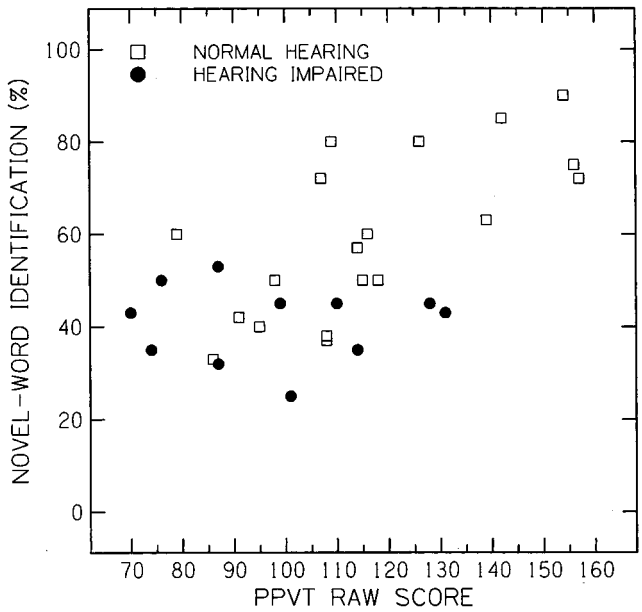

Figure 5. Novel-word identification (%) as a function of PPVT raw score for the normal-hearing (open squares) and hearing-impaired children (filled circles).

audibility, the results were arcsine transformed where necessary and entered together into a univariate regression analysis. A significant model emerged ($F_{6,239} = 6.962, p < 0.001$) with an adjusted R-square of 0.166. These results suggest that the model accounted for nearly 17% of the variability

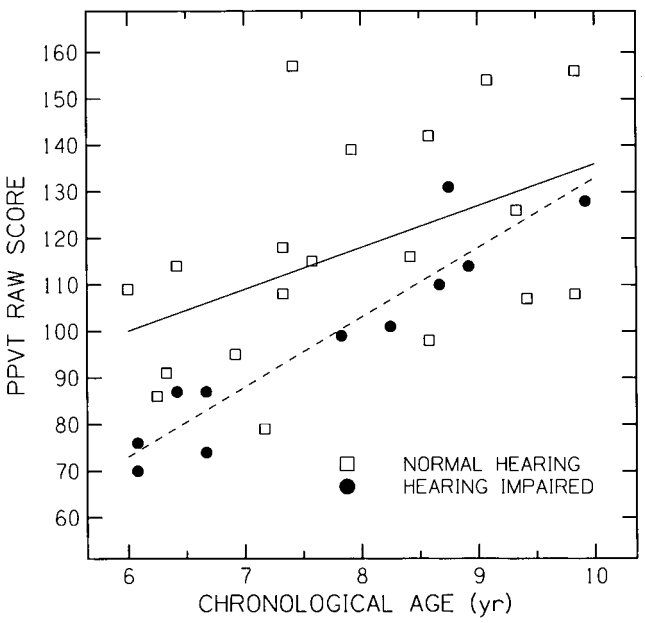

Figure 6. PPVT raw score as a function of chronological age for the normal-hearing (open squares) and hearing-impaired children (filled circles). Solid and dashed lines represent a best fit to the data for the normal-hearing and hearing-impaired subjects, respectively.

associated with these data. As shown in Table 3, the significant variables were PPVT raw score, group, level, and repetitions. As indicated by the colinearity statistic (tolerance), repetition was the strongest predictor variable of performance on the novel word identification task, followed by level, PPVT raw score, and group. The significant group effect indicates that the performance of the hearing-impaired children was poorer than that of the normal-hearing children. Likewise, performance improved with increases in level and number of repetitions. The variables age, audibility, word recognition, and form were not significant predictors in this model.

Recall that four of the children with hearing loss had been accustomed to compression limiting circuits and seven had been using wide dynamic range compression circuits. In theory, the latter group might be expected to demonstrate poorer performance for the 50 dB SPL condition because their personal hearing aids would have provided more gain than was applied during this experiment. A *t*-test was used to compare performance differences between the 50 and 60 dB SPL conditions for these two groups and the results were nonsignificant.

Because inter-subject variability was relatively high in this study, individual differences were examined to determine how many children were able to retain words at a specified level of performance and under what circumstances word retention occurred. It was arbitrarily assumed that, if a child scored 80% or better for a single word on the word-identification task, the word was retained. Table 4 shows the number of words (of eight possible) retained by each child in both the normal-hearing and hearing-impaired groups. Range of retention for the children with normal hearing varied from 0 to 7 words, with an average of 3.5 words. In contrast, children with hearing loss retained an average of only 1.8 words and exhibited a narrower range of performance (from 0 to 3 words). Thus, it appears that the children with normal hearing retained almost twice as many words as did the children with hearing loss.

