RUNNING HEAD: Malapropisms and children with hearing loss

The Devil in the Details Can Be Hard to Spot: Malapropisms and Children with Hearing Loss

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Abstract

Purpose: Better auditory prostheses and earlier interventions have led to remarkable improvements in spoken language abilities for children with hearing loss (HL), but these children often still struggle academically. This study tested a hypothesis for why this may be, proposing that the language of school becomes increasingly disconnected from everyday discourse, requiring greater reliance on bottom-up phonological structure and children with HL have difficulty recovering that structure from the speech signal.

Participants: 119 fourth-graders participated: 48 with NH, 19 with moderate losses who used hearing aids (HAs), and 52 with severe-to-profound losses who used cochlear implants (CIs).

Method: Three analyses were conducted. **#1:** Sentences with malapropisms were created and children's abilities to recognize them assessed. **#2:** Factors contributing to those abilities were evaluated, including phonological awareness, phonological processing, vocabulary, verbal working memory, and oral narratives. **#3:** Teachers' ratings of students' academic competence were obtained, and factors accounting for those ratings were evaluated, including the five listed above along with word reading and reading comprehension.

Results: **#1:** Children with HAs and CIs performed more poorly on malapropism recognition than children with NH, but similarly to each other. **#2:** All children with HL demonstrated large phonological deficits, but they were especially large for children with CIs. Phonological awareness explained the most variance in malapropism recognition for children with CIs. Vocabulary knowledge explained malapropism recognition for children with NH or HAs, but other factors also contributed. **#3:** Teachers rated academic competence for children with CIs more poorly than for children with NH or HAs, and variance in those ratings for children with CIs were primarily explained by malapropism scores.

Conclusions: Children with HL have difficulty recognizing acoustic-phonetic detail in the speech signal, and that constrains their abilities to follow conversations in academic settings, especially if HL is severe enough to require CIs.

Introduction

Prospects have improved tremendously over the past thirty years that children born with hearing loss (HL) will be able to develop functional spoken language. For children with mild-to-moderate HL, advances in the design of hearing aids (HAs) offer better signal processing than ever before, allowing for better speech recognition and noise reduction. For children with severe-to-profound HL, cochlear implants (CIs) now provide auditory stimulation that far surpasses anything previously available, but the signal quality of these devices remains degraded. And early intervention, made possible by newborn screening and diagnosis at young ages, facilitates the development of auditory and language skills during those years leading up to school admission for children with HL, regardless of degree of loss.

These changes in available treatments for childhood HL have led to dramatic improvements in language performance. Studies assessing language skills in children with HL who received appropriate treatments early in life report that at roughly the time they leave the preschool environment, mean standard scores on vocabulary and language instruments are usually between 85 and 100, meaning between -1 standard deviation and the normative mean (e.g., Bradham et al., 2018; Geers et al., 2009; Geers et al., 2016; Nittrouer, 2010; Tomblin et al., 2020). Such observations leave many professionals feeling confident that these children can enter mainstream educational environments ready to face any further language learning and academic hurdles they may encounter. Unfortunately, the extant literature does not support that optimistic prediction in all cases. There are indeed some studies reporting that children with HL on average continue to perform just one standard deviation below the mean of well-matched peers with NH on tasks measuring vocabulary or morphosyntax through elementary school (e.g., Boons et al., 2013; Geers & Sedey, 2011; Kronenberger et al., 2020; Ruffin et al., 2013; Schorr et al., 2008), but other studies have found that children with HL have more severe deficits (e.g., Antia et al., 2020; Fitzpatrick et al., 2012; Johnson & Goswami, 2010; Tobey et al., 2013). In particular, children with HL appear to encounter especially extreme difficulty on measures of higher-order, complex language functions at higher grades (Kronenberger &

Pisoni, 2019). Furthermore, measures of academic achievement by children with HL indicate that any gains made in language abilities due to improved auditory prostheses and earlier interventions are not necessarily translating into improvements in academic performance. In a study by Marschark et al. (2015), scores on the Woodcock-Johnson Test III (Woodcock et al., 2011) were examined in key areas of academic performance for roughly 500 children with HL in grades above seventh. Mean scores in all areas were well below standard scores of 100, with some as low as 70, revealing the significant challenges faced by these students. These findings match those of other investigators for academic performance (Qi & Mitchell, 2012; Sarant et al., 2015). When it comes to reading abilities, children with HL are achieving no better outcomes today than they were a generation ago (Harris et al., 2017). Overall, studies regarding outcomes for children with HL show depressed academic performance, even when standard language measures suggest skill levels close to those of peers with NH. The purpose of the current study was to examine one hypothesis for why this discrepancy may exist.

The fourth-grade problem

This apparent contradiction in language and academic outcomes for children with HL may be explained by differences in the language of school versus everyday discourse. Differences between academic and everyday language take a variety of forms, including specific vocabulary that is used only in the academic setting (Baumann & Graves, 2010; Dutro & Morran, 2003; Snow, 2010). In addition to vocabulary that is related to topic areas being studied (e.g., science), the vocabulary of instruction is idiosyncratic to the school setting, describing complex concepts, requiring higher-order thinking, and abstraction (Snow & Uccelli, 2008; Zweirs, 2008). Even when instructional language uses everyday vocabulary, it is often used in ways it is not used outside of school, and teachers may not overtly instruct students in these differences (Bailey et al., 2007). This school-specific vocabulary starts simply enough in early grades, but increases in amount and complexity as children go through school (Gottlieb & Ernst-Slavitt, 2014). Townsend et al. (2012) looked at the relationships among overall vocabulary, academic word knowledge in particular, and performance on standardized tests in a large and diverse population of children in middle school. They found that knowledge of academic words explained the most variance in standardized test performance. Additionally, there are syntactic constructions uniquely used in academic settings, and the occurrence of complex syntactic structures are greater in the school setting than in other, more casual settings (Snow, 2010). Moreover, academic language is decontextualized (Schleppegrell, 2004), meaning one cannot rely on one's own experiences to aid recognition. It is abstract and informationally dense, meaning more information is conveyed per unit of text (Nagy & Townsend, 2012; Uccelli et al., 2015). Such differences between everyday and academic language are frequently cited as the source of academic problems for children with a variety of language delays. There is even a name for it: Scarborough (2001) labeled it "the fourth grade problem," because it is around this time that children at risk for language delays thought to have been resolved by early intervention can start showing chinks in their linguistic armor and begin falling behind academically.

Although descriptions of academic language usually focus on its vocabulary or syntactic complexity, there is another way in which the processing of that academic language may differ from the processing of language in everyday settings: it may depend on having keener sensitivity to phonological structure or acoustic detail. The basis of this suggestion is the simple fact that it is possible to have casual conversations without accessing details in the signal, due to its highly predictable nature. The language of school, on the other hand, is commonly introducing new ideas, using less common vocabulary that may not necessarily follow closely the phonotactic constraints of a child's first language. As a result, there is a stronger need to access details of the acoustic signal. Of course, these two concepts – of phonological structure and acoustic detail – may be largely redundant. In the past we have suggested that access to detail in the acoustic signal is required more for developing sensitivity to phonological structure than for learning about lexicosyntactic structure, with the latter defined as whole words and how they are sequenced. That suggestion is based on findings from a longitudinal study involving children with HL and age-matched peers with NH who were tested between the ages of one and

14 years. (e.g., Nittrouer, 2010; Nittrouer & Caldwell-Tarr, 2016; Nittrouer, Lowenstein, et al., 2018).

The Hidden Deficit

Over the course of our longitudinal study, we have consistently observed that the children with HL show deficits in their phonological skills much greater in magnitude than any deficit measured for their lexicosyntactic skills. This phonological deficit is especially pronounced for children with HL severe enough to require CIs. For example, when language performance at second grade was compared for children with NH and those with CIs, effect sizes (given as Cohen's *d*) were larger than 1.0 for measures of phonological awareness, but less than 1.0 for measures of lexicosyntactic knowledge, including vocabulary, auditory comprehension of language, and productive syntax (Nittrouer, 2016; Nittrouer & Caldwell-Tarr, 2016). This finding for lexicosyntactic knowledge matches that of many other investigators, cited above, but phonological skills have been less often examined in children with HL. Consequently the disproportionately large deficit revealed in our longitudinal study has not been previously reported. We attribute this discrepancy in magnitude of effect to the fact that CIs provide only degraded acoustic signals, and suggest that such degradation is more damaging to the acquisition of phonological, rather than lexicosyntactic knowledge.

The likely reason this large phonological deficit has been overlooked in the past is that language assessments typically given to school-aged children incorporate little in the way of phonological measures. Denman et al. (2017) reviewed 15 standardized assessments widely used by speech-language pathologists. Overall, the areas assessed by the subtests comprising each instrument fit the definition of lexicosyntactic, rather than phonological skill. For example, the Clinical Evaluations of Language Fundamentals – 5th Edition (Semel et al., 2013), a very widely used instrument, has subtests evaluating sentence comprehension, linguistic concepts, word structure, word classes, following directions, formulated sentences, understanding spoken paragraphs, word definitions, sentence assembly, semantic relationships, reading comprehension, structured writing, and pragmatics. The other instruments reviewed by Denman et al. covered similar assessment areas, all of which are lexicosyntactic in nature. Furthermore, Denman et al. concluded that all 15 instruments had limitations regarding psychometric quality, which matches an earlier conclusion reached by Plante and Vance (1994) for 21 language assessment instruments. Both the paucity of assessments for phonologically based skills and the limitations on psychometric quality constrain the likelihood that typical language assessments would uncover the sort of language problems that could make it difficult for children with HL to succeed in academic settings, if the suggestion is correct that these problems are primarily associated with a lack of sensitivity to phonological structure. One goal of this project was to develop a method of assessing these potential deficits.

Bottom-up versus top-down

Boothroyd and Nittrouer (1988) characterized the processing of spoken language as a balance between bottom-up and top-down information. When the material is highly predictable (strong top-down information), not as much bottom-up information is needed (e.g., *Flowers grow in the garden*). But when that material is less predictable – as it is in academic discourse – a listener needs to be able to recover phonological structure (the bottom-up information) rapidly and accurately and use that for further language processing. The hypothesis behind the work reported here is that this is where children with HL encounter difficulty: they are challenged in their abilities to recover phonological structure from the language they hear. Outcomes of the longitudinal study reviewed above illustrate the deficits these children experience in recovering phonological structure, but the methods used to assess their phonological awareness or processing skills in that work did not involve continuous speech, which is what a child hears in the classroom. Therefore, it was necessary that the assessment method used in this study consisted of continuous speech, with the goal being to discover whether children with HL have deficits recognizing phonological structure in this context. If evidence of those deficits were observed it could help explain the continued academic struggles faced by these children.

