CHAPTER TWENTY

Measuring Auditory Performance of Pediatric Cochlear Implant Users: What Can Be Learned for Children who Use Hearing Instruments?

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Introduction

Demonstration of successful outcomes from use of a sensory device by individuals with hearing loss depends to a large extent on quantifiable improvements in auditory performance. Quantifiable improvements are typically characterized by speech perception outcomes, which involve speech awareness/detection, reception, discrimination, identification or recognition of speech-type materials (e.g., phonemes, syllables, words or sentences). Although performance outcomes are most often conceptualized in terms of percent-correct scores, speech perception outcomes may also be represented by dB level (as used in the speech reception threshold or when testing in background noise), reaction time, and other such metrics used to characterize the data. Improvements with the sensory device can be demonstrated by comparing performance pre- and post device activation, or by tracking performance over time with the device.

With specific reference to children who have hearing loss, there are several reasons why assessment of speech perception can be valuable as a means of documenting success (or lack thereof) with an auditory sensory device. Speech perception results may be of some use in determining whether a very young child should continue to use hearing aids or be considered for a cochlear implant. After fitting of the device, follow-up assessments can be beneficial for tracking rate of improvement. Lastly, speech perception data in combination with speech-language outcomes and other indices of development are essential for establishing guidelines for (re)habilitation.

Characterization of communication outcomes, with emphasis on speech perception, has become one of the hallmarks of pediatric cochlear implantation. Originating with the manufacturer-sponsored clinical trials required by the U.S. Food and Drug Administration (FDA) and progressing to independent studies funded by the National Institutes of Health (NIH), long-standing pediatric implant centers have become accustomed to conducting follow-up assessment protocols as part of their standard clinical practice. It is far from evident that this model has been extended to children who use hearing aids. As a consequence, parents of children with hearing aids may not feel as committed to a long-standing partnership with their audiological center as do parents of children with cochlear implants; such a commitment is often a requirement of the pediatric implant program.

Speech perception assessment in children with cochlear implants forms the focus of this chapter from both a clinical and research perspective. Considerations in measuring speech perception in the pediatric hearing-impaired population provide important background information. The evolving nature of auditory evaluation in cochlear implant candidates and recipients is discussed, including development of speech perception tests and test batteries for adult and pediatric cochlear implant users. New directions in behavioral test development for infants and toddlers follow.

Considerations in Pediatric Speech Perception Assessment

Assessing speech perception in children with hearing loss is complicated because of the interaction be-

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tween age and degree of loss. Whereas speech perception skills mature with increasing age, such abilities decrease with increasing hearing loss (see Eisenberg 2007; Johnson, Eisenberg and Martinez 2010). Age effects may be reflected in the child's limited set of phonemic categories, articulation difficulties, a limited vocabulary, and an inability to use contextual information effectively. The state of the child during testing, such as attentiveness to the task, motivation, and mood, also affects test results.

Severity of hearing loss adversely affects speech perception by reducing the level of audibility and distorting temporal, intensity, and spectral cues. In a classic study by Boothroyd (1984), the relationship between degree of hearing loss and the perception of speech contrasts was investigated in 120 orally-trained adolescents with three-frequency, pure-tone average losses that ranged from 55 to 123 dB HL. The children with losses between 55 and 70 dB HL were shown to have access to all the speech contrasts that were assessed. Performance on consonant place was shown to be most susceptible to hearing loss, with scores decreasing to 50% by 75 dB HL. The order in which scores fell to 50% for the other contrasts were as follows: initial consonant continuance (85 dB HL), initial consonant voicing (90 dB HL), vowel place (100 dB HL), talker sex (105 dB HL), syllabic pattern (115 dB HL), and vowel height (beyond 115 dB HL).

The relationship between degree of hearing loss and speech perception abilities has become obscured to some extent with the availability of cochlear implants. This finding was recently reported by Sininger, Grimes and Christensen (2010). In their study, the association between unaided degree of hearing loss and speech perception outcomes was not found to be significant in a sample of children with unaided hearing loss ranging from mild to profound, but who were assessed with hearing aids or cochlear implants.

