Factors Underlying Comprehension of Ambiguous Sentences in Children with Normal Hearing and Cochlear Implants

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Spring 2018

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Abstract

Problem Statement: Children with cochlear implants (CIs) receive a degraded auditory signal, which can negatively affect their language acquisition. It has been demonstrated that with early implantation and appropriate intervention, children with CIs can acquire similar language as their normal hearing peers. However, are children with CIs acquiring the same "depth" of language as children with normal hearing (NH), meaning is their knowledge about linguistic structures as rich? In order to measure their depth of language, children with CIs and NH were presented with a test on ambiguous sentences. These sentences can have two meanings, with ambiguity based on either double meanings of a word or complexity of syntax. Outcomes on this test could offer answers regarding whether children with CIs have the same depth of vocabulary and knowledge of syntax as their peers with NH. Furthermore, by including standardized tests of vocabulary and syntax we were able to explore whether these simpler tasks adequately assess depth of language knowledge.

Participants: Children participating in a longitudinal speech development study were used. Half of the children had NH and the other half used CIs due to severe-to-profound hearing loss. These children were all similar in age and socioeconomic status.

Methods: The data was gathered from these participants when they were approximately 14 years old. Measures of simple vocabulary, simple syntax, and ambiguous sentence comprehension were collected. The ambiguous sentence scores were further divided into ones associated with multiple word meanings and ones associated with complex syntax. The differences in outcomes between children with CIs and NH were examined, for children with NH and children with CIs separately. Partial correlation coefficients were computed to see if scores for multiple word meanings were related to vocabulary knowledge and if scores for complex syntax were related to syntactic knowledge.

Results: Children with CIs scored more poorly than children with NH on the ambiguous sentence task overall, but when scores for multiple meanings and complex syntax were examined independently differences were “marginally significant.” Children with CIs also scored more poorly on the simple vocabulary measure, but not on the simple syntax measure. For children with NH, partial correlations were as expected: simple vocabulary explained the largest proportion of variance in scores for multiple meaning items, and simple syntax explained the largest proportion of variance in scores for complex syntax items. However, for children with CIs the relationships were reversed.

Conclusion: For children with CIs, sentences that are difficult to interpret present special challenges, and these children appear poor at effectively using vocabulary and syntactic knowledge to resolve the ambiguity. This problem presents clear opportunities for intervention with these children.

Introduction

In order to communicate with spoken language before cochlear implants (CIs) were available, children with severe-to-profound hearing loss received auditory-oral education. Through this method, children with hearing loss relied on amplification from residual hearing through hearing aids. When this amplified residual hearing was combined with lip reading, these children were able to understand spoken language to a limited extent. They were also taught how to speak and listen as well as possible, using tedious methods of instruction that combined auditory, visual, and tactile feedback. However, even with the best intervention of the time these children could not be mainstreamed into classrooms and schools with normal hearing children because their spoken language skills were just not adequate. The invention of CIs gave children the ability to use listening and spoken language in a more advanced way that was not available before. Now, with identification of hearing loss shortly after birth, cochlear implants, and intensive intervention, many of these children are succeeding in mainstream educational settings. But are their language skills as good as they would be if they did not have hearing loss? In this study, we examined some especially sophisticated language skills to see if children with hearing loss who are the recipients of cochlear implants and high-quality early intervention are performing as well as their peers with normal hearing. We also ask if traditional language assessment instruments are sufficiently sensitive to detect any lack of sophisticated language abilities that children with CIs may exhibit.

Review of the Literature

History of CIs

The first notion of the CI started in 1800 when Alessandro Volta used an electrical current to stimulate his inner ear (Hainarosie, Zainea, & Hainarosie, 2014). From there, multiple experiments found that any kind of electrical stimulation in the inner ear caused audiological perception. House and Doyle first implanted a single channel device in 1972, but it was not until 1984 that the FDA approved a multichannel device, made by the Cochlear Company, similar to the CI we see today (Hainarosie et al., 2014). CIs were made to offer auditory nerve stimulation to patients with severe-to-profound hearing loss and have since been used and researched worldwide.