Because the materials developed were comprised of continuous speech, the question of how well children with HL can use top-down linguistic constraints for speech recognition is germane. This question has been explored in past work with the children in this current study, by asking them to recognize sentences composed of degraded signals, either speech in noise or sinewave replicas (Nittrouer et al., 2015). Outcomes for sinewave replicas are especially relevant because children with NH and those with HL did not differ in overall recognition, which was generally between 55 and 60 percent correct recognition for the words in the sentences. These sentences were five words in length, and were selected from the Hearing in Noise Test (Nilsson et al., 1994). To assess the contribution of top-down linguistic constraints in that work a metric devised by Boothroyd and Nittrouer (1988) was applied. With this metric, the number of independent channels of information required to recognize the sentences are computed based on the equation:

$$p_s = p^j_p \qquad (1)$$

In this formula, p_s is the proportion of whole sentences recognized correctly, and p_p is the proportion of parts, or words, recognized correctly. Expanding this equation results in the following:

$$j = \log(p_s)/\log(p_p) \qquad (2)$$

This metric j represents the number of channels of bottom-up information that are required for sentence recognition, and decreases in value as the contributions of top-down information increase. Nittrouer et al. reported j factors of 3.32 (standard deviation = 0.96) for children with NH and 3.77 (standard deviation = 1.80) for children with CIs. The difference was not significant, so it may be concluded that the contributions of top-down information were the same for the children with NH and CIs in this study. The mean j factor for children with HAs was not reported in that study, but it was 3.21. Based on these values it is reasonable to conclude that the children with HL in this longitudinal study are just as capable of applying top-down constraints as the children with NH.

Why malapropisms

In 1775, Sheridan developed a character for his play The Rivals who was comic in her misuse of words. In particular, she would substitute one word for another that rendered a statement humorous. Mrs. Malaprop was the eponym for this phenomenon, *malapropism*, which can be defined as a substitution of one word for another similar-sounding word in a sentence. Malapropisms have been studied almost exclusively for what they can reveal about the lexical organization of a speaker (e.g., Fay & Cutler, 1977; Goldrick et al., 2010; Vitevitch, 1997; Zwicky, 1982). In this current study, however, we employed malapropisms for a different reason: to test children's sensitivity to acoustic-phonetic detail in continuous speech. For current purposes these changes were made in the acoustic structure of the signals, but each change affected the phonological (mostly phonetic) structure, as well. For example, the test item *Make sure you race your hand once you know the answer*, with the word *race* substituted for *raise*, involved a change at the acoustic level in vowel length, as well as in low-frequency energy during the final fricative. At the phonological level, the manipulation can be described as a substitution of [s] for [z]. The premise of testing the abilities of children with HL to detect these acoustic-phonetic changes was that if they are challenged in doing so it could constrain their abilities to comprehend academic language. The role of sensitivity to phonological structure in other language processes that are surely related to academic language has been well studied, and found to be lacking in children with HL. In particular, a significant contribution of phonological sensitivity to reading in advanced grades has been reported (Geers & Hayes, 2011). In addition, it has been found that sensitivity to phonological structure is important for novel word learning, as measured by nonword repetition (Al-Salim et al., 2020; Dillon & Pisoni, 2006; Nittrouer et al., 2014), and for the operations of the phonological loop in verbal working memory (Nittrouer et al., 2013). However, the role of this sensitivity to the recognition of continuous speech has not been previously evaluated.

Current study

The purpose of the current study was to assess the abilities of children with HL and their peers with NH to recognize words that create malapropisms, when those words are components of meaningful sentences. There are two primary reasons why a child might fail to recognize a malapropism: First, the child's vocabulary might not be adequate to allow the child to recognize that the wrong word was used in a specific context. Second, the child might know what word belongs in the specific sentence context presented, but may not have keen enough sensitivity to the acoustic-phonetic structure of the word to recognize slight differences. It is this second reason that we hypothesized would underlie poor malapropism recognition by children with HL. The analyses implemented in this study were designed to test three specific predictions:

Prediction 1: Children with HL, especially those who use CIs, would be poorer at recognizing malapropisms than children with NH. The basis of this prediction was the simple fact that children with HL have poorer access to acoustic-phonetic detail in the signal, and access to that detail is required to detect malapropisms. It might also be predicted that children with CIs would perform more poorly than children with HAs, because the signals available through a CI are more degraded than what is provided by a HA, even to an impaired auditory system.

Prediction 2: Performance on the malapropism recognition task would be most strongly related to sensitivity to phonological structure, at least for children with HL, rather than to any other language measure, including vocabulary knowledge. The basis of this prediction is that sensitivity to phonological structure is based on how well children with HL can recognize acoustic detail. It is precisely that sensitivity to detail that underlies a listener's ability to detect malapropisms, if the vocabulary is within that listener's knowledge. For children with NH the prediction was that a language measure other than sensitivity to phonological structure would primarily account for performance on malapropism recognition. The premise of this prediction was that these children with NH should all have phonological sensitivity that is adequate for achieving some reasonable degree of detection.

Prediction 3: Performance on the malapropism recognition task would be related to teachers' perceptions of how these children performed in the classroom. Again, this prediction was most strongly made for the children with HL, whose performance was predicted to be poorer when it came to detecting malapropisms in continuous speech.

Overall, these specific predictions were meant to test the broader hypothesis that the continued discrepancy in performance on language tests and performance in academic achievement observed for children with HL has to do with the fact that they have poor access to the details of the speech signal. Those details are more important for academic language, we propose, than for everyday language.

In order to test these predictions, several kinds of measures were needed. To test the first prediction, measures of children's abilities to detect malapropisms were required. Thus, we developed a set of sentences with malapropisms. To test the second prediction, we selected five measures that assessed various kinds of language skills that might explain children's abilities to detect malapropisms. Two tests of phonological skills were implemented: one testing phonological awareness and one testing children's abilities to process (manipulate) phonological structure. A vocabulary test was also administered, to see if the strength of children's vocabularies was related to their detection of malapropisms. Finally, two additional measures were administered that could potentially be related to children's abilities to recognize malapropisms. First, verbal working memory was assessed. Because sentence-length material was used as the test of malapropism recognition, it was possible that children's working memory for verbal material might influence their abilities to report those errors in language structure. Second, children's overarching facility with language as a discourse tool was assessed, using a narrative sampling technique. General knowledge about the structure of discourse could facilitate children's recognition of structural errors in communication.

To test the third prediction, teachers' ratings of students' academic performance were obtained. Measures of malapropism recognition, as well as the five language measures, were used as predictor variables in regression analysis to see how well each predicted teachers' assessments. In this analysis, two measures of reading proficiency were added, because reading could explain teachers' overall ratings of academic success.

Summary

The goal of this study was to examine the problem that children with HL are performing reasonably well on conventional measures of language abilities, but continue to demonstrate serious weaknesses in academic performance. The general hypothesis underlying the study was that the language of school may require keener sensitivity to detail at the acoustic and phonological (especially phonetic) level than the language of everyday communication requires, and it may be the latter that is typically tested by the language instruments we use. To test this hypothesis, we constructed an instrument composed of malapropisms. This instrument was meant to replicate the kinds of fine-grained detail that might be important for students to access in classroom communications in order to succeed.

Method

Participants

One hundred and nineteen children participated in this study: 48 with NH, 19 with moderate-to-severe HL who wore HAs, and 52 with severe-to-profound HL who wore CIs. All children had just completed fourth grade at the time of testing, and all were participants in a longitudinal study involving children with HL (Nittrouer, 2010). At the time of testing, mean age (and standard deviation, or *SD*) was 10 years, 5 months (4 months) for children with NH; 10 years, 4 months (5 months) for children with HAs; and 10 years, 8 months (7 months) for children with CIs. This variability was statistically significant, F (2,116) = 5.741, p = .004, reflecting the fact that the children with CIs were on average a few months older than the children with NH and the children with HAs. Because all children were at the same academic level, however, this difference was not considered problematic. Furthermore, the slightly advanced mean age of the children with CIs would typically suggest that they had a small advantage, but predictions were that these children would show deficits.

Children were well matched on socioeconomic status. The metric used to make that assessment was one that had been used before, in which occupational status and highest educational level are ranked on scales from 1 to 8, from lowest to highest, for each parent in the family. These scores are multiplied together, for each parent, and the highest value obtained is used as the socioeconomic metric for the family (Nittrouer & Burton, 2005). According to this metric, means (and *SD*s) for the children with NH, HAs, and CIs were 35 (13), 31 (12), and 33 (12), respectively. This variability was not statistically significant. These scores indicate that the average child in the study had at least one parent who had obtained a four-year university degree. None of the children in the study had any disability (other than hearing loss) that on its own would be expected to negatively impact language learning.

All children had been given the Leiter International Performance Scales – Revised (Roid & Miller, 2002) two years earlier, just after completing second grade. This instrument provides a completely nonverbal assessment of cognitive functioning. All children performed within normal limits on this assessment, with means (and *SDs*) for the children with NH, HAs, and CIs of 105 (14), 103 (16), and 101 (17), respectively. This variability was not statistically significant.

Children with NH were administered hearing screenings of the octave frequencies between 250 Hz and 8 kHz at 20 dB hearing level, and all passed. Aided thresholds were measured for children with HAs and CIs. Mean better ear, 3-frequency (0.5, 1.0, and 2.0 kHz) aided pure-tone average (PTA) threshold at the time of testing was 30 dB (9 dB) hearing level for the children with HAs, and 24 dB (8 dB) hearing level for the children with CIs.

Table 1 shows audiologic data for the children with HAs and the children with CIs. The first line of this table indicates that all these children were identified with HL by 2 years of age. And although not shown on this table, they also all received amplification, and began intervention before turning 3 years.

The second line of Table 1 displays unaided 3-frequency PTA thresholds for children with HAs at the time of testing, and unaided 3-frequency PTA thresholds for children with CIs obtained just before implantation. Twenty-five of the children with CIs had at least one year of experience wearing a hearing aid on the ear contralateral to the ear that received the first CI (i.e., bimodal experience) at the time of receiving that first CI, and 16 of those children eventually received a second CI. In total, 35 children wore two CIs at the time of testing. Five children with some bimodal experience stopped wearing a hearing aid before this testing occurred, but did not receive a second CI. Four children with some bimodal experience were still using a hearing aid at the time of testing.

Equipment

The materials for the malapropism recognition, phonological awareness, and phonological processing tasks were presented through a computer, with a Creative Labs Soundblaster soundcard using a 44.1-kHz sampling rate with 16-bit digitization and a Roland MA-12C powered speaker, placed 1 m in front of the child at 0° azimuth. Audiovisual stimuli were presented on a widescreen monitor using a 1,500-kbps data rate and 24-bit digitization.

The working memory task was presented using the same soundcard and speaker as that used for the malapropism recognition, phonological awareness, and phonological processing tasks. Custom-written software controlled the audio and video presentation of the working memory stimuli. Computer graphics presented at 200 x 200 pixels on a 21-in. touchscreen monitor were used to represent each word. Responses were collected by having the child touch the pictures, shown on the monitor, in the order recalled.

Presentation level was always 68 dB sound pressure level. All tasks, except for the working memory task, were video-audio recorded using a Sony HDR-XR550V video camera so that scoring could be done later. Children wore Sony FM transmitters in specially designed vests. The FM receivers provided direct-line input to the video camera to ensure good sound quality on the recordings.

General Procedures

All procedures were approved by the local Institutional Review Board. Children came to the laboratory for two consecutive days of testing, in groups of two to six children. They were administered a number of tasks in individual test sessions lasting no more than one hour each, and were given breaks between sessions of no less than one hour each. All scoring for tasks that were video-recorded was done by two independent staff members so reliability could be checked.