When assessing speech perception abilities in children with hearing loss, selection of the test instrument(s) should take into consideration the child's age (chronologic, developmental and language) and auditory processing skills. Requisite motor skills should be demonstrated in accordance with the response being asked of the child (e.g., head turn, manipulation of objects, picture pointing, or button pushing). Phonological and vocabulary skills are important when a verbal response is required for a word recognition test. Accordingly, a battery of tests offers the most practical solution to accommodate these individual differences. Speech perception test batteries for young children typically incorporate test measures that are closed- and open-set tasks. In closed-set tasks, a limited number of choices are available to the listener. In contrast, there are no predefined response alternatives in open-set tasks, resulting in an unlimited number of choices. Assessing speech understanding in the presence of speech competition or noise also expands the options used in speech perception testing - as does testing under multimodal conditions (auditory-only, visual-only, and auditory-visual).

Live – voice and recorded presentation of stimulus items are options to be considered when administering tests selected for the battery. Live-voice delivery affords the clinician greater efficiency and flexibility than the use of recorded stimuli, particularly when working with very young children. However, variability due to different testers makes it difficult to compare results obtained with live voice presentation. Use of recorded stimuli provides for greater consistency in signal delivery across test sessions and test centers. Notably, there is now interest in using recorded measures with multiple talkers within one test to increase stimulus variability (Kirk, French and Choi 2009). Understanding these different considerations in assessment gives the necessary background information for the following section that addresses the assessment of children with cochlear implants.

Tracking Speech Perception Outcomes in Children with Cochlear Implants

Assessment of speech perception has always played an important role in the evolution of cochlear implant research and clinical practice. Almost from the beginning new tests were being developed because assessment on standard clinical measures yielded floor effects. In understanding the development of speech perception assessment in children with cochlear implants, one must look back at the early clinical trials with adults, both with single- and multichannel devices.

Clinical Trials with Adults

Single-Channel Cochlear Implants

With the introduction of cochlear implants for adults, pilot studies were initiated to better understand the promise of this new technology and to establish candidacy criteria. The team of clinical researchers investi-

gating the single-channel device created three closed-set tests to evaluate listeners' identification of environmental sounds, spondees, and rhyming words (House 1976; House, Berliner and Eisenberg 1979). Around this same time (1980), the FDA published regulations requiring a clinical trial be carried out on medical devices to determine efficacy before marketing approval would be conferred. For the FDA clinical trials with the single-channel implant, the environmental sounds tests and a new measure developed by Erber and Alencewicz (1976), the Monosyllable, Trochee, and Spondee (MTS) test, became the two primary speech perception measures selected for the trial. The MTS test assesses the listener's ability to identify the correct word and/or stress pattern from a closed set of words that differ in number of syllables and stress patterns. For a point of reference, adults with the single-channel implant achieved an average score of 35% word identification on this closed-set test (Thielemeir, Brimacombe and Eisenberg 1982). The MTS test has come to play an important role in future test development for children.

Multichannel Cochlear Implants

When experimentation with multichannel cochlear implants was initiated in the 1970s at the University of California, San Francisco (Michelson and Schindler 1981), the clinical team began to compile a test battery for adults called the Minimal Auditory Capabilities (MAC) Battery (Owens, Kessler, Telleen and Schubert 1982; Owens, Kessler, Raggio and Schubert 1985). The MAC battery consisted of tests that progress from closed sets of environmental sounds, phonemes and words to open sets of words and sentences. Standard measures, such as the CID sentences (Davis and Silverman 1978) and NU6 words (Tillman and Carhart 1966), also were included in the battery. When the Nucleus cochlear implant, designed in Australia, became the first multichannel device to undergo FDA clinical trials, the MAC battery was selected for those trials. This battery was able to accommodate a wide range of auditory capabilities, but was time-consuming to administer and the quality of recordings was not optimal. As a result, the University of Iowa produced a new battery using laser disc technology (Tyler, Preece and Tye-Murray 1983) that incorporated some of the tests from the MAC battery.

One consistent finding in the field of cochlear implants has been the systematic improvement in speech perception scores with advancements in technology. Today, adults with postlingually acquired hearing loss achieve moderate to high levels of open-set speech recognition with the multichannel implant. The speech perception test battery has been substantially reduced to include primarily open-set words and sentences.