Universal Newborn Hearing Screening

With the CI and other hearing assistive technology advances in our society, the use of universal newborn hearing screening (UNHS) and early intervention are becoming increasingly widespread. UNHS ensures early intervention techniques are used with children with hearing loss by testing their hearing as early as possible. The idea of UNHS started in 1993 when the National Institutes of Health held a Consensus Development Conference. Discussion at this conference included the endorsement of screening the hearing of all newborns before they left the hospital. This notion received enough support for Congress to pass the Newborn and Infant Hearing Screening and Intervention Act of 1999. This act funded state-wide newborn and infant hearing screening programs to mitigate the amount of pediatric hearing loss that goes untreated.

The American Speech-Language-Hearing Association promotes standard universal procedures to be used in the UNHS, but the procedures vary by hospital. The timing of the screening must be completed soon after birth and at least before one month of age. The screening can be completed in a quiet room; a sound booth is not needed. Auditory brainstem response (ABR) and otoacoustic emissions are two measures that work well for UNHS. To detect ABR activity, stimuli are presented through earphones into each ear. Surface electrodes attached to the patient's head can detect a response from the auditory neural pathway. A successful response from the auditory brainstem validates that the afferent neurons in the inner ear are functioning. A failed screening would be a lack of response from the auditory neural pathway once the stimulus is presented.

Otoacoustic emissions (OAE) are another noninvasive measure that can be used with newborns. This measure tests outer hair cell and cochlear function and can detect when there is an outer or middle ear dysfunction. A probe, containing a microphone and a speaker, is inserted into the ear canal and the speaker presents pure tones at different frequencies. With normal hearing, this pure tone will create an emission that does not travel up the nerve, but comes back through the infant's ear canal. The microphone records the emissions, and portrays results on a screen for audiologists to review. A failed screening would show that no emissions were produced when a stimulus is presented in the infant's ear. Hospitals may choose to use either ABR or OAE measures or both, if needed.

Since the passing of the Newborn and Infant Hearing Screening and Intervention Act in 1999, there has been extensive research done to support the practice. The initial idea behind UNHS was to detect hearing loss in children in order to start treatment as early as possible. Experts believed that by starting treatment before three months of age, children with hearing loss would be able to still develop language comparably to their peers. Research found that the timing matters significantly due to the critical period during which a child is sensitive to language learning. Without hearing, learning language during this critical period is almost impossible. Friedmann and Rusou (2015) explained the significance of this critical period and how a child with a hearing loss is hampered in the acquisition of language skills. Friedmann and Rusou reviewed studies of children who missed their critical period for language due to living in isolation or through hearing impairments. They found that without language input during the first year of life, a child was not be able to develop normal syntax. These risks make it crucial to diagnose and treat hearing loss as soon as possible after birth. These results support the idea of Early Intervention, the purpose of UNHS.

Early Intervention

Early Hearing Detection and Intervention (EDHI) guidelines consist of a hearing screening within one month of age, a diagnosis by three months of age, and then an intervention plan that starts by six months of age (Yoshinaga et al. 2017). Research supports the idea that early intervention allows children with hearing loss to develop language at a much faster rate and to a higher level than those children who are treated later. Kennedy et al. (2006) performed a study in which 120 children with bilateral permanent hearing loss were tested on their language and speech skills. They found that the children who had received a hearing screening and intervention before nine months of age had higher language skills in mid-childhood than children who did not receive a hearing screening and consequently did not have their hearing loss confirmed before nine months of age. This study supports the findings of Freidman and Rusuo that language input during the first year of life is beneficial to supporting a higher level of ultimate language proficiency.

While there have been studies that support UNHS and early intervention on a small scale, researchers remained skeptical regarding the benefits. Ching and colleagues (2017) performed a large study that analyzed 350 children with permanent hearing loss and various ages of implantation. Ching used multiple regression analyses to measure the effect of age of implantation on language outcomes at five years of age. This study found that there was a significant difference in language outcomes based on age of implantation—the earlier the implantation, the better the language outcomes. Ching also found that the benefit of early intervention was greater for those who had greater hearing loss. This study supports the motions made by the American Speech-Language-Hearing Association to continue funding UNHS and early intervention in order to promote language outcomes in children with permanent hearing loss.