Part 1: Malapropism Recognition

The goal of the first part of the report was to examine the first prediction addressed by this study, that children with HL would be poorer at detecting malapropisms than children with NH. Malapropism recognition was selected as the primary dependent measure in the study because it is a task that requires sensitivity to the acoustic-phonetic structure of words, which is the same structure that should be especially important for following discourse in academic settings.

Task-Specific Procedures

The Malapropism task designed for this study was loosely based on the Malapropisms subtest of the Test of Language Development – Intermediate, 3rd Edition (Hammill & Newcomer, 1997), and consisted of four practice and 47 test sentences. Three of the practice and 41 of the test sentences contained malapropisms; one practice and six test sentences did not contain malapropisms. Sentences for the current task are listed in the Appendix. Lists of malapropisms are available elsewhere (e.g., Fay & Cutler, 1977), but care was taken in assembling this set to ensure both that targets and substitutions differed from each other in acoustic-phonetic structure by as little as possible and that all items were appropriate for 10-year-old children. To check our process, these stimuli were assessed in several ways. First, the neighborhood density of each target and each substitution was derived using http://calculator.ku.edu/density/about.

Neighborhood density is defined as how many words differed from the target or substitution by one segment (Luce & Pisoni, 1998), and means for these items are 12 for the targets and 11 for the substitutions. Accordingly, targets and substitutions had equally probable phonotactic structures. In addition, both sentence length and the positions of target-substitutions within the sentences were varied so that subjects could not benefit by attending to a particular part of the sentence in anticipation of a malapropism. Length of the target-substitutions was varied, such that twenty-two of the target-substitutions were one-syllable words, and 19 were either two- or three-syllable (multisyllabic) words. Finally, care was taken to make sure that all target-substitutions could reasonably be expected to be within the vocabularies of 10-year-old children. To address this goal, these words were assessed for age of acquisition (AoA) according to Kuperman et al. (2012). Targets and substitutions were well matched on AoA, with AoA for targets equal to 5.9 years (2.0 years) and AoA for substitutions equal to 6.1 years (1.9 years). These values supported the conclusion that all children in this study could be expected to have some familiarity with both the targets and substitutions.

Sentences were produced by a man with a Midwest dialect who had no facial hair and were video-audio recorded for presentation. During testing the child sat in front of the monitor. After each sentence was presented, the child's task was to judge if the sentence was *right* or *wrong*, and if it was judged to be *wrong* state how to make it *right*. Testing was discontinued after six consecutive incorrect answers. For sentences without malapropisms (i.e., *right* sentences), children received one point for identifying each as such; for sentences containing malapropisms (i.e., *wrong* sentences), children received a half point for identifying each as such, and a half point for providing the correct fix. Percent correct scores (out of 47 items) were used in analyses.

Results

Because this malapropism task was newly developed, reliability was assessed prior to further analyses. Specifically, split-half reliability was calculated over the 47 items on the task across all subjects. The Spearman-Brown coefficient was .925, indicating that the task was internally consistent.

Next scores on this task were examined to check for normal distribution and homogeneity of variance. Both were found to be adequate. The alpha level for significance was set at .05, but p values are reported when $p < .10$. When $p > .10$, outcomes are reported simply as not significant (NS). This convention was followed for all analyses.

Figure 1 shows a Tukey's box and whiskers plot of percent correct responses for the malapropism recognition task. The children with HAs and the children with CIs performed similarly to each other and more poorly than the children with NH. A one-way analysis of variance (ANOVA) with hearing group as the between-subjects factor and post-hoc comparisons with Bonferroni corrections (.05) was performed. The main effect of group was significant, $F(2,116) = 24.534$, $p < .001$, $\eta^2 = .297$. The post-hoc comparisons for NH versus HAs and NH versus CIs were both significant at $p < .001$, and remained significant with corrections. The comparison for HAs versus CIs was not significant. Thus, the first prediction received support: children with HL performed more poorly than children with NH when it came to detecting malapropisms. Children with CIs, however, performed no more poorly than children with HAs, which is counter to the prediction.

One additional analysis was performed. Scores for one-syllable versus multisyllabic malapropisms were analyzed using a two-way, repeated-measures ANOVA with one or more syllables as the repeated measure and listener group as the between-group factor. The main effect of number of syllables was significant, $F(1,116) = 20.834$, $p < .001$, $\eta^2 = .152$, but the interaction of Number of Syllables x Group was not. Across all groups, mean correct recognition was 75 percent (21 percent) for one-syllable items and 69 percent (23 percent) for multisyllabic items. Thus it can be concluded that children with HL were not disproportionately affected by longer words.

Summary

This first analysis was undertaken to examine whether children with HL would be found to have more difficulty than children with NH at detecting the acoustic-phonetic changes in speech signals that create malapropisms. Indeed, children with HL were found to perform more poorly on the malapropism recognition task than children with NH, but children with HAs and those with CIs performed similarly, even though children with HAs should have keener access to acoustic-phonetic details in the speech signal than children with CIs.

Part 2: Correlates of Malapropism Recognition

The goal of this second part of the report was to address the second prediction of the study, that at least for children with HL, performance on the malapropism recognition task would be related more strongly to phonological sensitivity than to lexicosyntactic knowledge. Five measures were collected to examine the extent to which each might explain malapropism recognition. *Phonological awareness* and *phonological processing* were assessed. Both tasks fit into the broader category of phonological sensitivity, with the first evaluating how well children recognize phonological structure and the second evaluating how familiar they are with the ways in which it can be manipulated. *Vocabulary* was measured, because the size of the child's vocabulary might help explain skill at recognizing malapropisms, which involve changes in word structure. *Verbal working memory* was also assessed. Because the malapropism test materials consisted of sentences, it was speculated that children's working memory capacities could help explain variability in their scores. Finally, children's abilities to construct *oral narratives* were measured and those scores included. This measure assesses knowledge regarding higher level structural elements of language, which might be involved in recognizing when a sentence is incorrect.

Task-Specific Procedures

Phonological awareness. Phonological awareness was assessed with the final consonant choice task (e.g., Nittrouer et al., 2017; Nittrouer et al., 2013). This task consisted of 48 items, and testing was preceded by training. The words in this task were presented in audiovisual format, produced by a man with a Midwest dialect who had no facial hair. For this task, the child was presented with the target, and needed to repeat it. Then, three word choices were presented, also in audiovisual format. The child's task was to select the word that ended in the same sound as the target. Testing was discontinued after six consecutive errors. Percent correct scores (out of 48 items) were used in analyses.

Phonological processing. Phonological processing was examined using a backwards words task (e.g., Nittrouer et al., 2016; Nittrouer, Muir, et al., 2018). This task also consisted of 48 items with testing preceded by training. The words in the task were presented in the same audiovisual format as the phonological awareness task. In this task, the child was presented with a target word and repeated it. Then, the child needed to say the word that resulted when the order of phonemes was reversed. Testing was discontinued after six consecutive errors. Percent correct scores (out of 48 items) were used in analyses.

Vocabulary. The Expressive One-Word Picture Vocabulary Test – 3 (Brownell, 2000) was used to assess vocabulary knowledge. The task consists of showing the child a series of pictures one at a time on an easel and having the child name the item or action in the picture. Testing was discontinued after six consecutive errors. Raw scores were used in analyses. Although standard scores are closely aligned with raw scores for any specific age and most of these children were 10 years old, raw numbers of words labeled correctly is the most direct measure of vocabulary knowledge.

Working memory. This task has also been used extensively in this laboratory (e.g., Nittrouer et al., 2013; Nittrouer et al., 2017). It consisted of the presentation of a closed set of six words in 10 different sequences. The words were *ball*, *coat*, *dog*, *ham*, *pack*, and *rake*. These stimuli were presented as audio-only files. These word files were obtained from a male talker with a Midwest dialect. Pretest training introduced the words and associated pictures (shown on the computer monitor) to the children. All children demonstrated 100 percent reliability at matching the words heard to the pictures representing each word before testing started. During testing, the words were presented at a rate of one per second, in an order randomly determined by the software. After presentation of the six words, the associated pictures appeared at the top of the computer monitor. The child had to touch the pictures in the order recalled. After testing with the ten sequences, the child was again asked to match each word to the associated picture. All children were again able to perform this post-test task with 100 percent reliability. The percentage of items (out of 60) recalled in the correct order was the measure obtained from this task.

Oral narratives. The picture sequences of Fey et al. (2004) were used to collect a measure of children's oral narrative abilities. There are four of these sequences, each consisting of three pictures. However, one of the sequences (Blackie's Apples) was always used to demonstrate to each child what was expected by having the experimenter tell a story. The first picture in each sequence depicted the setting and key elements for the story, but with no conflict. The second picture illustrated the conflict or problem that required resolution. The final picture suggested a resolution that may have been implemented, but with enough ambiguity to support individual interpretation.

During testing, each child was first asked to select the picture sequence to be used for the narrative. Next, the examiner demonstrated the sample story. Children were then given 5 minutes to plan their own narratives, which were audio-video recorded upon presentation. There were 12 scoring categories, and between zero and three points could be obtained in each category, making 36 the maximum number of points obtainable. Categories for scoring and criteria for each score are provided in the appendix of Nittrouer et al. (2017). Laboratory staff trained with narratives from practice participants before scoring children in this study, and two members of the laboratory staff independently scored each narrative. Reliability between the two scorers was .983, which was considered adequate. Scores from the first scorer were used in analyses.

Results

All measures were examined for normal distributions and homogeneity of variances. All measures met that criterion except for the measure of phonological awareness. It was highly negatively skewed. Arcsine transformations were applied, and those transformations met the requirement of having a normal distribution. Thus they were used in further analyses for this measure, although scores are reported as percent correct.

General outcomes

Phonological awareness. The left panel of Figure 2 shows mean percent correct scores and standard errors of the mean (SEMs) for the phonological awareness measure. It is clear that the children with HAs performed more similarly to the children with NH on phonological awareness than did children with CIs. The first line of Table 2 presents statistical outcomes for this measure. The effect size for phonological awareness ($\eta^2 = .215$) was the largest out of the five language measures examined as potential predictors, reflecting the large difference in performance for the children with CIs compared to children in the other two groups. The significant post-hoc comparisons both for children with NH versus children with CIs and for children with HAs versus children with CIs confirm that children with CIs performed significantly more poorly than children in either of the other two groups. In fact, this was the only language measure on which the children with CIs performed significantly more poorly than the children with HAs.

Phonological processing. The middle panel of Figure 2 shows mean percent correct scores and SEMs for the phonological processing measure. Overall performance was lower on this task than on the phonological awareness measure. Children with HAs again performed more similarly to the children with NH, while the children with CIs performed more poorly. The second line of Table 2 presents statistical outcomes for this measure. The effect size for this measure, however, was not as large as the one for phonological awareness. Post-hoc comparisons confirmed that children with NH performed better than children with CIs.