Clinical Trials with Children

Single-Channel Cochlear Implants

Pediatric cochlear implantation commenced in the United States when a 10-year-old child received a single-channel device in 1980 (Eisenberg and House 1982; Eisenberg, Berliner, Thielemeir, Kirk and Tiber 1983). FDA clinical trials were soon initiated at select co-investigator sites around the United States to determine device efficacy in children ages 2 through 18 years (Berliner, Eisenberg and House 1985). The average age of children participating in those first trials was approximately 8 years, and more than half communicated by sign language. The two primary speech perception tests selected for those trials were the Test of Auditory Comprehension (TAC, Los Angeles County Schools 1980) and the Discrimination After Training (DAT) test (Thielemeir, Tonokawa, Peterson and Eisenberg 1985). The TAC evaluates auditory comprehension of environmental sounds and speech in ten subtests that increase in difficulty. The subtests range from linguistic versus nonlinguistic identification to the recalling of five details of a story with competing messages. On average, children with the single-channel implant were able to differentiate between linguistic versus human nonlinguistic versus environmental sounds (subtest 2) after three years of experience with the device.

The other test administered, the DAT, was adapted from the Erber and Alencewicz (1976) MTS test but segmented into smaller, more discriminable units. The DAT subtests range from subtest 1 (visual discrimination between a monosyllable and spondee) to subtest 12 (identification of four spondees). The DAT also incorporates a training paradigm within each subtest. Early results from clinical trials showed that, on average, children with the single-channel implant were able to discriminate between two spondees after three years experience with the device (Thielemeir et al. 1985). During these trials, a few children began to show limited open-set speech recognition (Berliner and Eisenberg 1987; Berliner, Tonokawa, Dye and House 1989). Open-set words and sentences from the Glendonald Auditory Screening Procedure (GASP, Erber 1982) were added to the speech perception test battery.

Multichannel Cochlear Implants

Pediatric clinical trials with multichannel cochlear implants began in 1986 with the Nucleus device (Staller 1991). Cochlear Corporation, the U.S. distributer of the Nucleus multichannel system, sponsored a two and a half day conference in Durango, Colorado to establish guidelines for their upcoming FDA clinical trials (Mecklenburg 1986). One outcome from that conference was the establishment of a "potential for success hierarchy" to help determine candidacy for an implant. It was evident from the single-channel trials that children having the highest potential for success with an implant were either postlingually deafened or prelingually deafened but using oral communication. Consequently, the first FDA investigation for a multichannel cochlear implant was fairly rigid in its candidacy criteria, requiring that children be oral communicators and enrolled in strong auditory/oral training programs. A variety of closed- and open-set measures were selected, including the DAT, MTS, subtests from the MAC and Iowa batteries, and the GASP (Staller, Beiter, Brimacombe, Mecklenburg and Arndt 1991; Staller, Dowell, Beiter and Brimacombe 1991). Eventually, the stringent selection criteria were relaxed and, despite the high variability in speech perception scores, it soon became evident that children with multichannel implants demonstrated significant improvements in speech perception when compared to pre-implant performance with hearing aids or vibrotactile devices; a small proportion of children achieved open-set speech recognition (Staller, Beiter, Brimacombe, Mecklenburg and Arndt 1991; Staller, Dowell, Beiter and Brimacombe 1991). The FDA approved the Nucleus multichannel cochlear implant for children in 1990. This was followed by FDA clinical trials by the other manufacturers of multichannel implants, Advanced Bionics and Med-El.

NIH-Funded Research

In addition to FDA clinical trials, there are investigations that are independent of manufacturer sponsorship. The large-scale studies have been those funded by the National Institutes of Health (NIH). Indiana University School of Medicine and the Central Institute for the Deaf (CID) were the first NIH-funded programs to conduct large-scale studies that focused on communication outcomes in children with cochlear implants. In the early studies, performance outcomes were systematically compared between multichannel implants, conventional hearing aids, vibrotactile devices and, in some cases, single-channel implants on measures of speech perception, speech production and language (Osberger et al. 1991; Geers and Moog 1994). With the first-generation devices, children with multichannel implants obtained significantly higher scores on a variety of measures compared to children with single-channel implants or vibrotactile devices. Performance was equivalent to that of children with hearing losses in the 100-dB HL range or poorer who used hearing aids (e.g., Osberger, Maso and Sam 1993). The first speech perception batteries used in these NIH-supported studies are briefly described below.

