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Assessing Speech Pattern Contrast Perception in Infants: Early Results on VRASPAC

Amy Martinez, Laurie Eisenberg, Arthur Boothroyd, and Leslie Visser-Dumont

House Ear Institute, Children's Auditory Research and Evaluation Center, Los Angeles, California, U.S.A.

Abstract

Objective—To assess perception of specific speech pattern contrasts in infants with normal hearing (NH) and infants with sensorineural hearing loss (HL).

Study Design—Prospective longitudinal and cross-sectional study.

Setting—Tertiary referral center.

Patients—Nine infants with NH and 11 infants with HL ranging from mild to profound.

Methods—Speech pattern contrast perception was evaluated in infants with NH and HL using a new behavioral test called Visual Reinforcement Assessment of the Perception of Speech Pattern Contrasts (VRASPAC). VRASPAC assesses the infant's ability to distinguish the speech features of vowel height and place and consonant voicing, continuance, and place. Detection of a phonetic change is indicated by a conditioned head-turn response. Performance is reported as the percent confidence that responses are not random.

Results—The infants with NH attained high confidence scores for the vowel height and place contrasts used in this study. The infants with HL achieved high scores for the vowel height contrast regardless of degree of hearing loss. High scores were attained for the vowel place contrast by infants with losses less than 60 dB HL. Performance for the consonant contrasts was variable for all of the infants. Results from 1 infant assessed precochlear and postcochlear implantation indicated substantial improvement in speech pattern contrast perception with the implant.

Conclusion—Perception of speech pattern contrasts in infants, particularly for the vowel contrasts, can be evaluated with a high level of confidence using VRASPAC. Consonant contrast perception is much more variable than vowel contrast perception and requires further investigation.

Keywords

Cochlear implant; Hearing aids; Hearing loss; Infant speech perception; Pediatric

Improvements in early identification of hearing loss (HL) coupled with advances in sensory device technology have resulted in improved speech detection skills by infants with sensorineural HL. Despite this tremendous progress, the field of pediatric audiology still lacks the clinical tools needed to describe and quantify auditory perceptual capabilities in this population. Such tools are important for determining the child's ability to process

phonologically significant contrastive information and the contribution of this information to the emergence of spoken language. Performance outcomes from formal measures of speech perception can bolster decisions regarding prosthetic intervention and track progress thereafter.

To address the need for new assessment tools, investigators from the House Ear Institute have been engaged in developing a progressive test battery to evaluate speech perception in children from infancy to school age (1). Composed of 4 computerized tests, these measures evolved from the Speech Pattern Contrast Test concept, developed originally by Boothroyd (2). The stimulus set and perceptual task are essentially the same across the 4 tests, but the response task changes according to the age, maturity, and interest level of the child (3). The data presented here represent preliminary findings for 9 children with normal hearing (NH) and 11 children with HL on 1 test of the battery. These results will contribute to a larger data set that addresses specific research questions about auditory perceptual development in young children with HL and will also contribute to the development of a progressive speech perception test battery for infants and toddlers.

In this article, we focus on the test developed for infants, Visual Reinforcement Assessment of the Perception of Speech Pattern Contrasts (VRASPAC) (4,5). VRASPAC has been designed specifically to evaluate speech pattern contrast perception in infants as young as 6 months. During testing, the infant indicates awareness of a phonetic change in a string of repeated utterances through a conditioned head turn, with reinforcement for correct responses. VRASPAC was modeled after the Visual Reinforcement Infant Speech Discrimination Test developed by Eilers et al. (6), which uses an operant conditioning paradigm (visually reinforced head-turn response) to study developmental changes in speech discrimination skills in infants. The conditioned head-turn response is a well-established clinical technique for assessing hearing sensitivity in infants as young as 6 to 8 months because this is the approximate age when infants are able to turn their head to a sound source.

At the same time that VRASPAC was being developed, a research group in Belgium (7,8) began developing a software-driven test battery, called Auditory Speech Sounds Evaluation. This battery is composed of tasks that assess phonetic detection, discrimination, and identification in children and adults. The task that assesses discrimination is appropriate for use with infants. The Auditory Speech Sounds Evaluation is primarily intended as a clinical assessment tool, with expectations that it will be particularly useful for determining cochlear implant candidacy and for fitting the implant after surgery. VRASPAC, in contrast, has been developed as part of a research protocol to address specific questions about hearing-impaired infant's auditory perceptual capabilities as they mature. Although development of these pediatric tests may be motivated by different objectives, together they attempt to fill a void in pediatric audiology—the need for tests that evaluate speech perception in infants and toddlers.