Because equal numbers of words were presented at 50 and 60 dB SPL, results also were analyzed in terms of presentation level. For the normal-hearing group, an average of 2.4 words were retained at 60 dB SPL, decreasing to 1.1 words at 50 dB SPL (~2 fold difference). This level effect is even more pronounced for the hearing-impaired group where 1.5 words were retained at 60 dB SPL and only 0.4 words at 50 dB SPL (~4 fold difference).

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TABLE 3. Significant predictor variables from the regression analyses.

Predictor Variable	Beta	t	*p*	Colinearity (Tolerance)
PPVT raw score	0.291	3.478	$p = 0.001$	0.498
Group	−0.272	−2.448	$p = 0.015$	0.283
Level	0.242	3.744	$p < 0.001$	0.833
Repetitions	0.127	2.149	$p = 0.033$	1.000

TABLE 4. Number of words retained (using a ≥ 80% criterion) by individual subjects in both the normal-hearing and hearing-impaired groups.

NH Group	# Words Retained	HI Group	# Words Retained
1	0	1	2
2	1	2	3
3	1	3	3
4	2	4	1
5	2	5	3
6	2	6	1
7	3	7	0
8	1	8	1
9	3	9	1
10	3	10	2
11	4	11	3
12	5		
13	4		
14	4		
15	5		
16	6		
17	7		
18	6		
19	7		
Mean	**3.5**	**Mean**	**1.8**
SD	**2.1**	**SD**	**1.0**

Also shown are the means and standard deviations for each group.

General Discussion

The results of this study suggest that a child's ability to learn new words can be predicted from the current size of the child's vocabulary (bigger is better), the child's hearing status (normal is better), presentation level of the novel word (higher is better), and the number of exposures to the word (more is better).

The relation between the child's current lexicon and novel-word learning is consistent with previous reports that the ability to learn new words increases with vocabulary size (Fenson et al., 1994; Evey & Merriman, 1998; Graham et al., 1998). Only one other study (Gilbertson & Kamhi, 1995) has compared novel-word learning in normal-hearing and hearing-impaired children. Although they found significant group effects, the children with hearing loss appeared to exhibit two different levels of performance. They concluded that 50% of the children with hearing loss had a language impairment unrelated to their hearing loss. No such pattern emerged in the current study. Rather, the PPVT raw scores were lower than those of the children with normal hearing, but the differences appeared to decrease with age.

In the current study, presentation level of the novel words (50 and 60 dB SPL) also was found to be a significant predictor of performance. For the hearing-impaired children, these performance differences are consistent with the commonly held belief that low-level speech often requires greater amplification via mechanisms such as wide dynamic range compression and/or FM systems. For the normal-hearing children, the level differences are somewhat surprising, particularly since the PBK-50 scores revealed near maximum performance for most children at 50 dB SPL. These results suggest that signal level may play an important role in incidental word learning in both normal-hearing and hearing-impaired children and raise a number of interesting questions. Would word learning continue to improve at higher stimulus levels? Can wide dynamic range compression schemes optimize word learning and how should parameters (e.g., compression threshold, compression ratio) be set?

Other factors, such as age, speech perception ability, audibility, and type of word (noun versus verb) did not appear to influence word learning. It is of interest to note that word-recognition scores on the PBK-50 test were not a significant predictor of novel word identification in this study. This was expected for the children with normal hearing because their range of speech recognition scores was quite narrow. The range of scores for the children with hearing loss was considerably greater, so the lack of a correlation between speech recognition and novel-word learning cannot be attributed to a narrow dispersion of scores. Aided audibility also was not a predictor of novel-word identification. From a clinical perspective, these findings suggest that good aided speech recognition and optimized aided audibility of speech will not necessarily ensure good language development for a particular child. This does not imply, however, that speech recognition and signal audibility are not important. Both of these factors should be viewed as necessary prerequisites for word learning. Interestingly, the findings from this study do suggest that good speech recognition and signal audibility are not sufficient to ensure novel-word learning. Rather, the ability to learn new words is most likely a complex phenomenon that is influenced by a variety of auditory and non-auditory factors.