Vocabulary. The right panel of Figure 2 shows mean raw scores and SEMs for the vocabulary task. Raw scores were used in statistical analysis, because they are a more sensitive measure of performance on the task than standard scores, but standard scores were also computed. Mean standard scores for all groups were within the normal range: the mean standard score for children with NH was 107 (SD = 11), for children with HAs it was 102 (SD = 17), and for children with CIs it was 97 (SD= 16). Regardless of whether raw or standard scores are considered, it is clear that children with HL did not perform as well as children with NH, and the performance of the children with HAs fell between that of those two groups. The third line of Table 2 presents statistical outcomes for raw vocabulary scores. Post-hoc comparisons reveal that children with NH performed better than children with CIs, but the comparison of either group to children with HAs was not significant.

Even though children with CIs in this study had poorer mean vocabulary scores than children in the other two groups, their vocabulary knowledge should nonetheless have been adequate to allow them to know both the targets and the substitutions in this malapropism task. The lowest raw score for any child in this study was 62 items correct. That raw score would place this child at the normative mean for an 8-year-old, which is older than the mean AoA for the targets and substitutions in the malapropism recognition task.

Verbal working memory. The left panel of Figure 3 shows mean percent correct scores and SEMs for the measure of working memory. Again, the children with CIs performed the most poorly and the performance of children with HAs fell in the middle. The fourth line of Table 2 presents statistical outcomes for this measure. The effect size was somewhat larger than the effect size for phonological processing, but not as large as the one for phonological awareness. Post-hoc comparisons confirm the observation that children with NH performed better than children with CIs. Scores for children with HAs were not significantly different from those of either children with NH or children with CIs.

Oral narratives. The right panel of Figure 3 shows mean scores and SEMs for the oral narrative task. Examining this figure, it appears that the children with HAs performed more similarly to the children with NH, and the children with CIs had more difficulty with the narrative task. The fifth line of Table 2 presents statistical outcomes for this measure. Post-hoc comparisons again reveal that only the comparison of children with NH and children with CIs was significant.

Correlations with malapropism recognition

In order to examine relationships between performance on the malapropism recognition task and each of the other five language measures, Pearson product-moment correlation coefficients were calculated, for each group separately. These coefficients are shown in Table 3, and complete inter-variable correlation tables for each group are provided in the supplemental materials. Reviewing Table 3 reveals that only the correlations of malapropism recognition and each of phonological processing and vocabulary were significant for the children with NH. For the children with HAs, significant correlations were found for phonological processing, vocabulary, and oral narrative abilities. The correlations of malapropism recognition with phonological awareness and working memory failed to reach significance, but this may have been due to the smaller number of participants with HAs than in the other two groups. At least in the case of phonological awareness, it is fair to suggest that a correlation coefficient of .430 would be statistically significant for a sample with more participants. For children with CIs, significant correlation coefficients were obtained between malapropism recognition and all five language measures, although the coefficient for phonological awareness was largest at .688.

To determine which of the measures explained the most variance in performance on the malapropism recognition task, stepwise regressions were performed with malapropism recognition scores as the dependent measure and phonological awareness, phonological processing, vocabulary, working memory, and oral narrative as the predictor variables, for each group separately. Although the number of participants in the HA group was smaller than in the other two groups, it reached the criterion of at least two participants per variable required for such analyses (Austin & Steyerberg, 2015). Outcomes of these analyses are shown on Table 4.

Performance on the malapropism task for children with NH was explained both by vocabulary and phonological processing, with vocabulary explaining most of the unique variance, and phonological processing explaining a significant amount of the remaining variance. For children with HAs, vocabulary and oral narratives explained performance on the task, with vocabulary explaining most of the unique variance and oral narratives explaining a significant amount of the remaining variance. For children with CIs, phonological awareness and vocabulary explained performance on the task, with phonological awareness explaining most of the unique variance and vocabulary explaining a significant amount of the remaining variance. Thus, for these children with CIs, the prediction was largely confirmed: their awareness of phonological structure explained most of the variance in their abilities to detect malapropisms.

Finally, audiologic factors were examined to see whether they accounted for any variance in performance on the malapropism recognition task. For children with HAs, Pearson product-moment correlation coefficients were calculated between the malapropism recognition score and both the age of identification and the unaided, three-frequency PTA. Neither of these was significant. For the children with CIs, Pearson product-moment correlation coefficients were calculated between the malapropism recognition score and each of the following: age of identification, the unaided, three-frequency PTA obtained just before implantation, and age at first implant; for children with two implants, age of second implant was also considered. Again, none of these correlations was significant. These results indicate that audiologic factors did not explain any variance on the malapropism recognition task.

Summary

The analyses reported in this second section were undertaken to examine the language skills that might explain variability in malapropism recognition. The primary hypothesis was that children with HL – especially those with CIs – would be constrained in their abilities to recognize malapropisms, due to their diminished access to the acoustic-phonetic structure in the speech signal that marks the substituted word. This hypothesis was largely supported: Sensitivity to phonological structure explained the most variance in outcomes for children with CIs. Vocabulary knowledge was found to explain a significant amount of variability in malapropism recognition scores for all three groups, and the most variance for both the children with NH and those with HAs. Finally, scores on the task of constructing an oral narrative were found to correlate with malapropism recognition, but only for children with HAs.

Overall, the results of this second set of analyses confirmed the second prediction: Children with CIs have difficulty recognizing details of the acoustic speech signal, which leads to problems detecting small perturbations in verbal material. Figure 4 shows the relationship between phonological awareness and malapropism recognition for children with CIs, and illustrates this finding clearly.

Part 3: Malapropisms and Academic Achievement

The goal of the third part of this report was to test the prediction that scores on the malapropism recognition task would be related to teacher assessments of the participants' academic competence at fourth grade. The basis of this prediction was that children with HL, especially those with CIs, would have difficulty following either in-class discussions conducted with academic language or subject-specific, lecture-type presentations because of difficulty processing spoken language that depends strongly on a listener's ability to use bottom-up phonological structure. For this study, academic competence was assessed using the teacher form of the Social Skills Ratings System (SSRS; Gresham & Elliott, 1990). Not all of the classroom teachers agreed to complete these rating scales, but teacher ratings were available for 43 children with NH, 18 children with HAs, and 44 children with CIs. These numbers were adequate for addressing this third goal.

In this third part of the report two additional predictor variables were included: word reading and reading comprehension. These additional variables were included because reading abilities are viewed by many professionals as critical predictors of academic success. That view, however, is difficult to support with empirical data. One study that examined this question in rigorous manner found that strong readers at kindergarten demonstrated strong academic performance at fifth grade, unaffected by other factors; academic performance at fifth grade for kindergartners who were not strong readers was strongly influenced by social skills (Cooper et al., 2014). It is fair to conclude that the role of early reading on later academic performance is currently not well understood. Nonetheless, this factor is included in this third analysis of this study.

Task-Specific Procedures

Teachers' ratings. Parents of the children in the study were sent a copy of the SSRS teacher form labeled with a code number, along with a business-reply envelope and an IRB-approved cover letter informing the teacher about the form and their rights as a participant. Each parent signed and dated the cover letter and gave it to the teacher along with the SSRS form and envelope. Each teacher mailed the completed form back to the authors' laboratory, where it was then scored. These teachers all received these forms in the spring, near the end of the academic year, so they all had adequate time to make valid observations of these children.

The SSRS teacher form includes a 30-question section that asks the teacher to assess the student's social skills, an 18-question section that asks the teacher to assess the student's problem behaviors, and a nine-question section that asks the teacher to assess the student's academic competence. The questions in the academic competence section are rated from 1-5, on a scale from lowest to highest, and include questions about the child's overall academic performance, reading and math skills, motivation, and behavior. The academic competence raw score is calculated by adding the scores for each of the 9 questions. Scores on this part of the instrument range from 9 to 45.

Reading measures. Two reading measures were obtained, both taken from the Qualitative Reading Inventory (QRI) – 4 (Leslie & Caldwell, 2006). For this task, children were asked to read two passages at the fourth-grade level. One was a narrative and one was an expository. After a child read a passage, ten comprehension questions were asked by the examiner. Children were audio-video recorded reading each passage, and answering the questions. Scoring was done later by a staff member, with a second staff member checking that scoring. Dependent measures were the percentage of words read correctly and the number of questions answered correctly, out of the 20 asked across the two passages. Outcomes for this measure were reported previously (Nittrouer et al., 2020).

Results

Mean raw scores (and SEMs) on the academic competence measure are shown in Figure 5, along with mean scores and SEMs for word reading and reading comprehension. Table 5 shows outcomes of one-way ANOVAs performed on each of these measures, along with results of post-hoc analyses. These results show that children in the three groups had similar academic ratings, although children with CIs had lower scores than children with NH. Children with CIs performed more poorly than children in the other two groups on word reading, as would be expected given their poor phonological awareness. Children in the three groups performed similarly on reading comprehension, demonstrating the abilities of these children with HL to make use of top-down contributors to comprehension.

For each of the three groups, Pearson product-moment correlation coefficients were calculated between the academic competence measure and each of the other eight measures: malapropism recognition, phonological awareness, phonological processing, vocabulary, working memory, oral narrative abilities, word reading, and reading comprehension. Those correlation coefficients are presented in Table 6. For both the children with NH and those with CIs, all eight correlation coefficients were significant, or close to significant in the case of vocabulary for the children with NH. For children with HAs, only two correlation coefficients were statistically significant: working memory and oral narratives.

To examine which of the measures accounted for the most variability in the ratings of academic competence, stepwise regressions were performed for each group separately, with malapropism recognition, phonological awareness, phonological processing, vocabulary, working memory, oral narrative abilities, word reading, and reading comprehension as the predictor variables. Outcomes of these analyses are shown in Table 7. For children with NH, phonological processing ($\beta = .476$, $p = .001$) accounted for the largest amount of unique variance. However, in a second and third step it was found that each of the reading measures also accounted for some of the unique variance. For children with HAs, oral narrative was found to be the only variable to account for a significant proportion of the variance. For children with CIs, performance on the malapropism task accounted for the largest proportion of variance, but working memory accounted for some significant amount of remaining variance in a second step.

Summary

In this third set of analyses it was found that teachers rated children with CIs only slightly poorer in academic competence overall than children with NH or HAs. The primary focus of this analysis, however, was on the prediction that the ability of children with CIs to detect acoustic-phonetic changes in the speech signal could help explain how well they were performing academically. Figure 6 displays the relationship between scores on the malapropism recognition task and teachers' ratings of academic competence for these children with CIs, and illustrates that the prediction was well supported by these data. For children with NH, sensitivity to phonological structure – or their ability to manipulate that structure – was the primary determinant of academic success, with reading skills also explaining some of the variability. For children with HAs, a different outcome was observed: their ability to construct an oral narrative was the main determinant of academic ratings of competence.