The CID test battery was hierarchical, beginning with detection and progressing from closed- to open-set speech recognition. Children were required to achieve a criterion score on one test before progressing to the next. In addition, the battery included auditory-only and auditory-visual measures (for a detailed listing, see Geers 1994). In particular, one test from this battery, the Early Speech Perception (ESP) Test (Moog and Geers 1990), has continued to enjoy widespread use because it can be administered to very young children (2 years of age and older). Similar to the DAT test used in the early clinical trials with single-channel implants, the ESP test also evolved from the original MTS test. The ESP progresses through four categories, ranging from awareness of sound and pattern perception to inconsistent and consistent word identification.

The investigative team at Indiana University School of Medicine compiled separate speech perception test batteries for preschool-age and school-age children. Many of the tests were developed by the team of researchers, particularly those tests designed for preschool-age children. More detailed descriptions of these tests will be found in Kirk, Diefendorf, Robbins and Pisoni (1997) and Kirk, French and Choi (2009). The Indiana School of Medicine test batteries differed from the CID batteries in that all tests within the specified battery would be attempted. In this way, no assumptions can be made about the progression of auditory skill development. The Lexical Neighborhood Test (LNT) and Multisyllabic Neighborhood Test (MLNT) are two of the more recent additions to the battery (Kirk, Pisoni and Osberger 1995). These two tests have brought a new dimension to speech perception testing by tapping into the underlying processes involved in the word recognition process. The tests are composed of "easy" and "hard" word lists. "Easy" words are those that are phonemically dissimilar from other words and of high frequency

usage. In contrast, "hard" words are those that are phonemically confusable with other words and are of low frequency use. These tests have become standard measures used both in clinical and research protocols.

The CDaCI Study

The Childhood Development after Cochlear Implantation (CDaCI) study was funded in 2002 by NIH to investigate the impact of early implantation on language development in a large group of early implanted children. Six centers from around the United States are tracking performance outcomes in 188 children with cochlear implants and 97 children with normal hearing in this longitudinal investigation. The CDaCI study supports a global view of childhood development by assessing language, speech recognition, psychosocial skills, and quality of life.

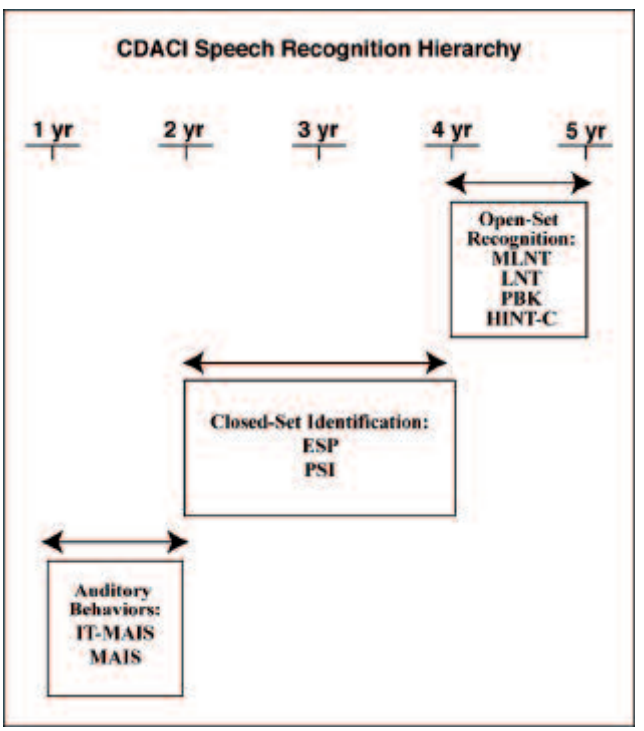

Figure 1. The CDaCI speech recognition test hierarchy. The tests listed are: the Meaningful Auditory Integration Scales (MAIS, Robbins, Renshaw and Berry 1991) and the Infant-Toddler version (Zimmerman-Phillips, Robbins and Osberger 2000); Early Speech Perception (ESP) Test (Moog and Geers 1990); Pediatric Speech Intelligibility (PSI) Test (Jerger and Jerger 1980); Lexical Neighborhood Test and Multisyllabic version (M/LNT) (Kirk et al. 1995); Phonetically Balanced Word Lists—Kindergarten (PBK; Haskins 1949); and, Hearing In Noise Test for Children (HINT-C; Gelnett, Sumida, Nilsson and Soli 1995).