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The lack of a significant word form effect also was somewhat unexpected. Previous studies in which word form (nouns, verbs) was varied have produced mixed results. Rice et al. (1990) and Eyer et al. (2002) reported that young children (3½ to 5½ yr) learned nouns more readily than verbs. In contrast, Rice et al. (1994) and Horohov & Oetting (in press) showed a verb advantage for 4- to 7-yr-old children. In the current study, performance for the normal-hearing children was 3% higher for nouns and performance for the hearing-impaired children was 10% higher for verbs, but these differences were not statistically significant. As such, the results from the current study are not in agreement with either of the earlier findings. In explaining the differences between their results and previous studies, Rice et al. (1994) and Horohov & Oetting (in press) suggested that various experimental differences might explain why some studies show a noun advantage and others show a verb advantage. Specifically, factors such as story details, the interest value of each scene, and salient actions of characters or objects may contribute to high verb scores. In addition, it is possible that verb inflections and morphosyntatic cues also may denote a verb interpretation. In the current study, verb action was a repetitive motion of a known object (e.g., bathtub) and a different object was used with each repetition. Because verbs are often learned in the absence of a tangible physical reference, it is possible that these procedures reduced the ambiguity often present when learning new words, thus influencing verb performance. In addition, morphosyntactic cues often were available for both nouns ("he especially likes *the* waser") and verbs ("I wonder what would happen if my bathtub started *to* bealer"). Because the hearing-impaired children in the current study were slightly older than the children in the earlier studies, they may have learned to use these types of cues to form categories. The results of the current study support the notion that experimental details can have a strong influence on outcome. If the results of novel-word learning studies are to be used to predict word learning under naturalistic circumstances, it will be important to design materials that are both age appropriate and that mimic the syntactic, semantic, and morphological cues that are likely to be available in daily activities.

It is also important to note that the small sample sizes in this study may have created an environment for a Type II error in which the null hypothesis should have been rejected, but was not. In this study, the loss of statistical power was determined to be acceptable given the nature of the data, the questions of interest, and the heterogeneity of hearing loss in children. Locating and recruiting enough hearing-impaired children with similar losses to meet the statistical requirements (approximately 100) is a difficult task in any single geographic location. However, the results of this study are in general agreement with the findings of previous investigations and should serve as an adequate baseline for future studies.

Recall that a primary motivation for this study was to find a technique that would predict enhanced word learning in a single test session. It remains to be seen whether this type of task may be useful in predicting the efficacy of different types of signal processing for hearing aids. Given the heterogeneity of children with hearing loss, this could be accomplished by focusing on a single acoustic attribute in a repeated measures design. For example, two different single-microphone noise reduction schemes might be compared by creating a story in which the signal-to-noise ratio is varied. Half of the novel words could be processed with one scheme and half with the other. While noise reduction should improve the ability to learn novel words, it is also possible that this type of signal processing may alter or eliminate signal characteristics that are important for language development. This type of paradigm might be useful in distinguishing between successful and unsuccessful algorithms. Similarly, the effects of compression threshold or compression ratio on novel-word learning might be explored by creating a story in which novel words are presented over a range of levels. In this case, optimum compression characteristics would be those that facilitated novel word retention across the widest range of stimulus levels. Additional studies are needed to determine the feasibility of using novel-word learning paradigms to address such issues.

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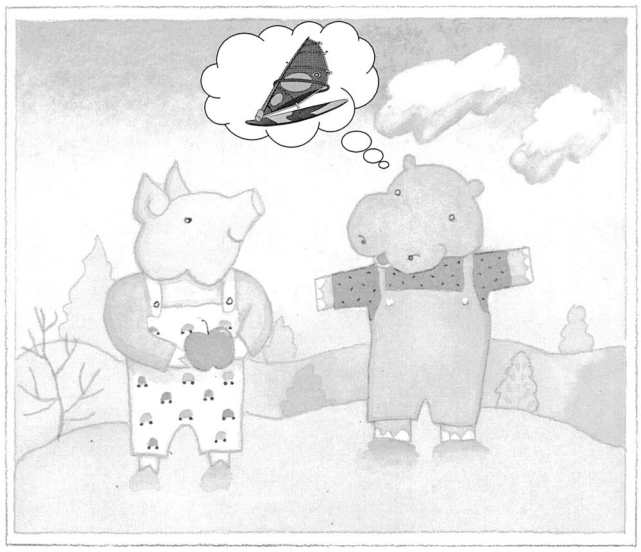
APPENDIX



"I tell my best friend Jimmy about my Dad's special toy. He likes to hear about the toys I make up. He especially likes the waser."

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