General Discussion

Childhood hearing loss is a condition that has historically put children at risk for significant language deficits, especially where spoken language is concerned. In the past, these language deficits have interfered greatly with the abilities of children with HL to achieve academic success. The last generation of children born with HL, however, has been the beneficiary of substantially improved treatments. In turn, these improved treatments have been associated with better language performance among children with HL. Where lexical and syntactic skills are concerned, roughly half of these children are typically found to score within the normal range on standard language measures, with the normal range defined as better than -1 SD below the normative mean (Antia et al., 2020; Geers et al., 2016; Nittrouer, 2016; Nittrouer & Caldwell-Tarr, 2016). But when it comes to demonstrating sensitivity to phonological structure, children with HL show larger deficits, especially if the hearing loss is severe enough to require cochlear implants. For this specific skill, a more reasonable estimate of performance would be that only about 15 percent of children with CIs demonstrate the ability to recognize word-internal phonological structure at a level better than -1 SD of the mean for their peers with normal hearing (Antia et al., 2020; Nittrouer, 2016; Nittrouer & Caldwell-Tarr, 2016). These general descriptions of differences in language performance between children with HL and peers with NH were largely borne out in data presented in this report: Referring back to Table 2 we find that the effect size for phonological awareness was .215, but for vocabulary it was .086. An argument against this depiction of the relative lexicosyntactic and phonological skills in children with HL might be the finding that the effect size for phonological processing was .097, which is not that much larger than the one for vocabulary. This trend of performing better on phonological processing than awareness tasks has been observed previously for the children with HL (especially those with CIs) in this current study (Nittrouer et al., 2018b). The apparent contradiction suggests that children with HL have less difficulty manipulating phonological structure – if they can recognize it in the signal. For them, the core problem appears to be recognizing that structure, because the acoustic signal they receive is highly degraded. That problem in turn leads to challenges with other language processes, such as novel word learning and storing verbal material in a short-term memory buffer.

The study described in this report examined another potential consequence of poor phonological awareness. The central hypothesis of this study was that children with HL may have difficulty following the material presented in class because that material is less predictable than everyday communications, and consists of school-specific vocabulary used in abstract contexts. As a result of the less-familiar nature of this language, access to bottom-up phonological structure is likely more beneficial in academic than in everyday communication settings. The degraded nature of the signal available to children with HL prohibits them from having ready access to that phonological structure. It is proposed that this problem has been overlooked previously because most standard language instruments primarily assess lexicosyntactic skills, rather than phonological sensitivity, leading to the apparent and heretofore unexplained contradiction of improving language skills, but continued academic deficits among children with HL. To test this general hypothesis, children with HL and their peers with NH were asked to identify malapropisms in sentence contexts. Additional measures of language skills were obtained, as were teachers' ratings of the children's academic competence. Three specific predictions were posited: (1) Children with HL would perform more poorly than children with NH when it came to detecting malapropisms; (2) The poor performance of those children with HL would be associated with poor phonological sensitivity; and (3) Problems recognizing malapropisms would be associated with teachers' ratings of academic competence for children with HL. Overall the data supported each prediction – at least for children with CIs. Outcomes for children with HAs strayed from those predictions.

Looking first at the children with CIs, their performance on the malapropism recognition task was found to be significantly poorer than that of children with NH. When potential predictors of that performance were examined, their awareness of phonological structure was found to be the strongest correlate. In this case, the phonological awareness task implemented was one that assessed children's abilities to recognize consonantal structure at the ends of words;

consequently, it could be characterized as a test specifically of phonetic awareness. Thus, these children performed more poorly than children with NH, and that performance was largely explained by sensitivity to phonetic structure. These findings support the first two predictions of this study. The third prediction of the study was supported by the finding that scores on the malapropism recognition task were the major correlates of teachers' ratings of academic competence for these children.

Turning to children with HAs, the findings were quite different. These children were significantly poorer than children with NH at detecting malapropisms; in fact, their performance on that task did not differ significantly from that of children with CIs. Nonetheless, these children with HAs had scores on the other five language measures that did not differ significantly from those of children with NH. In addition, for children with HAs, performance on the malapropism recognition task was explained largely by their vocabulary knowledge and their skill at constructing oral narratives. Furthermore, for these children, teachers' ratings of academic competence were largely explained by the children's oral narrative scores; no other measure explained any remaining variance. Not only do these outcomes for this group differ from outcomes for children with CIs, they differ from outcomes for children with NH, as well. For children with NH, performance on the malapropism task was largely explained by their vocabulary knowledge, with phonological processing abilities explaining some remaining variance. And phonological processing was the only measure on its own to account for a significant proportion of variability in teachers' ratings of academic competence for children with NH, although reading skills explained some additional variance. Thus, although patterns of outcomes differed for children with NH and children with CIs, some aspect of phonological sensitivity was an important correlate to both malapropism recognition and teachers' ratings of academic competence for both groups. This was not the case for children with HAs. Instead it appeared that knowledge regarding communication at a higher level was the primary correlate with both their performance on the malapropism task and teachers' ratings of their academic competence. This general finding highlights the need to treat children with HAs and those with CIs separately in designing intervention programs.

Limitations of Current Study

The significant role that vocabulary knowledge played in malapropism recognition for the children with NH is difficult to explain. It cannot be accounted for simply by the idea that it determined whether these children knew that a specific word belonged in the sentence context or not because all children with NH had vocabulary skills that exceeded the presumed age of acquisition for all these words. Thus, another aspect of vocabulary skill – perhaps ease of lexical access – must instead account for this relationship. None of the measures in this current study are able to identify this component of lexical operations.

Another limitation of the current study is the fact that children with HAs demonstrated different patterns of relationship among the constructs tested than either the children with NH or those with CIs. For both of these latter groups, language processes that can be viewed as related to phonological sensitivity explained both performance on the malapropism recognition task and teachers' ratings of academic competence. For children with NH, their abilities to manipulate phonological structure explained large amounts of variance on both of those dependent measures. For children with CIs, phonological awareness explained most of the variance in their abilities to recognize malapropisms, and in turn, their abilities to recognize malapropisms explained variability in teachers' ratings of their academic competence. For children with HAs, strong effects of broader language skills were observed, most notably their abilities to construct oral narratives. This skill involves understanding how elements of a story should fit together, as well as linguistic devices such as reference. It is tempting to dismiss this finding as spurious, because children with HAs formed the smallest group. But 19 children is not an especially small sample, and the effects were robust. Future work is left to explain this finding. However, it may be relevant that Cooper et al. (2014) found that academic success at fifth grade for children who at kindergarten were found to be poor or average readers was largely explained by social skills. Perhaps the ability to tell a story well is related to social skills.

Clinical Implications

The results reported here reveal that it is not enough to administer standard tests of language functioning to children with HL in order to ascertain their ability to function in mainstream classrooms. In this study, means for both the children with HAs and the children with CIs were very close to the normative mean on the one standardized assessment given: the Expressive One-Word Picture Vocabulary Test (Brownell, 2000). Nonetheless, almost all the children in both groups scored below the 25th percentile of performance by the children with NH on the malapropism recognition task, as seen on Figure 1. This finding indicates that, regardless of the basis, these children could not recognize details in the speech signal, and that situation can constrain their abilities to follow discussions of a technical or scientific nature: in other words, academic language. Here it is proposed that this discrepancy in findings for general lexicosyntactic abilities and for sensitivity to bottom-up phonological structure in continuous speech can help explain the discrepancy in outcomes for language and academic performance by children with HL. This is a problem that must be addressed by educators and clinicians working with children with HL. Both remedial and compensatory strategies should be used. Table 8 provides suggestions for ways to facilitate better auditory comprehension of academic language by students with HL.

A central concern for these children must be ensuring that signal quality is as clear as it can be. Hearing aids should be kept in optimal working condition, and checked regularly. Teachers of young children should check batteries, and older students should be taught how to check batteries themselves. Similarly, cochlear implants should be monitored closely to ensure optimal operating conditions. Noise and reverberation in the classroom should be minimized.

Instruction should consist of helping children discover the phonological structure of spoken language. Tasks implemented for this purpose can be similar to those used in reading instruction. However, precisely because the signal quality to which they have access is – and for the foreseeable future is likely to remain – degraded, educators and clinicians should be aware that these children will continue experiencing difficulty in recovering phonological structure. Nonetheless, there are ways to help these children develop appropriate representations in spite of their poor access to phonological structure through audition. First, children with HL can acquire knowledge about phonological structure through the reading process itself (Nittrouer, Muir, et al., 2018). Therefore, that instruction should start early for these children, and take a phonics approach. Teachers can then help students acquire salient representations of the phonological structure of new vocabulary items by always showing new words in text format. Second, children with HL acquire information about phonological structure through learning about the articulatory organization of words. In general, teachers should introduce new vocabulary items to children with HL by giving them ample opportunity to hear, read, and say the new words.

Vocabulary should be taught explicitly, prior to the start of new topical units that will incorporate those vocabulary items. Similarly, related syntax and grammar should be introduced. Variances in how common syntactic and other grammatical structures are used in academic settings should be explained. Visual aids should be incorporated frequently, and material should be presented in both oral and written format. When possible, small-group instruction should be used.

Conclusions

Improvements in available treatments for children with HL have dramatically improved the prospects that these children will develop age-appropriate language skills, but many of these children continue to struggle in school. This study tested the hypothesis that this mismatch in academic and language achievement can be explained in part by children with HL having difficulty recognizing acoustic-phonetic detail in the speech signal. It was proposed that this problem constrains children’s abilities to easily recognize orally presented information in the school setting. Materials consisting of sentences containing malapropisms were used to test the hypothesis, because malapropisms represent acoustic-phonetic deviations from standard structure. Children with NH and with HL – both those with HAs and those with CIs – were tested on their abilities to recognize these malapropisms, and five other language measures were collected as potential covariates. Teachers' assessments of students' academic competence were obtained.

Results showed that children with HAs and CIs performed more poorly on the malapropism recognition task than children with NH, but similarly to each other. Performance on the five language measures revealed a disproportionately large phonological deficit for the children with HL, especially for those with CIs. Phonological awareness explained the most variability in malapropism recognition for children with CIs, but not for children with NH or HAs. For children with NH, phonological processing explained a significant amount of unique variance, and for children with HAs, their abilities to construct oral narratives were associated with malapropism recognition scores. In addition, vocabulary knowledge explained a significant amount of variability for children in all three groups. Teachers rated academic competence for children with CIs as slightly poorer than that of children with NH; variability in those ratings for children with CIs were primarily explained by malapropism scores. For children with NH, the main correlate was phonological processing, and for children with HAs it was oral narrative scores.

Previous reports have demonstrated that children with HL have difficulty acquiring sensitivity to phonological structure. This study adds to our understanding of the problem by showing that not only are some language skills affected by a phonological deficit, but functioning in academic settings is impeded, as well.

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Supplemental Files

Supplemental Table 1: Pearson product-moment correlation coefficients for pairs of dependent measures computed for children with normal hearing (NH).

Supplemental Table 2: Pearson product-moment correlation coefficients for pairs of dependent measures computed for children with hearing aids (HAs).

Supplemental Table 3: Pearson product-moment correlation coefficients for pairs of dependent measures computed for children with cochlear implants (CIs).

Figure Legend

FIGURE 1: Tukey's box and whiskers plot of percent correct responses for the malapropism recognition task for children with normal hearing (NH), children with hearing aids (HA), and children with cochlear implants (CI).

