Communication Intervention for Children With Cochlear Implants: Two Case Studies

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ABSTRACT: This article describes the intervention programs attended and progress made by 2 children who exhibited considerable differences in benefit from their cochlear implants. The children differed in many ways, including age at onset of deafness, preimplantation communications skills, age at implantation, the amount and types of intervention services received, and the rate at which they developed oral communication skills. Their intervention programs employed both analytical and synthetic auditory training and emphasized the development of speech production and language skills. These case studies help to illustrate the range of outcomes among cochlear implant recipients and the adaptability needed to design and implement individualized intervention programs.

KEY WORDS: cochlear implant, intervention, children, auditory perception, speech, language

CASE 1: A CHILD WITH PERILINGUAL ONSET OF DEAFNESS

Background Information

Drew was a typically developing child with normal hearing for the first 3 years of life. Shortly after his third birthday, he contracted pneumococcal meningitis, resulting in a moderate hearing loss in his right ear and a severe loss in his left ear (see Table 1). No cognitive or motor deficits were observed following his illness. He was fitted with binaural hearing aids and enrolled in a preschool classroom for children with hearing impairments. Simultaneous communication [speech with Manually Coded English (MCE)] was used in the home and school, although Drew continued to express himself almost exclusively by speaking. His parents reported that, despite hearing aids, his speech intelligibility and auditory comprehension decreased noticeably following his illness.

Approximately 4 years after Drew’s bout with meningitis, his hearing levels suddenly decreased to the profound range, making him a candidate for a cochlear implant. He received a Clarion MultiStrategy implant at 7;6 (years;months) and his aided thresholds showed substantial improvement (see Table 1). At that time, he was enrolled in a resource room for children with hearing impairments and was mainstreamed in a first-grade classroom with a sign interpreter for several academic subjects. He received 20 minutes of speech and language intervention twice weekly at school. This case study describes Drew’s progress in developing oral communication skills and the instructional techniques used in his private intervention sessions. His improvements also reflect the benefits received from the implant itself and from his family, teachers, and school-based speech-language pathologists.

Intervention Program

Drew began to attend individual, 1-hour intervention sessions with the first author twice weekly soon after his
implant was activated. His program lasted for approximately 20 months, and health insurance covered 80% of the cost of the sessions. Although Drew’s hearing sensitivity was greatly increased with his implant, the electrical signal it provided was perceptually different from the amplified acoustic signal that his hearing aids had supplied. Therefore, the main goals of intervention were to help Drew “make sense” of this new signal and to use his increased hearing sensitivity to improve his speech and language skills. To address these goals, each intervention session included activities in four main areas: auditory perception, speech production, language skills, and the integration of these skills. These areas were targeted to help Drew learn how to identify and comprehend speech via his implant; improve speech intelligibility and prosody; stimulate age-appropriate semantic, syntactic, morphological, and pragmatic skills; and apply his skills and knowledge in academic and social situations. Drew was highly motivated to communicate orally and participated readily in intervention activities.

As with other children who have communication disorders, Drew’s intervention program was designed to lessen speech and language deficits by building on his strengths and interests. Several resources were especially useful in developing Drew’s intervention program. Tye-Murray (1993) and Robbins (1990) provided insightful suggestions regarding auditory training. Ling (1976) and Robbins (1994) offered guidelines for facilitating improvements in speech production. Commercially available programs for children with cochlear implants also provided ideas for improving oral communication (Firszt & Reeder, 1996; Moog, Biedenstein, & Davidson, 1995; Vergara & Miskiel, 1994).

Auditory training activities will be described in greater detail than those for speech and language because of page limitations and because the procedures used for the latter areas were similar to those used for normally hearing children with speech and language disabilities. This disparity should not be interpreted to mean that auditory training was stressed to a greater degree than other communication skills. Rather, auditory and speech training activities were viewed as supporting language development so that functional communication gains could be made as quickly as possible. As with other children who have communication disorders, Drew’s intervention program was designed to lessen speech and language deficits by building on his strengths and interests. Several resources were especially useful in developing Drew’s intervention program. Tye-Murray (1993) and Robbins (1990) provided insightful suggestions regarding auditory training. Ling (1976) and Robbins (1994) offered guidelines for facilitating improvements in speech production. Commercially available programs for children with cochlear implants also provided ideas for improving oral communication (Firszt & Reeder, 1996; Moog, Biedenstein, & Davidson, 1995; Vergara & Miskiel, 1994).