Other variables exist that have effects on language outcomes in children with permanent hearing loss. Yoshinaga-Itano et al. (2017) performed a cross-sectional study on 448 children with bilateral hearing loss that analyzed various demographic factors to see which predicted better vocabulary outcomes. This study found six variables that accounted for 41% of the variance in vocabulary outcomes: whether the EDHI guidelines were followed, age, degree of hearing loss, whether parents were deaf, and maternal education. Specifically, children who met EDHI guidelines, were younger in age, had mild-to-moderate hearing loss, had parents who were deaf, or had mothers with a higher education level all had significantly greater language outcomes. This study supported the EDHI principles of early detection and intervention by demonstrating their value in later language outcomes, while also identifying other demographics that have an effect. Yoshinaga-Itano found other factors that SLPs and audiologists should look out for when providing treatment. Extra assistance should be provided to mothers with lower levels of education, patients who have additional disabilities, or parents without any experience with deafness or hearing loss.

Willstedt et al 2004 performed an additional study that supported the idea that there are factors besides age of implantation that affect language outcomes. This study focused on three different factors (time factors, complex working memory, and phonological short term memory) and their effect on lexical and grammatical development. Fifteen children with at least 18 months of CI use were the subjects in this study. The results showed that of the time factors, age of implantation correlated the most with novel word learning and grammar. However, the percentage of vowels correctly produced in non-word repetitions had a higher correlation for novel word learning and grammar than age of implantation. This study showed that while age of implantation does have an effect on word learning, other factors play roles too. This study shows that SLPs and audiologist should also focus on speech perception and recognition when working on language development.

Language Acquisition

Fast mapping, retention, and extension best define the word learning process. Fast mapping is the ability to link a word to a referent after minimal exposures. Retention is the capacity to perform the same action but once time has passed since the exposure. Extension is the ability to link a referent to other examples similar to that referent (Walker and McGregor 2013). These three skills work together for a child to learn more words and create a larger vocabulary. The vocabulary works along with syntax and grammar to form language. In general, Geers and colleagues found that children with CIs perform one standard deviation lower on most language outcomes than their normal hearing peers. Geers et al. measured the language outcomes of 135 children with CIs. On measures of receptive vocabulary, expressive vocabulary, verbal intelligence, and receptive language, children with CIs had age appropriate scores around 50% of the time, with expressive vocabulary being the highest at 58%. The only language measure far lower than 50% was expressive language, which fell at 39%. These statistics explain that there are some language measures that children with CIs are better at than others on average, which can offer instruction for educators of deaf children.

Vocabulary Differences

Recent literature shows a positive relationship between both early intervention and the age of CIs and multiple parts of a child's language (Blamey et al., 2001, Walker and McGregor 2013). The real question, however, is if CIs are able to put a child on par with their age-matched peers. One study compared speech perception, production, and language measures between children with CIs and hearing aids (Blamey et al., 2001). The goal of this longitudinal study was to see if the students would achieve age-appropriate language skills over time. Through tests that quantified their speech and language skills, Blamey analyzed the subjects' progress over time to determine their predicted scores when they would be entering secondary school. He found that when children with hearing impairments enter secondary school at the age of 12, their language skills could be delayed by about 4 to 5 years. This delay can only be mitigated by effective and specialized therapy. Walker and McGregor (2013) aimed to compare the word learning process between children with CIs and their age-matched and vocabulary-matched peers through measures of fast mapping, retention, and extension. After using nonsense monosyllabic words to test the three groups' skills, the researchers found that children with CIs encounter difficulty with the word learning process, especially during retention. Children with CIs performed significantly worse than their age-matched peers, but performed similarly to their younger, vocabulary-matched peers. These results support the conclusion that despite early intervention, children with CIs still do not perform at the same language level as their age-matched peers.

In another comparison study, researchers tested the word learning performance between children with CIs and children with normal hearing (Lund and Schuele et al., 2017). The investigators gave both groups synchronous and asynchronous cues to learn words. In the synchronous condition, the examiner would pick up an object while naming it. In the asynchronous condition, the examiner would name the object and then pick it up two seconds after. The child was then asked to name the objects. They found that children with normal hearing used the synchronous cues to learn words better, while the asynchronous cues did not help word learning. For the children with CIs, neither cue fostered word learning. Lund and Schuele proposed that this study offered insight to the difference between how children with normal hearing and those with CIs learn words. If children with CIs are unable to use techniques intended to ease the word learning process, they must have a harder time learning words in general than children with normal hearing.