A hierarchical approach was implemented for the speech recognition component of the CDaCI study (Eisenberg et al. 2006). Using this approach, the tests being administered are selected on the basis of the child's chronologic age and the age requirements of the test. In addition, the child must meet criteria on the preceding (easier) test before progressing to a more difficult test. The advantage of the hierarchical approach is that floor and ceiling effects are substantially reduced. Figure 1 lists the tests that comprise the hierarchy.

Because children are not typically assessed on each measure at the same test interval or by a specific age, analysis of individual and group data for the CDaCI speech recognition hierarchy becomes a challenge. In response, Wang et al. (2008) developed the Speech Recognition Index (SRI-Q), wherein each of the six tests administered in quiet is assigned a range of values within a 100-point range. The six tests are then stacked from easiest (MAIS, score range = 0-100) to most difficult (HINT-C, score range = 500-600), resulting in an index that spans 0 to 600. Individual data points on the SRI-Q represent the highest level achieved at a specific age and test interval. When analyzed across different test intervals, rate of growth can be determined for different variables (e.g., age at time of implant, preimplant residual hearing, etc.). Further development of this index is in progress to incorporate those tests administered with speech competition (PSI) and in background noise (HINT-C).

Speech recognition data for the CDaCI study have been analyzed through 36 months post-implant (Johnson et al. 2010). Figure 2 displays the SRI-Q data for preimplant baseline (left panel) and 36 months post-implant (right panel) as a function of the child's age. The tests comprising the hierarchy are shown on the right side of the figure, each corresponding to their location on the SRI-Q. The Index score of 300 marks the boundary between performance on closed-set (0-299) and open-set (300-600) tests. The gray circles and solid black line represent the data for the children with cochlear implants; the open squares and dashed black line represent the data for the children with normal hearing.

Floor effects predominated at baseline (left panel) for the children with implants, although a few were able to achieve closed-set and limited open-set word recognition with their hearing aids. The normal-hearing children achieved near ceiling on age-appropriate tests. The black dashed line indicates a much steeper rate of progression through the hierarchy for the normal-hearing children when compared to the rate of progression for the children to be implanted (solid black line).