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**Auditory Training**

An eclectic approach to auditory training was begun soon after Drew received his cochlear implant. This approach included both analytic and synthetic listening activities (Schow & Nerbonne, 1996). Analytic auditory training focused on the “parts” of speech in an attempt to improve Drew’s perception of distinctions between speech sounds and consonant and vowel features. It is a “bottom-up” approach in which progressively finer acoustic distinctions are introduced and practiced in syllables and words. For example, minimal pair words might be used to show the differences between vowel height (hat vs. heat) or consonant manner of production (cat vs. sat). Minimal pair words were presented in the auditory-only condition by using a cloth-covered needle-point hoop to cover the mouth. Both auditory and speechreading cues were provided as each target word was introduced and whenever Drew was unable to identify words through listening alone.

Recent studies indicate that stress and timing patterns and vowels are among the most readily perceived speech elements for children with cochlear implants (Fryhauf-Bertschy, Tyler, Kelsay, Gantz, & Woodworth, 1997; Miyamoto, Osberger, Robbins, Myers, & Kessler, 1993). Consonant features including manner, voicing, and place are reported to be more difficult to perceive via an implant (Dowell et al., 1991; Tyler, 1990). These findings provided the basis for the sequence of analytic auditory training goals used with Drew (see Appendix).

Synthetic auditory training involves greater emphasis on the comprehension of meaningful speech rather than the recognition of consonant and vowel features. Using this “top-down” approach, whole sentences were presented for repetition, completion, or answering, allowing Drew to take advantage of context and syntactic cues (Schow & Nerbonne, 1996). For example, single sentences from a paragraph or story were read aloud and then Drew was asked to repeat them. Sentence repetition activities were usually conducted without speechreading cues. However, speechreading cues were available during all other speech, language, and integration activities.

Finally, communication repair strategies were modeled and reinforced in auditory training activities and throughout each session (Tye-Murray, 1993). Drew was encouraged to request clarifications whenever he did not understand what he heard. Several different ways to ask for repetitions and clarifications were discussed (e.g., “Please say that again,” and “I didn’t hear you.”), and Drew was prompted to use these phrases until he began to apply them spontaneously.

### Table 1. Audiometric information for Drew and Bobby.

<table>
<thead>
<tr>
<th>Age at identification of hearing loss (years;months)</th>
<th>Etiology</th>
<th>Unaided 3 frequency PTA (better ear)</th>
<th>Age implanted (years;months)</th>
<th>Implant type, processing strategy</th>
<th>3 frequency PTA with cochlear implant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drew</td>
<td>3;0 Meningitis</td>
<td>107 dB HL</td>
<td>7;6</td>
<td>Clarion MultiStrategy, CIS</td>
<td>34 dB HL (6 months postimplant)</td>
</tr>
<tr>
<td>Bobby</td>
<td>0;5 Meningitis</td>
<td>105 dB HL</td>
<td>3;0</td>
<td>Nucleus 24, ACE (11/22 electrodes inserted)</td>
<td>42 dB HL (1.5 years postimplant)</td>
</tr>
</tbody>
</table>

Note. PTA = pure-tone average; CIS = continuous interleaved sampling; ACE = advanced combination encoder.
His parents were also encouraged to expect and reinforce the use of repair strategies in all situations.

**Nonspeech sounds in auditory training.** Relatively gross acoustic stimuli were used to promote awareness of the characteristics of environmental and musical sounds during the initial sessions. Rhythm band instruments (e.g., cymbals, tambourine) provided an enjoyable way to help Drew recognize grossly different sounds. He improved from 70% to 90% correct in identifying musical instruments (in sets of 4) over two sessions. Prerecorded audiotapecs of environmental sounds (e.g., telephone, sirens, barking) were also introduced. These materials were not as useful because the recorded sounds were often distorted, atypical, or uncommon in Drew’s environment (e.g., typing on a manual typewriter). A third material, “Thinking Things” software (1994), provided auditory discrimination and auditory memory practice with nonspeech sounds. This program combined visual and auditory stimuli in an entertaining way and provided increasingly complex items to challenge Drew’s auditory memory. Nonspeech materials appeared to help Drew become oriented to his implant. In many cases, he was initially unable to identify a sound, only to recognize it consistently after a few presentations. The usefulness of auditory training with nonspeech stimuli has been questioned because practice with these materials may have little or no benefit for speech perception (Tye-Murray, 1993). Practice with nonspeech stimuli was discontinued after a few sessions in order to focus exclusively on speech stimuli during auditory training.