Nittrouer and colleagues performed two studies to determine the best predictors of language outcomes in children with CIs. In the first study in 2012, Nittrouer et al. performed a longitudinal analysis of data from 50 children, who had CIs, hearing aids, or normal hearing. Between 12 and 48 months of age, researchers tested the children’s language and vocabulary skills at 6-month intervals. They tested six different predictor variables to see which ones predicted the language outcomes at a kindergarten level. Results showed that the most accurate predictor variable was language comprehension and the cognitive processing of language. This shows that the gap between language outcomes for children with hearing loss and those with normal hearing is most likely due to language comprehension. SLPs and audiologists can use this information to help diminish the gap in language learning between children with normal hearing and those with CIs. In 2016, Nittrouer performed another study with 100 second graders; 51 of the subjects used CIs and 49 had normal hearing. This study analyzed data from ten measures of phonological and morphological skills. It showed that children with CIs were delayed in language acquisition compared to children with normal hearing, especially in phonological skills. These results offer SLPs and audiologists the idea to focus on phonological development when providing treatment to obtain the best language outcomes.

Sentence Comprehension

The area of syntactic development and comprehension is also of interest when comparing children with CIs and normal hearing. Faes and colleagues (2015) longitudinally studied nine children with cochlear implants to see how their syntax development compared to a control group of ten children with normal hearing. They measured syntactic development by measuring the children's Mean Length of Utterance (MLU). They found that children with CIs are delayed up to age 6 years on measures of MLU, however they do catch up to their normal hearing peers by age 7 years. This study shows that there is a difference in syntactic development between children with CIs and normal hearing, however it is temporary. For sentence comprehension, Gallego and colleagues (2016) studied the reading comprehension of children with early and late cochlear implantation and their normal hearing peers. The children were presented with a short passage and afterwards asked questions regarding the story. The multiple choice questions had three semantically related answers, all related to the story, and one syntactically related answer, which would fit with the question but is not related to the story and therefore incorrect. The overall results were that early-CI children performed better than late-CI children, and that the results from early-CI children were very similar to the normal hearing group. Both the early-CI and normal hearing groups were able to use the syntactic cues to answer the questions correctly, while the late-CI group made inconsistent errors without using any strategies. Both of these studies show that with early implantation, children with CIs can have syntactic development and comprehension similar to their normal hearing peers after childhood.

Ambiguous Sentences

While previous research shows that children with CIs have adequate vocabulary skills, some deficits clearly remain. One lingering question is when children with CIs do know a word, if they know all the different definitions, such as multiple meanings if they exist. These meanings are referred to as a depth of vocabulary. A way to test a children's depth of vocabulary is through ambiguous sentences. A child is presented with one sentence and must use their vocabulary knowledge to tell the tester how that sentence can have two meanings without changing any words in the sentence. The sentence can be ambiguous based on either multiple meanings of one word or through syntactic structure that can convey more than one meaning. Knowledge of the double meanings of words shows that the child has a strong association with the vocabulary in question.

There has not been sufficient research on the depth of language between children with NH and CIs to see if CIs allow the same facility of language for children with severe-to-profound hearing loss. This research aims to see if children with normal hearing and CIs have the same level of vocabulary and syntax and if simple measures of these skills are able to predict a deeper level of knowledge regarding each. Evidence from this study will hopefully give professionals in the field more information about the language capacity of children with CIs and how to alleviate a potential language gap for future generations.

Methods

Participants

The children who participated in this study are from a longitudinal study. In order to participate, children must have parents with normal hearing and no other handicaps. These children return to the University of Florida every other summer to test their speech and language skills. The data used in this report are from when the participants were in 8th grade and approximately 14 years old. The test group consisted of 28 children with CIs, while the control group consisted of 28 children with NH. The children with CIs were all born deaf and have severe-to-profound hearing loss. The median age of identification is 2 months while the median age of implantation is 14 months of age. To test for the participants' socioeconomic status, a two-factor scale was used, which analyzed the household primary income earner's occupational status and highest education level. Both of these aspects are ranked on a scale from 1-8 and then multiplied, giving the range of possible scores from 1 to 64. A score of 30 would represent a primary income earner as having a college bachelor's degree and a job corresponding to that education level. The mean for these groups are 35.57 for children with NH and 32.57 for children with CIs. With standard deviations (SDs) of 13.14 and 10.70 respectively, the difference is not statistically significant. The IQs of these participants were also tested to make sure this factor would not affect their speech and language outcomes. Through the Leiter International Performance Scale-Revised (Roid & Miller, 2002), children were given four subtests nonverbally to get a "brief IQ". These subtests tested the children's figure-ground perception, form completion, sequencing capabilities, and repeated patterns. The mean IQ for the children with NH is 106.89, with a SD of 14.56, while the mean for the children with CIs is 104.82 with a SD of 12.47. These numbers show that the IQs were not statistically different among the participants.