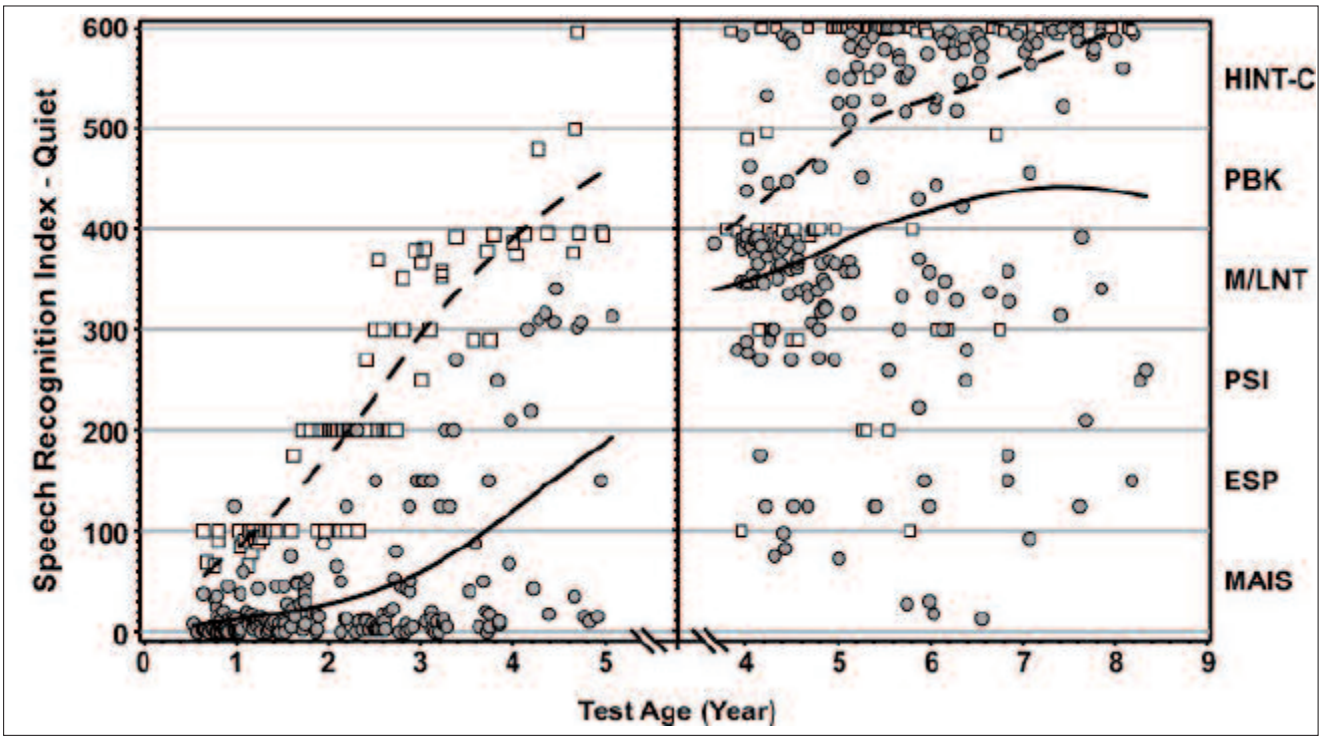

Figure 2. Baseline (left panel) and 36-month (right panel) CDaCI data as summarized on the Speech Recognition Index (SRI-Q) as a function of test age. Filled circles and solid black lines represent the implant data. Unfilled squares and dashed black lines represent the normal-hearing data.

The black filled circles and unbroken line on the right panel of figure 2 displays the 36-month data for both groups. Approximately 70% of the children with cochlear implants had progressed to open-set tests, but still lagged behind their normal-hearing peers. It is also notable that about 11% of children with implants had not progressed beyond pattern perception on the ESP by the time that they reached the 36-month test interval.

Growth curves are shown in Figure 3, illustrating the rate of progression through the hierarchy as computed from baseline to 36 months (including 6, 12 and 24 month test intervals). The solid black lines represent the mean trajectories for skill growth for children with implants. The dashed black line shows the mean rate of progression for children with normal hearing. The gray lines represent baseline, 6-, 12-, 24- and 36-month data as a function of age. The solid black lines indicate that children implanted below the age of 36 months had mean growth rates that roughly paralleled those of the normal hearing children. However, the extent of delay in skill acquisition was markedly better (i.e., less) between those implanted before the age of 18 months and those implanted between 18 and 36 months. Those children implanted after 36 months showed further delays in skill acquisition and at a slower rate of progression. These results not only provide insight into the effects of early im-

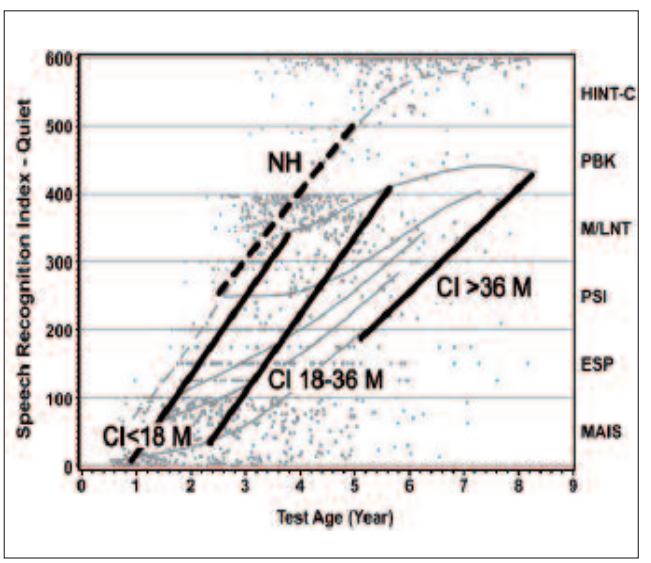

Figure 3. Mean trajectories for skill growth from baseline to 36 months for children with cochlear implants (solid black line) and children with normal hearing (dashed black line). Gray lines represent the data at each test interval (baseline, 6 months, 12 months, 24 months and 36 months) as a function of test age.

plantation on the auditory development of children, but also demonstrate the use of the SRI-Q for documenting rate of growth over time.