**Analytic auditory training procedures and progress.** The Ling 6 sound test (Ling, 1976) was administered in the auditory-only condition at the beginning of each intervention session by asking Drew to repeat [m, j, s] in isolation and [a, i, u] in syllables with an initial consonant (e.g., [bi], [ba], [bu]). These six items were presented three times each in random order to determine how well Drew perceived speech sounds across a wide range of frequencies. Drew was 20% correct on the Ling test during the first post-activation session, but became consistently correct after five sessions. The Ling test was given during each session thereafter—despite Drew’s improved scores—to check implant functioning.

Once the Ling test was completed in the first few minutes of each session, a short but intensive period of auditory training was conducted. During this 10- to 15-minute activity, suprasegmental and segmental contrasts were introduced and practiced in the order found in the Appendix. In general, speech sound contrasts progressed from gross to finer acoustic distinctions, and the number of response choices was increased as Drew experienced success. A criterion of 80% accuracy for two consecutive sessions was initially set for each contrast (e.g., minimal pair /t/ words vs. /d/ words). However, this level was later modified to accept 90% accuracy for a single session so that more time was spent on difficult contrasts and less on those that were already salient to Drew.

Drew’s progress in identifying vowel and consonant features is presented in Figure 1. The initial levels in this figure represent average scores after specific vowel and consonant contrasts were first introduced and practiced. The contrasts were introduced consecutively beginning with wide vowel contrasts and ending with consonant place contrasts. Wide vowel contrasts consisted of minimal pair words with different point vowels. Narrow vowel contrasts included minimal pair words with vowels that were near neighbors on the vowel quadrilateral (e.g., heed vs. hid). Drew’s final scores are averages from the last session in which a vowel or consonant contrast type was targeted. Scores for each contrast except consonant place are based on minimal pairs tasks that have a chance performance level of 50%. Scores for consonant place contrasts are based on tasks with three choices (e.g., labial vs. alveolar vs. velar consonants) and have a chance performance level of 33%. The number of practice sessions for each contrast type appears in parentheses.

**Figure 1.** Drew’s percentage correct scores for speech feature contrasts at the beginning and end of auditory training for each contrast. Dashed lines indicate chance-level performance. The number of sessions per contrast appears in parentheses.
As Figure 1 illustrates, Drew’s initial scores ranged from 75% to 90% correct after one training session for each contrast. In some cases, his performance met the 90% criteria and further training for a specific vowel or consonant contrast (e.g., /i/ vs. /u/) was not undertaken. Other contrasts required more practice. For example, three or more sessions were needed to reach criterion for the following contrasts: /e/ versus /æ/, stops versus fricatives, affricates versus stops, and fricatives versus affricates. Criterion was not reached for consonant place contrasts for nasals [m, n, n] or the /l/ versus /θ/ contrast, because private intervention sessions were discontinued soon after they were introduced.

Drew’s relatively high initial scores and his rapid improvements in speech perception suggest that his implant allowed him to distinguish between many speech sounds with little training. This finding was verified by his composite score of 93% correct on the Minimal Pairs Test (Robbins, Renshaw, Miyamoto, Osberger, & Pope, 1988) after only 6 months of implant experience. This test is a two-choice, auditory-only, closed-set procedure that assesses the ability to identify words differing by a single vowel or consonant feature (e.g., vowel height, consonant place of production). Drew had achieved a composite score of 54% (chance level) on the Minimal Pairs Test 3 months before implantation.

**Synthetic auditory training procedures and progress.**

The perception of meaningful, connected speech was emphasized throughout Drew’s program. All speech production, language development, and integration activities were conducted with auditory and speechreading cues and without signs, providing practice in face-to-face communication. Activities to improve auditory-only comprehension of meaningful speech were also undertaken. Four useful procedures are described below.