Equipment

All testing was done in sound booths. Three tasks involving vocabulary and syntax were administered. For the vocabulary task, children were shown pictures of items and asked to say what it was. For the other two tasks, test materials consisted of sentences that are normally presented by a clinician. In this case, these sentences were audio-video recorded for presentations so that all children saw the same samples. These sentences were presented through a computer with a Creative Labs Soundblaster soundcard, a Samson C-Que 8 mixer, and a Roland MA-12C powered speaker. The speaker was placed one meter in front of the child at zero degrees azimuth. Custom-written software controlled presentation of the stimuli, and recording of responses.

Responses to testing were video-audio recorded using a SONY HDR-XR550V video recorder. Children wore SONY FM transmitters to ensure good sound quality on the recordings. At a later time, an independent experimenter checked all scoring done at the time of testing.

Procedures

The Institutional Review Board at the University of Florida approved all procedures. All auditory stimuli were presented at 68 dB sound pressure level. Children came to the laboratory for two consecutive days. 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.

Simple measures of vocabulary and syntax were first tested to see the participants' skill level regarding each. The test used for the simple measure of vocabulary is the Expressive One-Word Picture Vocabulary Test (EOWPVT – 4; Martin & Brownell, 2011). This test requires the use of an easel with a series of pictures. In a specific order, participants are asked to identify the item or action that the picture depicts. This is an accurate test of the children's expressive vocabulary. For sentence comprehension, the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999) was administered. In this task, participants were presented with two sentences. These sentences were similar in topic, but may or may not have had the same meaning. This task tested the participant's sentence comprehension by seeing if they could understand when the sentences had the same or different meanings. For these two tasks, rules for when to discontinue testing were followed.

The ambiguous sentences task was also administered through the CASL. These sentences were ambiguous based on multiple meanings of one word or syntax. An example of an ambiguous sentence based on multiple meanings is "The cold kept him from going to the party." The participant would then be expected to say that the weather could be cold or the speaker could have a cold. An example of an ambiguous sentence based on syntax is "Hiking trails can be boring." The participants would then have to clarify the ambiguity by saying that the action of hiking could be boring or the trails themselves could be boring. Some sentences could have more than two meanings, but the participant was only required to give two. For this task, participants were given all test items, to ensure that they had complete opportunities to respond to both kinds of ambiguity.

The videotapes of all of these tests were watched by two scorers to ensure accuracy of scores. The two scorers worked independently, and then their scores were compared. Although these independent scores were used to compute reliability, the two scorers worked together later to reach agreement on any items for any children where they gave different scores. Once scores were collected for all the tests, partial correlation coefficients were calculated to see if simple measures of vocabulary and syntax predicted any of the variance in the two types of ambiguous sentences. Partial correlation is the measure of the correlation between two variables in a linear relationship, controlling for the effect of other variables. Significant levels of .05 were used.

Results

The dependent measures were examined to confirm that the results were normally distributed and met the standards for homogeneity of variance. All of these measures were normally distributed without any skewness or kurtosis so they were used for further testing. The means of the standard scores of the three tasks are presented in Figure 1. Table 1 shows the results of the *t* tests between the NH and CI groups for the three main tasks. P-values are bolded to show significance at less than 0.05.