DESCRIPTION OF VRASPAC

As illustrated in Figure 1, the infant sits in the caregiver's lap while the caregiver listens to music, via headphones, from a CD to prevent giving cues to the child when phonetic changes occur. A string of repeated vowel-consonant-vowel (VCV) utterances (the standard “oodoo”) is presented through the loudspeaker at 70 dBA until the child habituates to the sound. Sound-field testing at conversational level speech is typically carried out for children with hearing aids and/or cochlear implants. When the phonetic contrast is introduced (e.g., “aadaa”), the child is conditioned to turn toward the reinforcer (either an animated toy or computer animation). If an infant is able to detect a specific contrast, he or she is typically

conditioned within 2 or 3 trials. Test trials commence after the child is conditioned. Stimulus presentation and activation of reinforcement are computer controlled. The tester registers all head-turn responses via computer keyboard, including responses that occur outside of a designated response window. Performance on each contrast is scored as percent confidence. This type of scoring derives from probability theory, taking into account the number of standard and deviant utterances, trials, and responses occurring within and outside of the hypothetical response window. Accordingly, the score represents the level of confidence that the head-turn responses did not occur by chance. A preset stopping rule, determined by a confidence-level criterion (e.g., 90%), is used to increase test efficiency. Assessment of each phonetic contrast can be accomplished within 1 or 2 minutes on the average.

The stimulus set for VRASPAC consists of VCV nonsense syllables, representing 6 phonetic contrasts. As can be seen in Table 1, the contrasts are vowel height, vowel place, consonant voicing, consonant continuance or manner, and consonant place (front or bilabial-alveolar and rear or alveolar-palatal).

Upon completion of a test, a summary of the data is retrieved in graphic and numeric format. An example of the data summary is presented in Figure 2 for a 9-month-old hearing aid user with sensorineural HL. Included in the figure is the unaided and aided audiogram. Confidence scores for each of the phonetic contrasts are presented. Scores 90% or higher suggest that the head-turn responses are synchronized to the phonetic change. Scores below 75% suggest that responses may be random, as indicated for consonant continuance in this example. It can be seen that performance for all contrasts, except CC, is well above 90% confidence.

In this article, we present VRASPAC results gathered to date on infants and toddlers, herein referred to as infants. This is followed by a case study presented on an infant with a cochlear implant for whom data have been collected before and after implant surgery.

PARTICIPANTS

Participants were a subset of infants with NH and HL being followed as part of a larger study assessing auditory-perceptual development in children 6 months to 5 years. The 9 infants with NH were between the ages of 7 and 17 months (mean age, 11 mo) at the time of testing. All of these children passed their newborn hearing screenings and also demonstrated normal otoacoustic emissions and normal tympanograms before participation in VRASPAC testing. The 11 infants with HL were between the ages of 9 and 21 months (mean age, 13.9 mo). Hearing loss for this group ranged from mild to profound in severity. All of these infants were fitted with hearing aids, and 4 subsequently received a cochlear implant. Table 2 provides additional information about the infants with HL regarding age when hearing aids and/or cochlear implants were fitted.

RESULTS

Confidence scores for vowel and consonant contrast perception for the set of stimuli, shown in Table 1, are displayed in Figure 3 for both groups of infants as a function of 3-frequency pure-tone average (3FA). Vowel scores are shown in the upper panel, and consonant scores are shown in the lower panel. The dashed line in each panel highlights the 90% confidence level. Data for the infants with NH are represented by unfilled symbols, whereas data for the infants with HL are represented by filled symbols. As shown in the upper panel, high confidence percent scores were attained by the infants with NH for “oo” versus “aa” vowel height and “oo” versus “ee” vowel place contrasts. Performance by the infants with HL indicated that the vowel height contrast was perceived with a high degree of confidence for

all but 1 child. For the vowel place contrast, however, high confidence scores were attained only by infants with losses less than 60 dB HL. For infants with 60 dB HL or greater, there was less confidence that the head-turn responses coincided with presentation of the vowel place contrast.

Unlike performance for the 2 vowel contrasts, perception of the 4 consonant contrasts (lower panel) was variable regardless of hearing status or contrast. Exploration of the data suggested an effect of age, particularly for the infants with HL; performance was shown to decline after the age of 12 months. Results were less clear for the infants with NH. There seemed to be an age affect for consonant voicing and continuance, similar to that shown for the group with HL. No trends were apparent for the consonant place contrasts. These results may partly reflect the limited data set.

CASE STUDY

VRASPAC performance outcomes are presented for a child with a cochlear implant in Figure 4. The left side of the figure shows the aided audiogram and performance profile for this 16-month-old child before implant surgery. It can be seen that high confidence scores were obtained for the vowel height contrast only. Confidence levels for the consonant voicing and place (front) contrasts were well below the 75 to 90% range of performance, suggesting that the responses may have been random. He could not be conditioned to the specific phonetic contrasts for vowel place, consonant continuance, or consonant place (rear). The right side of the figure displays this same child's audiogram and performance profile 6 months after cochlear implant activation. Confidence scores were at or above 90% for the vowel height and place contrasts. Although this child did not achieve the criterion score of 90% for the consonant contrasts, emerging consonant contrast perception was evident, particularly for the voicing and place (front) contrasts. Notably, this child was able to be conditioned to all of the consonant contrasts.