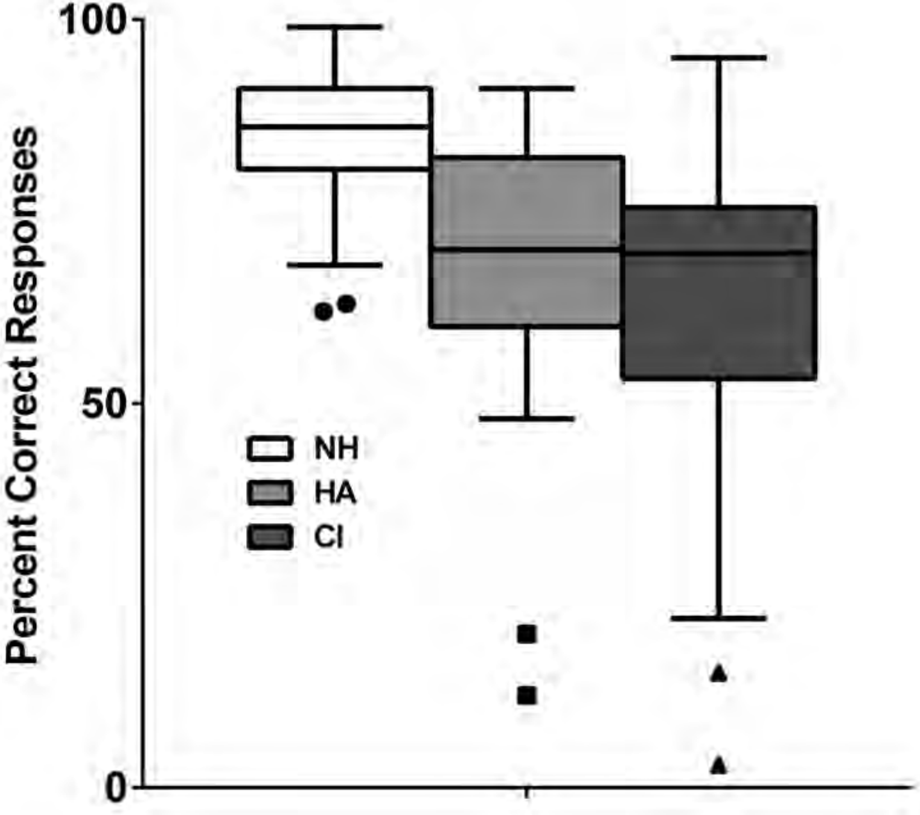
FIGURE 2: Mean percent correct scores for phonological awareness (left) and phonological processing (center), and for mean number of vocabulary items recognized correctly (right) for children with normal hearing (NH), children with hearing aids (HA), and children with cochlear implants (CI). Error bars represent standard errors of the mean.

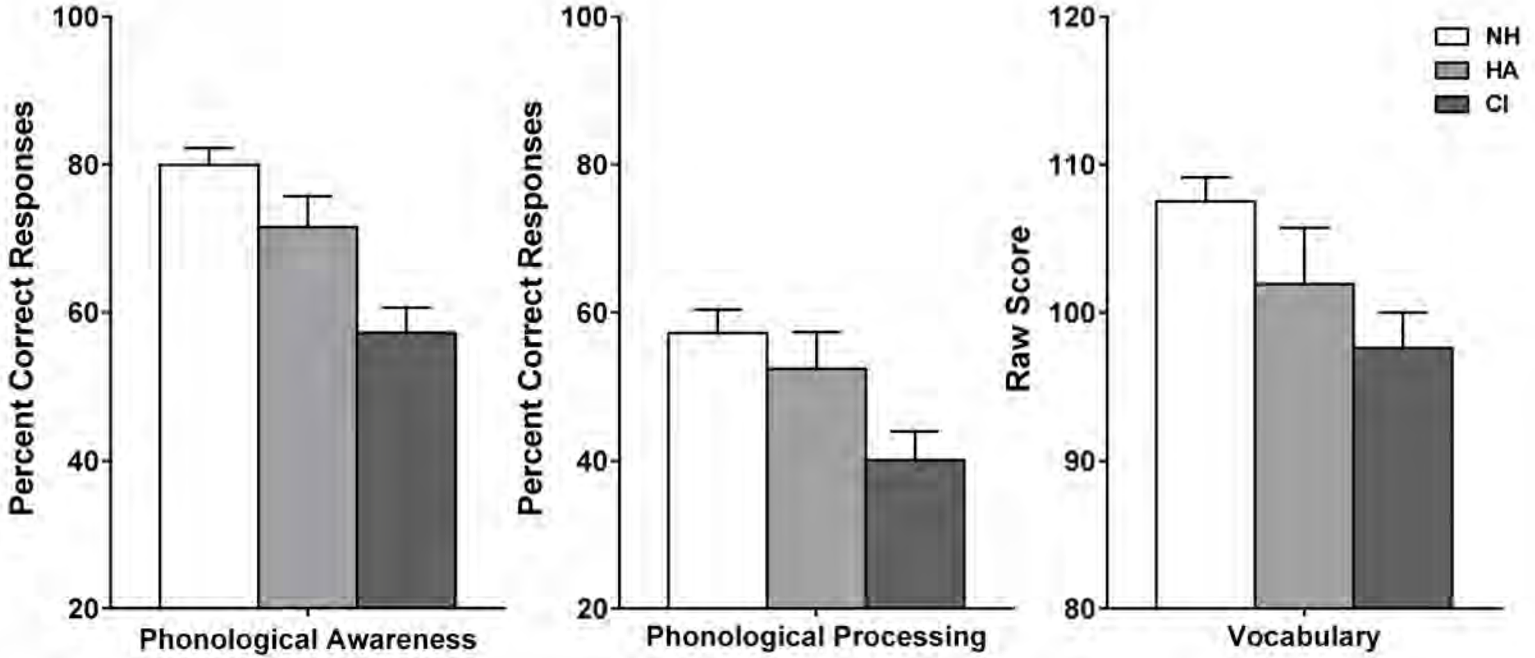
FIGURE 3: Mean percent correct recall for verbal working memory (left) and for the mean raw scores according to the rubric for scoring oral narratives (right) for children with normal hearing (NH), children with hearing aids (HA), and children with cochlear implants (CI). Error bars represent standard errors of the mean.

FIGURE 4. Scatter plot of percent correct responses for malapropism recognition versus percent correct scores for phonological awareness, for children with cochlear implants.

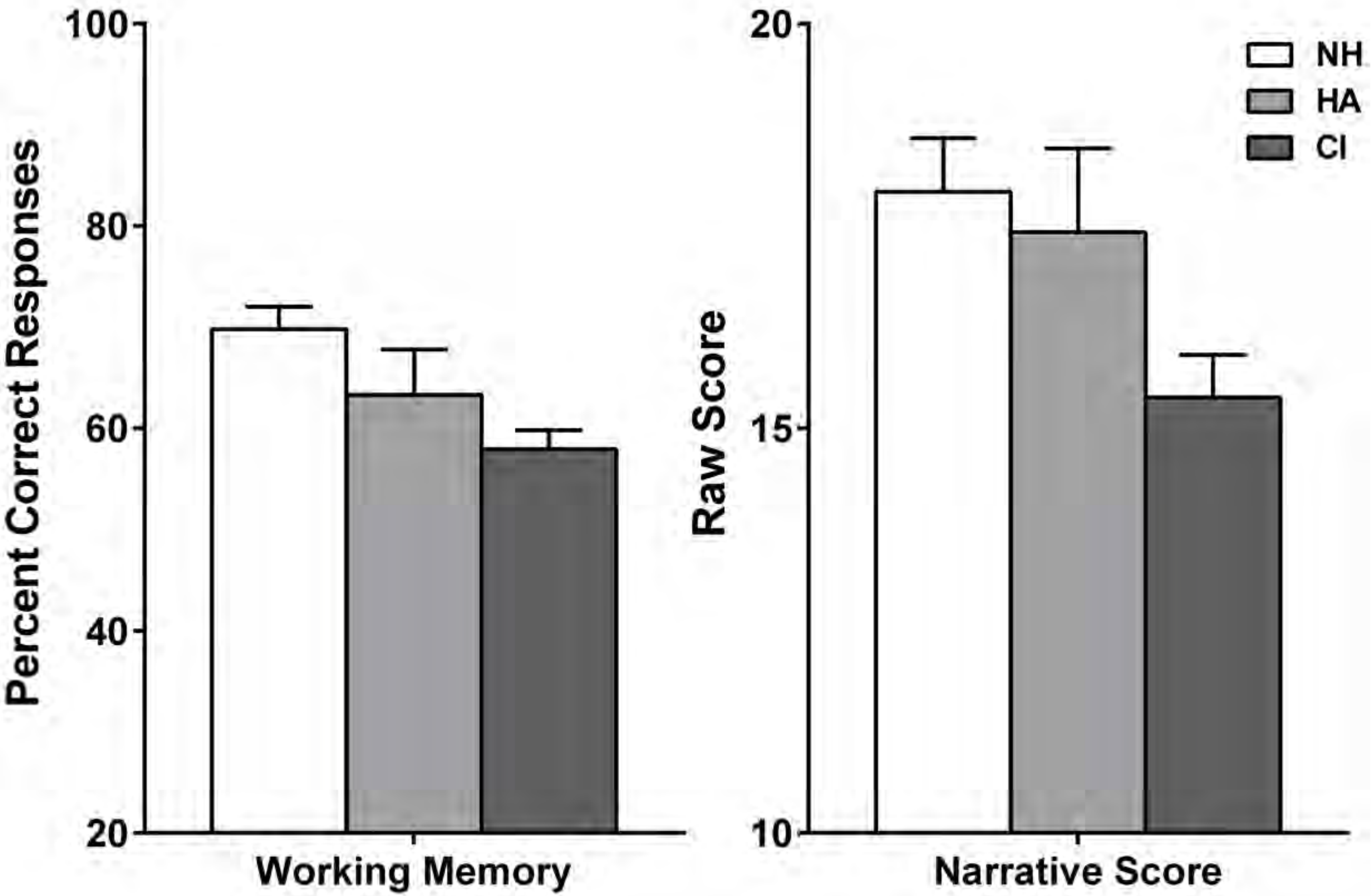
FIGURE 5: Mean raw scores for teachers' ratings of children's academic performance (left), mean percent word reading (center), and mean number of comprehension questions answered correctly (right) for children with normal hearing (NH), children with hearing aids (HA), and children with cochlear implants (CI). Error bars represent standard errors of the mean.

FIGURE 6. Scatter plot of teacher's ratings for academic competence versus percent correct responses for malapropism recognition, for children with cochlear implants.