Figure 1. *Standard scores of the tasks shown for both groups with standard error of the means.*

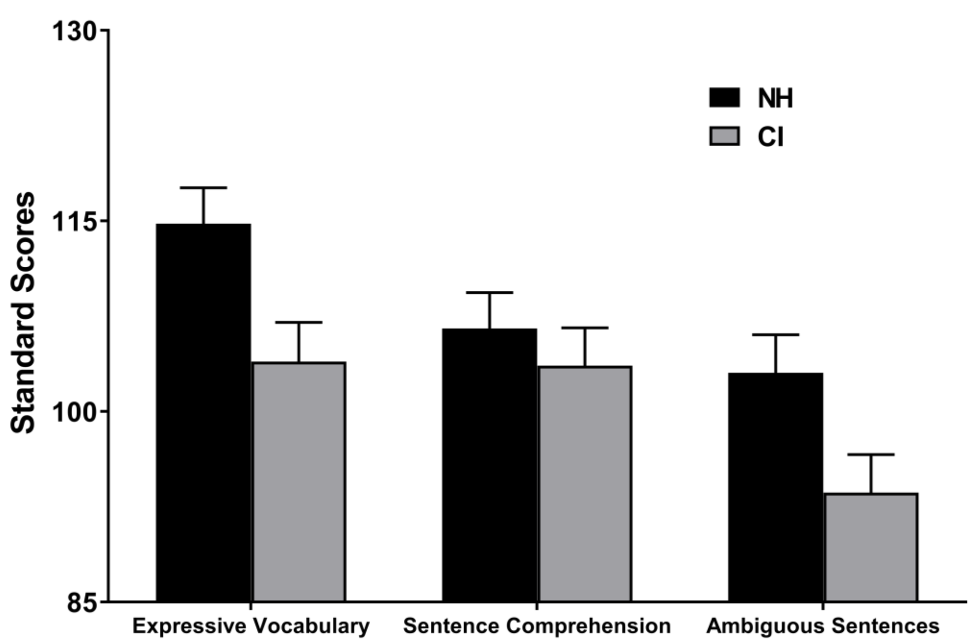
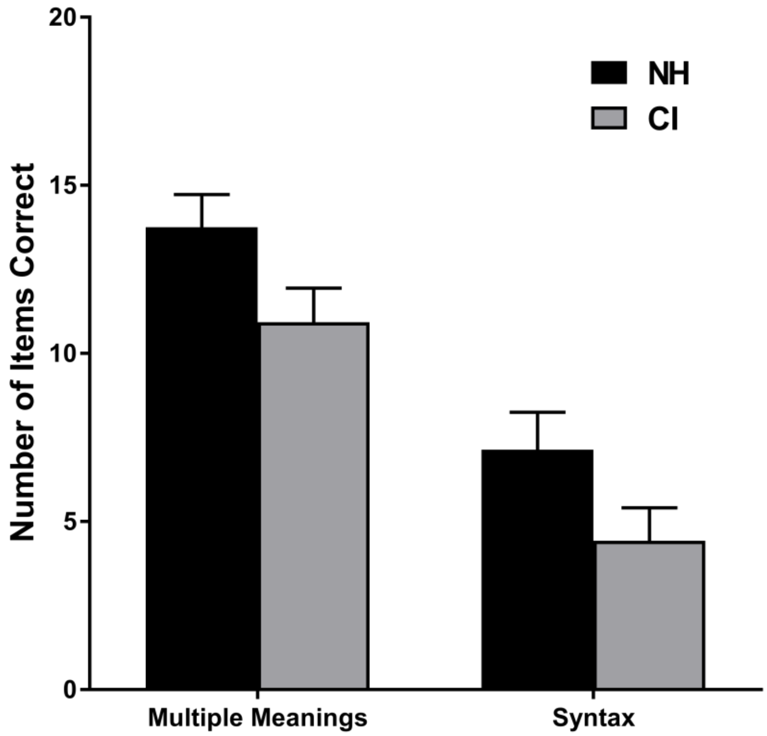


Table 1.	***t***	***p***	**Cohen's d**
Expressive Vocabulary	2.59	**.012**	**.**69
Sentence Comprehension	.732	.467	.20
Ambiguous Sentences	2.22	**.031**	.59

For the task of expressive vocabulary, it is clear that the children with NH performed significantly better than the children with CIs. The mean of the standard scores for children with CIs was 104, while the children with NH performed better, on average, with standard scores closer to 115. For the task of sentence comprehension, the groups performed more similarly. With a mean of 107 for the NH group and 104 for the CI group, the results are not statistically different. These test results show that the two groups have similar levels of sentence comprehension. The ambiguous sentences task showed greater differences between the two groups. The children with NH performed around the 50th percentile compared to the general population, with an average standard score of 103 while the children with CIs performed worse with an average standard score of 94. Cohen's d was calculated to determine the standardized difference between the two groups regarding these three tasks. For the expressive vocabulary and ambiguous sentences tasks, the Cohen's ds show that there is a meaningful effect size between these two groups. For the sentence comprehension task, the Cohen's d shows a small effect size. These ambiguous sentences scores are statistically different and prompt further investigation as to the reasons for the different performance.