New Developments in Speech Perception Testing for Infants and Toddlers

Clinical assessment of speech perception in very young children has been difficult to accomplish because of a scarcity of age-appropriate measures. Parent questionnaires and rating scales are the primary tools available. In collaboration with Arthur Boothroyd, our laboratory has been in the process of developing a battery of behavioral measures that may be useful for tracking speech contrast perception in infants as they mature through early childhood. The different measures are designed to assess the perception of vowel height (VH) and place (VP), and consonant voicing (CV), continuance (CC), front place (CPf) and rear place (CPr) using vowel-consonant-vowel (VCV) stimuli. The use of these stimuli enables speech perception testing with minimal influence from linguistic cues. The measures are derived from the Speech Pattern Contrast Test (SPAC) concept (Boothroyd 1984). As described in Table 1, four tests have been developed for preschool-age children. They are VRASPAC, PLAYSPAC, OLIMSPAC, and VIDSPAC. Detailed information about these tests is available elsewhere (Eisenberg, Martinez and Boothroyd 2003, 2007; Martinez, Eisenberg, Boothroyd and Visser-Dumont 2008; Boothroyd, Eisenberg and Martinez 2010). Highlighted for this chapter is the VRASPAC, the test designed specifically for infants.

VRASPAC is adapted from the Visual Reinforcement Infant Speech Discrimination (VRISD) Test (Eiler, Wilson and Moore 1977). In this procedure, the infant is conditioned to respond to a phonetic change using a head-turn response. Figure 4 displays a diagram of VRASPAC. A standard VCV stimulus (oodoo) is presented repeatedly (e.g., "oodoo, oodoo, oodoo, oodoo, …") until the child habituates to this standard. The contrasting VCV stimulus is introduced (e.g., "aadaa, aadaa, aadaa …"), and the child is trained to turn toward a toy reinforcer. Testing follows training. The diagram illustrates a child seated on the caregiver's lap, turning his or her head toward the reinforcer and loudspeaker when the contrast is introduced. The head-turn responses are computed from probability theory, generating a percent-confidence value that the head – turn responses are not random. A high percent confidence suggests that the head turns are synchronized to the change in contrast within a specified time window.

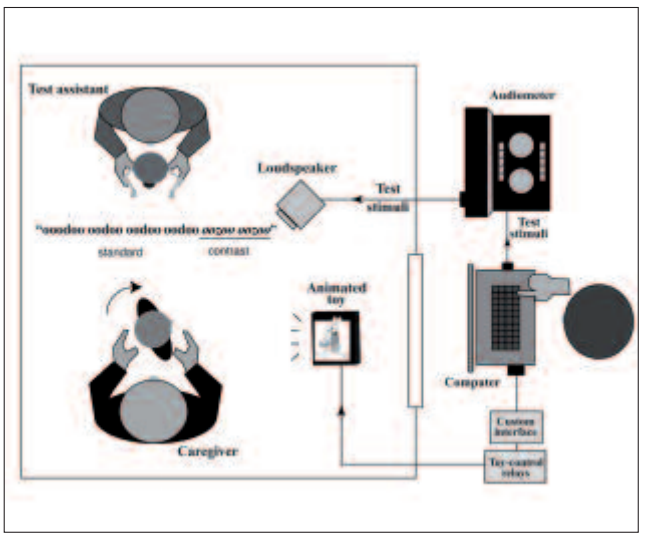

Figure 4. Diagram of the VRASPAC test set-up.

Figure 5 displays VRASPAC results on four 9-month-old infants with increasing degrees of hearing loss. Testing was conducted in the sound field with hearing aids activated. The results show confidence levels for each of the contrasts. The confidence scores are high across most contrasts for the two children with mild and moderate hearing loss. The scores are reduced for the children with severe and profound hearing loss, particularly for the child with 115 dB HL hearing loss. Notably, this pattern of results is similar to the group data reported by Boothroyd on adolescents in his 1984 publication.