DISCUSSION AND CONCLUSION

The VRASPAC is part of a battery of tests that are being developed at the House Ear Institute to assess auditory perceptual capabilities in young children with HL. Although we are in the early stage of this development, we hope that this test battery may someday prove to be useful to pediatric audiologists. In this article, we present early results on a small group of children assessed on the VRASPAC.

Preliminary data indicate that all of the infants assessed in this study were able to differentiate the vowel height contrast with a high degree of confidence. Perception of the vowel place contrast was less confident specifically for those infants with HL in the moderately severe to profound range. Thus, the vowel place contrast seems to be somewhat sensitive to severity of HL in infants. Perception of consonant contrasts seems to be difficult, even for the infants with NH. One explanation for this outcome may be that VCV stimuli are too difficult, from a cognitive standpoint, for infants to differentiate with a high degree of confidence. Use of less complex stimuli (e.g., consonant-vowel [CV]) is being considered for future investigations. Recall that these results pertain to a particular set of contrastive stimuli. Expansion of the stimulus set to include other pairs of contrastive stimuli is being considered for future development of the test.

Whereas the other 3 tests in the progressive test battery (Play Assessment of Speech Pattern Contrasts [PLAYSPAC], On-line Imitative Test of Speech Pattern Contrasts [OLIMSPAC], and Video Speech Pattern Contrast Test [VIDSPAC]) are providing valuable information regarding speech pattern contrast perception in children aged 3 to 5 years (1,9), the most difficult age for assessing speech pattern contrast perception in young children remains to be

1 to 3 years. This limitation requires further consideration in test development for children of this particular age range.

Despite these limitations, there is evidence to suggest that VRASPAC in its current version holds promise as a clinical tool in assessing speech pattern contrast perception in infants and toddlers with HL. The potential clinical use of VRASPAC is illustrated by the case presentation of the child assessed both preimplant and postimplant (Fig. 4). Although this child had aidable residual hearing, he was only able to perform above chance levels on the vowel height contrasts with hearing aids activated. Thus, VRASPAC was successful in providing additional information to the aided audiogram in this very young deaf child. Improved perception of specific speech pattern contrasts was evident after cochlear implantation. In another clinical application, VRASPAC is proving to be useful for assessing older children with developmental delays who are not able to be assessed on more conventional speech perception measures.

To conclude, we have been developing a progressive test battery not only to address the need for new speech perception tests for infants and toddlers but also to address specific research questions about auditory perceptual development in young children with HL. VRASPAC is the test designed specifically for assessing infants. Early results are promising, and test development is continuing.

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FIG. 1.
VRASPAC test setup.

FIG. 2. Audiogram and performance profile for a 9-month-old hearing aid user assessed on VRASPAC. VH indicates vowel height; VP, vowel place; CV, consonant voicing; CC, consonant continuance; CPf, consonant place (front); CPr, consonant place (rear).

FIG. 3.

Confidence scores for NH and HL infants as a function of 3-frequency pure-tone average for vowel and consonant contrasts. VH indicates vowel height; VP, vowel place; CV, consonant voicing; CC, consonant continuance; CPf, consonant place (front); CPr, consonant place (rear).

FIG. 4.

Audiogram and VRASPAC performance profile for an infant before and 6 months after cochlear implant activation. VH indicates vowel height; VP, vowel place; CV, consonant voicing; CC, consonant continuance; CPf, consonant place (front); CPr, consonant place (rear).

TABLE 1

Examples of Visual Reinforcement Assessment of the Perception of Speech Pattern Contrasts phonetic contrasts

Phonetic contrasts	
Vowel height	“ oodoo ” vs “ aadaa ”
Vowel place	“ oodoo ” vs “ eedee ”
Consonant voicing	“ oodoo ” vs “ ootoo ”
Consonant continuance	“ oodoo ” vs “ oozoo ”
Consonant place (f) ^a	“ oodoo ” vs “ ooboo ”
Consonant place (r) ^b	“ oodoo ” vs “ oogoo ”

Note: The characters in bold font represent the portion of the VCV syllable that conveys the phonetic contrast.

^a f, front (bilabial).

^b r, rear (alveolar-palatal).

TABLE 2

Demographic information for the 11 children with hearing loss

Mean age (range)	13.9 mo (9–21 mo)
Mean 3FA (range)	77.5 dB (HL) (32–115 dB HL)
Mean age fit HA (range)	5 mo (3 wk–20 mo)
Mean age fit CI (n = 4) (range)	14.3 mo (12–16 mo)
Mean HA use (range)	8.8 mo (1–17 mo)

3FA indicates 3-frequency pure-tone average; HA, hearing aid; CI, cochlear implant.