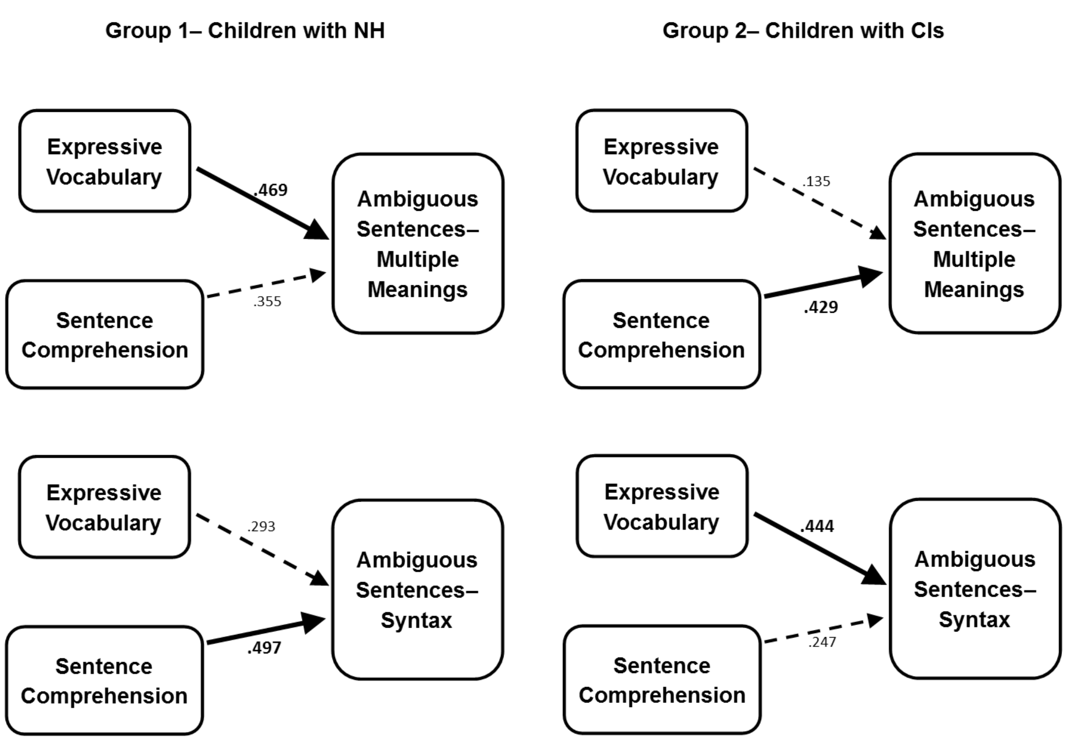
Figure 2. *The average numbers of items correct for both types of ambiguous sentence questions are presented for each group with the standard error of the means.*



The ambiguous sentences task was then examined based on the two types of questions- word multiple meaning ambiguity or syntactic ambiguity. The results in Figure 2 show that both groups performed worse on the syntactically ambiguous items than on the multiple meaning ambiguous items. Also, the children with CIs performed significantly worse on both tasks than the children with NH. The average number of correct responses out of the 23 total multiple meaning items was 14 items correct for the NH group, and was lower for the CI group at 11 items correct. For syntactically ambiguous items, the average number correct was much lower for both groups, with a mean of 7 items correct for children with NH and 4 items correct for children with CIs out of 20 total possible items.