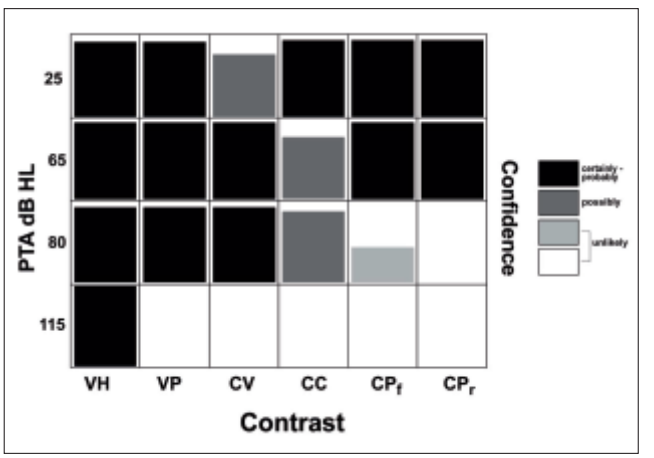

Figure 5. VRASPAC results on four infants with different degrees of hearing loss. The filled blocks represent percent-confidence scores for the speech contrasts being assessed: vowel height (VH), vowel place (VP), consonant voicing (CV), consonant continuance (CC), front consonant place (CPf), and rear consonant place (CPr).

Test	Child's Response	Age Range
VRASPAC *Visual Reinforcement Assessment of the Perception of Speech Pattern Contrasts*	Conditioned head-turn	~ 9-18 months
PLAYSPAC *Play Assessment of Speech Pattern Contrasts*	Conditioned play	3 years +
OLIMSPAC *On-Line Imitative Test of Speech Pattern Contrast Perception*	Imitation	3.5 years +
VIDSPAC *Video Speech Pattern Contrast Test*	Button-push	4-5 years

Table 1. Four tests designed to assess speech pattern contrast (SPAC) perception in young children with hearing loss.

Summary and Conclusions

Demonstration of successful outcomes with an auditory sensory device depends to a large extent on speech perception data. Throughout the past 30 years of pediatric cochlear implantation, major effort has been devoted to the development of new speech perception measures and test batteries. The need for such development was most important in the early years when there were few measures appropriate for children with profound hearing loss.

Speech recognition performance in children with cochlear implants has continued to improve with advances in technology (Geers, Brenner and Davidson 2003) and the implantation of younger children (Hammes et al. 2002; Kirk et al. 2002; Johnson, Eisenberg, Visser-Dumont et al. 2010). On average, children with cochlear implants have achieved scores on open-set tests that are comparable to scores of hearing aid users with severe hearing loss (Blamey et al. 2001; Boothroyd and Boothroyd-Turner 2002; Eisenberg, Kirk, Martinez, Ying and Miyamoto 2004). Important issues today concern the implantation of children younger than 12 months of age, the use of bilateral implants in young children, and candidacy of children with developmental delays or other debilitating handicaps. Speech perception assessment will continue to play an important role in defining performance outcomes in the pediatric implant population.

Considering that hearing loss is now being identified in newborns, there is an urgent clinical need for speech perception tests that track auditory performance in the developing child. Assessment of speech pattern contrasts appears to be one useful means for obtaining speech perception information in infants and toddlers. Electrically evoked cortical responses to acoustic changes in speech sounds may also become an important clinical tool in assessing this population.

It has been our experience that children with hearing aids do not receive the same level of follow-up care as has been shown for children with cochlear implants. It is not clear why there is a discrepancy in management; however, much of it is probably rooted in historical origins. Nonetheless, there are a number of speech perception tests available for children of different ages and skill sets that should be of high interest to audiologists who work with children who are hard of hearing. The larger pediatric cochlear implant centers also assess speech production, language skills, and cognition and/or intelligence, particularly during the pre-implant evaluation to determine candidacy. Although these measures have not received attention in this chapter, their use provides a more complete profile of the child at different stages of development. Due to present economic conditions

and reduced reimbursement, tracking communication outcomes in young children with hearing loss may not be economically feasible for some practices. Nevertheless, speech perception assessment, at the very least, should be considered a necessary part of standard management even within small private practices.

For manufacturers of hearing aids, sponsors of multicenter studies designed to track performance with new devices or processing strategies should consider a hierarchical battery of tests for tracking speech perception. This approach has been shown to be advantageous when assessing children of different ages and auditory skill sets. Use of rigorous research protocols may also encourage participating centers to implement comprehensive speech perception assessment as an important component of routine clinical practice.

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