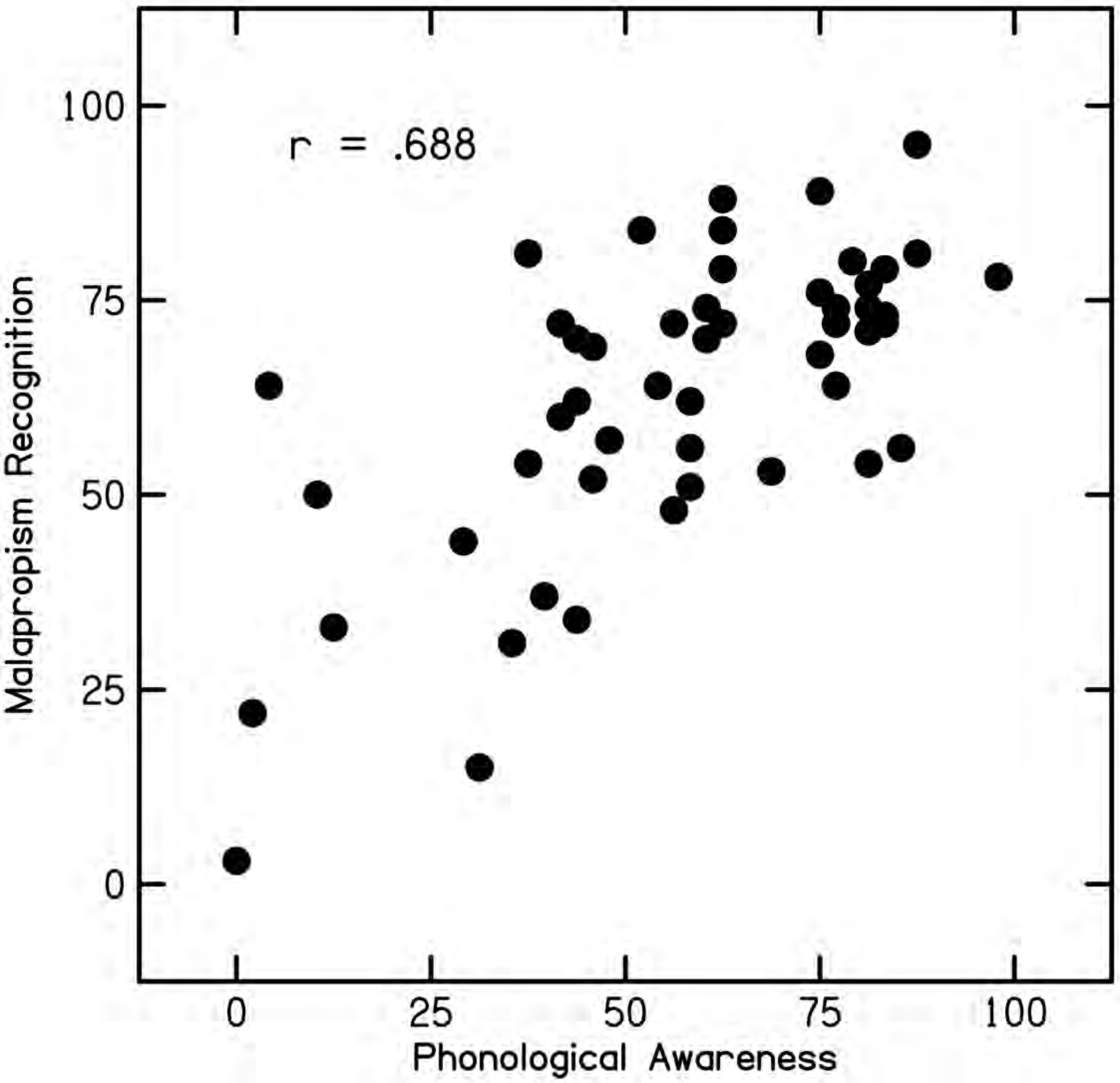

100
50
0
Percent Correct Responses
NH
HA
CI



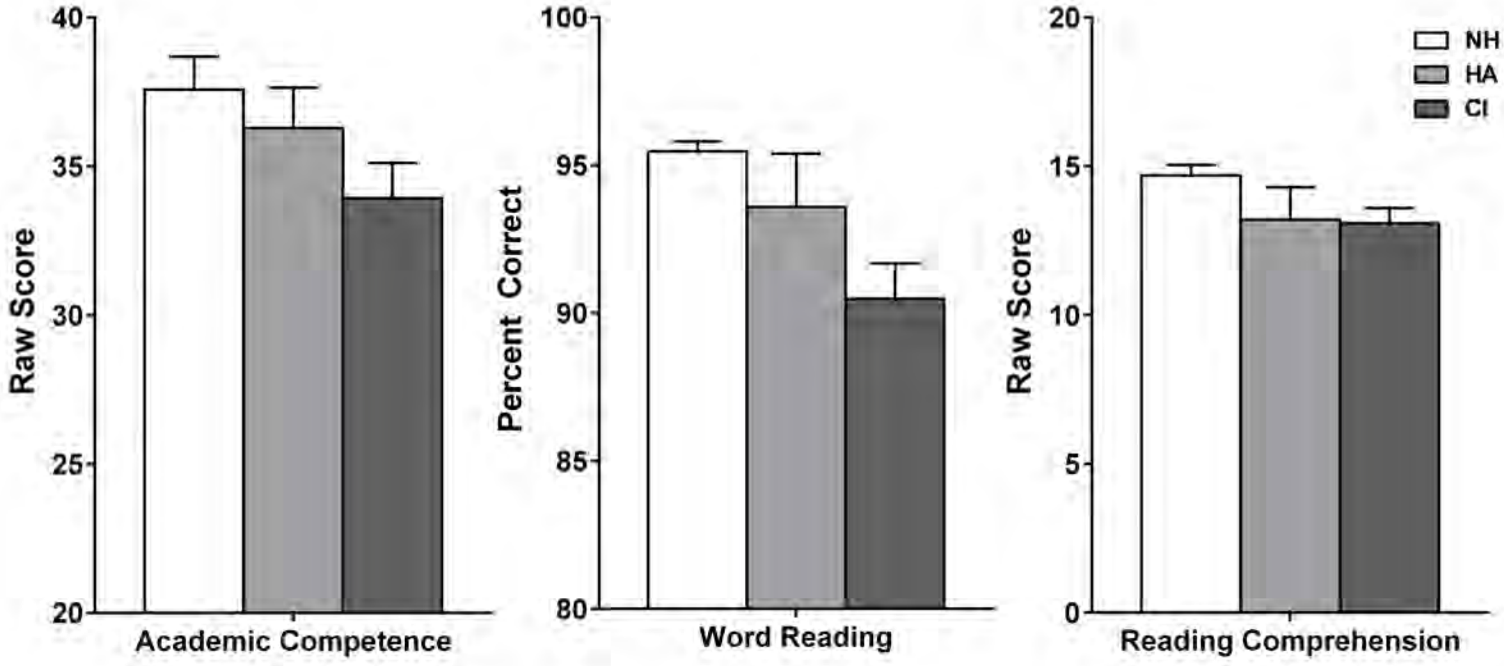
100
80
60
40
20
Percent Correct Responses
Phonological Awareness
100
80
60
40
20
Percent Correct Responses
Phonological Processing
120
110
100
90
80
Raw Score
Vocabulary
NH
HA
CI



100
80
60
40
20
Percent Correct Responses
Working Memory
20
15
10
Raw Score
Narrative Score
NH
HA
CI



r = .688
Malapropism Recognition
Phonological Awareness
0
25
50
75
100



40
35
30
25
20
Raw Score
Academic Competence
100
95
90
85
80
Percent Correct
Word Reading
20
15
10
5
0
Raw Score
Reading Comprehension
NH
HA
CI

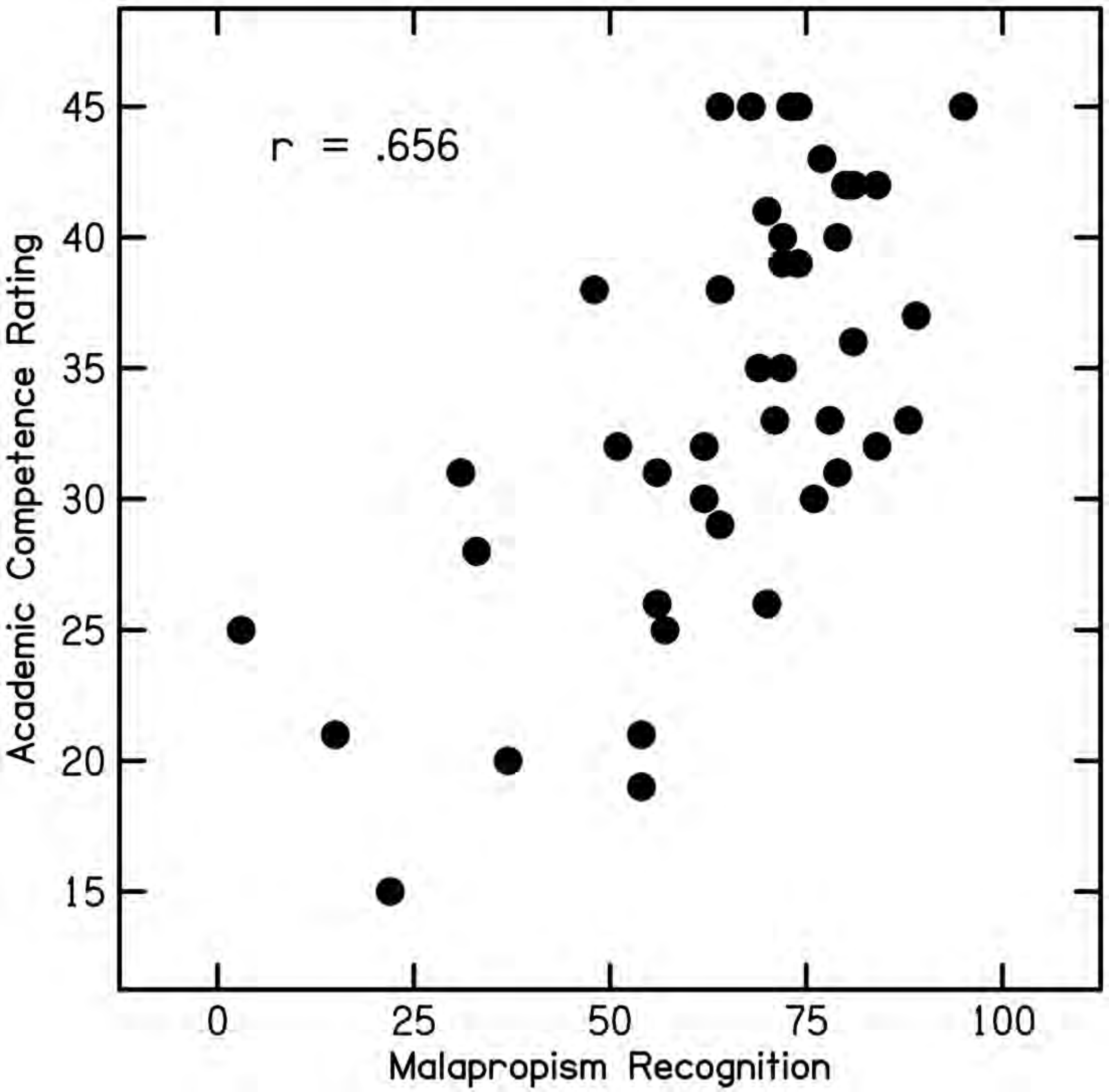

r = .656
Academic Competence Rating
45
40
35
30
25
20
15
0
25
50
75
100
Malapropism Recognition

Table 1.

Means, medians, standard deviations (SD), and ranges for audiometric measures for children with hearing aids (HA) and children with cochlear implants (CI). Except where noted, numbers in each group are 19 for HA and 52 for CI.