The measures of expressive vocabulary and sentence comprehension were then examined to see the correlations between these variables and the results on the types of ambiguous sentences tasks. Both vocabulary and syntactic knowledge would be expected to contribute to the children's understanding of the ambiguous sentences. Our goal was to see which contributed the most to each kind of item. To do that, partial correlation coefficients were computed, controlling for each simple measure, while examining the correlations of the other with the complex measure of interest. These were measured separately to see if the children used their skills of vocabulary or sentence comprehension to help them distinguish the ambiguity of the two types of items, multiple meaning and complex syntax. Figure 3 shows the partial correlation coefficients between the variables.

Figure 3. *Results of partial correlation coefficients, looking at relationships between simple measures of language and complex measures of language.*



The correlations show distinctive results for the two groups. For the normal hearing group, the results show that the relationship between expressive vocabulary and the ambiguous sentences with multiple meanings was correlated positively with a partial correlation coefficient of .469. Similarly, sentence comprehension was significantly and positively correlated with the ambiguous sentences task based on syntax with a partial correlation coefficient of .497. The inverse relationships of these variables were not significant for the NH group. For the CI group, however, the results were reversed. The variable that correlated the most with the multiple meanings ambiguous sentence task was sentence comprehension, with a partial correlation coefficient of .429. Also, the correlation between expressive vocabulary and the syntax ambiguous sentences task was more strongly correlated than their sentence comprehension, with a partial correlation coefficient of .444.

Discussion

The results in this research have offered insight as to the future of standard measures of language and how they are used for intervention. Looking at just the standard scores of the expressive vocabulary task, one could argue that these children with CIs have adequate vocabulary for their age. However, that is not the case. All of these children were measured on their SES and on average, had a high enough score that meant that at least one parent has a 4-year college degree. With one parent with a college degree, a child should be expected to be at one standard deviation above the population norm in terms of vocabulary, which is exemplified by the children with normal hearing. While these children with CIs are performing at the population norm, we can safely assume that they would be performing at a higher level if they did not have any hearing impairments. Also, looking at the overall standard scores for the ambiguous sentence task, it is clear that the children with CIs do not have the same complex language skills as their normal hearing peers. These 8th graders are showing severe delays in their knowledge of complex language, which is a problem that continued intervention and therapy could mitigate. These results distinctly show that there is continuous language learning, even after the critical period of language, and that intervention needs to continue throughout a child's school career.

The crossed-lag figure shows definite differences between the NH and CI groups. The NH group performed as expected. Their expressive vocabulary skills were responsible for most of the variance in their ambiguous sentences based on multiple meanings results, while their syntactic knowledge accounted for most of the variance in the ambiguous sentences based on syntax. The exact opposite was observed for the children with CIs. The variance in their ambiguous sentences based on multiples meanings was mostly due to their syntactic skills while the variance in the syntactically ambiguous tasks was accounted for by their vocabulary skills. While this is unexpected, there is a clear rational behind these results. The CASL test makers develop these ambiguous sentence tasks making sure that the specific ambiguous skill, vocabulary or syntax, is the one being tested. To do this, they make sure that the other skill is at a level that the 8th grade children would be sure to understand. With the example of the syntactically ambiguous task, "Hiking trails can be boring", the test makers made sure that the vocabulary in this task was simple. The opposite was done for the ambiguous sentences based on multiple meanings. In the example, "The cold kept him from going to the party", the syntax was kept simple so that the focus is on the vocabulary in the sentence. As previously stated, the children with cochlear implants performed very poorly on these tasks. The children with CIs use their vocabulary skills for the syntactically ambiguous items, and vice versa, because it is all they are able to grasp in the task. They see the simple vocabulary or syntax, and use that to try to decipher the ambiguity.

Overall, this study was done to explore the depth of language in children with NH and CIs. It is clear that children with NH have greater knowledge of complex language than children with CIs even in 8th grade, when most children are not still in therapy. It is crucial that children with CIs continue language therapy, as language learning continues into secondary education. Not only was the depth of language assessed in this study, but also the means and uses of standardized testing. These results show that standardized test results of a simple measure of language will not always correlate with results of the same measure on a deeper level. Speech-language pathologists should still perform a standardized test on complex language, such as the ambiguous sentences task, in order to gain a clear understanding of a child's full language capacity. Measures of simple language may seem normal for some children, while the results on a deeper level of language test can indicate a problem.

Acknowledgements

This work was supported by Grants R01 DC006237 and R01 DC015992 from the National Institute on Deafness and Other Communication Disorders, the National Institutes of Health.

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