	Group							
	HA				CI			
	Mean	Median	SD	Range	Mean	Median	SD	Range
Age at identification (months)	9	4	10	0 – 29	6	4	7	0 – 28
Current (HA)/pre-implant (CI) PTA (dB)	66	66	13	52 – 98	101	102	16	55 – 120
Age at first implant (months)					21	15	16	8 – 93
Age at second implant (months); N = 35					47	44	26	11 – 108

Note: PTAs are unaided, and given in decibel hearing level and are for the three speech frequencies of 500, 1000, and 2000 Hz. PTA = pure tone average.

Table 2.

Statistical outcomes for ANOVA and post hoc (least significant difference) tests for language measures. Degrees of freedom for all measures are 2,116.

	F	*p*	η^2	NH vs HA	NH vs CI	HA vs CI
Phonological awareness	15.853	< .001	.215	NS	< .001*	.010*
Phonological processing	6.256	.003	.097	NS	.001*	.064
Vocabulary	5.483	.005	.086	NS	.001*	NS
Working memory	7.411	.001	.113	NS	< .001*	NS
Oral narrative	4.707	.011	.075	NS	.004*	.077

Note: NS = not significant ($p > .10$); * significant with Bonferroni correction ($p < .05$)

Table 3.

Outcomes of Pearson product-moment correlations between the malapropism recognition task and the other language measures, for each group separately.

	NH		HA		CI	
	r	*p*	*r*	*p*	*r*	*p*
Phonological awareness	.171	NS	.430	.066	.688	< .001
Phonological processing	.410	.004	.480	.038	.548	<.001
Vocabulary	.467	.001	.673	.002	.620	< .001
Working memory	-.008	NS	.391	.098	.279	.045
Oral narrative	.240	NS	.639	.003	.479	< .001

Note: NS = not significant.

Table 4.

Stepwise regression outcomes using malapropism recognition scores as the dependent measure, for each group separately.

	NH	HA	CI
Step #1	Vocabulary, $\beta = .467$, $p = .001$	Vocabulary, $\beta = .673$, $p = .002$	Phon. Aware., $\beta = .688$, $p < .001$
Step #2	Vocabulary, $\beta = .400$, $p = .003$ Phon. Process., $\beta = .329$, $p = .012$	Vocabulary, $\beta = .475$, $p = .021$ Oral Narrative, $\beta = .409$, $p = .042$	Phon. Aware., $\beta = .520$, $p < .001$ Vocabulary, $\beta = .402$, $p < .001$

Table 5.

Statistical outcomes of ANOVA and post hoc (least significant difference) tests for teachers' ratings of academic competence, word reading, and reading comprehension.

	df	*F*	*p*	η^2	NH vs HA	NH vs CI	HA vs CI
Academic competence	2,102	2.742	.069	.051	NS	.022	NS
Word reading	2,116	8.288	< .001	.125	NS	< .001*	.040
Reading comprehension	2,116	2.976	.055	.049	NS	.022	NS

Note: NS = not significant (p > .10); *significant with Bonferroni correction (p < .05)

Table 6.

Outcomes of Pearson product-moment correlations between the academic competence score and each of the language measures, for each group separately.

	NH		HA		CI	
	r	*p*	*r*	*p*	*r*	*p*
Malapropism recognition	.344	.024	.256	NS	.656	<.001
Phonological awareness	.426	.004	.335	NS	.431	.003
Phonological processing	.476	.001	.379	NS	.424	.004
Vocabulary	.298	.052	.459	.055	.504	<.001
Working memory	.381	.012	.506	.032	.445	.002
Oral narrative	.321	.036	.561	.015	.486	.001
Word reading	.361	.017	.208	NS	.481	.001
Reading comprehension	.369	.015	.340	NS	.587	<.001

Note: NS = not significant.

Table 7.

Stepwise regression outcomes using academic competence ratings as the dependent measure, for each group separately.

	NH	HA	CI
Step #1	Phon. Process., $\beta = .476$, $p = .001$	Oral Narrative, $\beta = .561$, $p = .015$	Malapropisms, $\beta = .656$, $p < .001$
Step #2	Phon. Process., $\beta = .421$, $p = .003$ Read Comp., $\beta = .289$, $p = .037$		Malapropisms, $\beta = .572$, $p < .001$ Work. Memory, $\beta = .264$, $p < .030$
Step #3	Phon. Process., $\beta = .299$, $p = .041$ Read Comp., $\beta = .335$, $p = .014$ Word Reading, $\beta = .291$, $p = .043$		

Table 8.

Methods to enhance comprehension of academic language by students with hearing loss.

Acoustic signal	• Ensure that auditory device is optimally fit and properly maintained • Keep classroom noise and reverberation to a minimum • Remember that visual signals provide the same information about phonetic structure as acoustic signals; let children see you talk
Phonological skills	• Help children discover phonological structure within words by using similar instructional methods as used for reading phonics • Explicitly teach morphological structure, such as those of inflectional morphemes • Draw attention to the phonological structure of new vocabulary items; let children hear, read, and say them
Vocabulary	• Pre-teach new vocabulary that will be used in specific topic areas, such as science or social studies • Vary the sentence context in which new vocabulary items are being taught • Ask students to generate sentences using new vocabulary items
Syntax and grammar	• Explicitly teach syntax and grammar that is specific to academic setting or to an individual topic area • Recast statements that use academic sentence constructions into other forms when possible to facilitate learning • Test comprehension frequently by asking students factual questions
Presentation style	• Use visual aids as often as possible • Integrate oral and written language when possible • Implement small-group instruction as much as possible

Supplemental Table 1

Pearson product-moment correlation coefficients for pairs of dependent measures computed for children with NH.

	Mal	PA	PP	Vocab	WM	Narr
Malapropism Recognition (Mal)	1					
Phonological Awareness (PA)	.171	1				
Phonological Processing (PP)	.408**	.556**	1			
Vocabulary (Vocab)	.467**	-.115	.198	1		
Working Memory (WM)	-.008	.457**	.407**	.044	1	
Oral Narrative (Narr)	.240	.129	.256	.248	.132	1

Note: * $p < .05$; ** $p < .01$

Supplemental Table 2

Pearson product-moment correlation coefficients for pairs of dependent measures computed for children with HAs.

	Mal	PA	PP	Vocab	WM	Narr
Malapropism Recognition (Mal)	1					
Phonological Awareness (PA)	.430	1				
Phonological Processing (PP)	.480*	.805**	1			
Vocabulary (Vocab)	.673**	.292	.484*	1		
Working Memory (WM)	.391	.585**	.504*	.308	1	
Oral Narrative (Narr)	.639**	.348	.481*	.485*	.493*	1

Note: * $p < .05$; ** $p < .01$

Supplemental Table 3

Pearson product-moment correlation coefficients for pairs of dependent measures computed for children with CIs.

	Mal	PA	PP	Vocab	WM	Narr
Malapropism Recognition (Mal)	1					
Phonological Awareness (PA)	.688**	1				
Phonological Processing (PP)	.583**	.610**	1			
Vocabulary (Vocab)	.620**	.419**	.629**	1		
Working Memory (WM)	.279*	.177	.360**	.435**	1	
Oral Narrative (Narr)	.479**	.399**	.290*	.401**	.183	1

Note: * $p < .05$; ** $p < .01$

Appendix: Malapropisms Task

Instructions: Say, "You are going to hear and see a man say a sentence; some of the sentences have a mistake in them and some do not. The mistake is that a wrong word has been used. For example, the man might say 'Mary had a little ham.' You know that he should have said 'Mary had a little lamb.' The man will say the sentence and you tell me if it was right or wrong. If it was wrong, tell me what word he should have said". The student does not need to state the entire sentence to receive credit. Simply stating "teeth" would be acceptable.

Practice	
1. We should brush our feet every morning.	teeth
2. Dad said, "There are *floor* tires on the big truck."	four
3. The large snake slithered past the tree.	*correct*
4. The baby slept best when she had a *battle* in her mouth.	bottle

Score correct answers as 1 and incorrect answers as 0. Discontinue after 6 consecutive malapropism fails.

Item	Acceptable Responses	Score 1 or 0 or NR
1. Make sure you *race* your hand once you know the answer.	raise	________
2. Tyler's favorite birthday *pleasant* was a toy train.	present	________
3. The white sheep jumped over the fence.	*correct*	________
4. I like to use a big *soon* when I eat soup.	spoon	________
5. *Arch* is the third month of the year.	March	________
6. She ate bread and *better* with dinner.	butter	________
7. John flies all around the *word* for business.	world	________
8. My *cap* purrs whenever I come around.	cat	________
9. The *specific* ocean is the world's largest body of water.	pacific	________
10. Aunt Mary came to the holiday concert.	*correct*	________
11. The puppet show starts every day at *free* o'clock.	three	________
12. My father works at a *constriction* site building houses.	construction	________
13. I rode an *alligator* to the top of the building.	elevator	________
14. Father said, "You can't eat *desert* before your dinner."	dessert	________
15. Give the dice a good *snake* before you toss them.	shake	________
16. The rain made my hair and clothes *soaping* wet.	soaking, sopping	________
17. We climbed from the valley to the *peep* of the mountain.	peak	________
18. The *picture* won the baseball game with his fastball.	pitcher	________
19. I need a good *raisin* to do that.	reason	________
20. Look both ways before you cross the street.	*correct*	________
21. Chris put on his best pants and *skirt* and went to the party.	shirt	________
22. Our feet were burnt from the hot sand on the *bleach*.	beach	________
23. I *trade* to play football, but I was unable to keep a hold of the ball.	tried, trained	________
24. Cinderella wore an *elephant* dress to the ball.	elegant	________
25. The dentist said, "Open your *moth* very wide."	mouth	________
26. Asia is the largest *consonant* in the world.	continent	________
27. The winter *buzzard* dropped 20 inches of snow in town.	blizzard	________
28. King Arthur rules his kingdom with his beautiful queen.	*correct*	________
29. I like to eat my *beagles* with cream cheese.	bagels	________
30. Sam *thread*, "You must rinse your plates after dinner."	said	________
31. The horse *bugged* the cowboy right off the saddle.	bucked	________
32. You should sit over *ear*, Jake	here	________
33. I jumped into the deep end of the *slimming* pool .	swimming	________
34. Emily won the third grade *spilling* bee with the word Wednesday.	spelling	________
35. The doctor listened to my heart and told me it sounded strong.	*correct*	________
36. Don't touch the flame or it will *born* your hand.	burn	________
37. Go *instead* the house to get out of the cold.	inside	________

38. The sun was so *brought* that I had to put on glasses.	bright	________
39. The detective had to *finger* out the case of the stolen lunch.	figure	________
40. By winning the fifth *gain,* our team earned the tournament trophy.	game	________
41. My mom always makes a *lift* before she goes to the grocery store.	list	________
42. I put on my socks and *tried* my shoes.	tied	________
43. Everyone was invited to the party *expect* her.	except	________
44. The teacher said, “Don’t forget to *cost* your “t’s” and dot your “i’s”	cross	________
45. Sara could not tell the *distance* between the colors red and pink.	difference	________
46. The white *spoke* billowed out from the chimney.	smoke	________
47. I think that the state of Hawaii is made up of more than one island.	*correct*	________