1. Picture books such as *The First 1000 Words* (Amery & Cartwright, 1979) were particularly useful during the first months after implantation because they contained abundant vocabulary words for everyday situations and allowed auditory training to be game-like. For example, after reviewing the vocabulary items on a given page (i.e., Drew would name as many pictures as he could and the remaining items would be labeled and discussed by the clinician), Drew and the clinician took turns making up sentences such as, “I see a red hat on the table.” The listener would then find the corresponding picture. At first, a short, simple sentence format was used repeatedly (e.g., “I see X.” or “Can you find X?”). As Drew’s auditory, syntactic, and semantic skills improved, more complex and varied sentences were introduced.

2. Conversations about selected topics (e.g., basketball, vacation plans, school) also provided practice in auditory comprehension and clarification strategies. A topic was selected and then discussed for a few minutes. Drew was encouraged to guess if he did not understand what was said. False assertions (e.g., “Michael Jordan can’t jump.”) were made to check Drew’s comprehension. Communication repair strategies were also practiced and reinforced during these conversations.

3. A “tracking” procedure adapted from DeFilippo and Scott (1978) was used with high-interest stories to improve sentence comprehension and syntax skills. During this activity, Drew was asked to repeat sentences exactly as they were read to him. He was also encouraged to ask for repetitions and clarifications as needed. This task was often difficult when Drew was unfamiliar with the story. He was most successful when the page had been read with the clinician before the sentence repetition task. Although Drew enjoyed humorous stories such as *Amelia Bedelia* (Parish, 1991) and *The Stupids* (Allard & Marshall, 1994) series, this task was tiring and was usually limited to 2–4 paragraphs.

4. Riddles and jokes provided challenging material for synthetic auditory training activities during the second year of intervention. The clinician would read a riddle or joke and then Drew would repeat what he heard before guessing the answer. For example, “What has 18 legs and catches flies?” (Answer: a baseball team). Words with multiple meaning and synonyms were also introduced through riddles during the later stages of intervention. Drew was motivated to tell his parents and friends the riddles, thereby increasing opportunities for speech and language reinforcement.

**Speech Production**

During the first postimplantation session, a total of 35 consonant and consonant cluster errors were transcribed during administration of The Fisher–Logeman Test of Articulatory Competence (Fisher & Logeman, 1971). Most of Drew’s errors involved stopping or omitting fricatives, affricates, and s clusters. Drew was stimulable for the correct production of the majority of these consonants in the initial position in words. Vowels and diphthongs were produced correctly during testing and in spontaneous speech. The Speech Intelligibility Evaluation for Children (Monsen, Moog, & Geers, 1988) was also given, and a listener who was unfamiliar with the speech of deaf children identified 72% of Drew’s spoken words on this assessment. This score fell into the fair range of intelligibility. Drew’s conversational speech was usually low in intensity and lacking variation in intonation and stress. In sum, although Drew produced all vowels and many consonants correctly, his misarticulations and his soft, monotonous delivery made his speech hard to understand and noticeably different from that of his hearing peers.

Speech training activities followed auditory training during most sessions. The phonemes [s, z, j, ʒ, ɹ, ʃ, dʒ] were selected as targets, along with a variety of s clusters. These sounds were introduced singly or in cognate pairs and, for the most part, Drew produced them correctly in single words after brief instruction and practice. He did not, however, produce them accurately at a conversational speaking rate or use them in spontaneous speech without considerable concentration. In order to improve the
automaticity of Drew’s speech (Ling, 1978), an emphasis was placed on his saying target phonemes in words at a rate of approximately 3 words per second. This technique was applied to all targets as they were introduced across the first year of intervention. Prosody concerns were addressed by having Drew sing simple songs and imitate nursery rhymes and poems with varied stress and intonation. Increased “expression” was also stressed during conversation. The following techniques were also useful in speech training: self-evaluation, false assertions, negative practice (saying the target correctly and then incorrectly), and minimal pair contrasts.

Several pragmatic activities appeared to motivate Drew to improve and use his speech targets spontaneously. Jokes and riddles containing target sounds were practiced and then told to family and friends. Sports-related words were emphasized so that Drew would pronounce them correctly with his teammates. Magic tricks were learned and a script was written for a magic show that was presented to parents, teachers, and preschoolers. Drew was expected to self-correct speech errors during rehearsals. To make his voice louder, he practiced his performance while the clinician listened from the hallway.

At the time that private sessions were discontinued, Drew’s spontaneous speech was readily intelligible to familiar and unfamiliar listeners although misarticulations of s clusters were still observed. His vocal intensity was usually acceptable for face-to-face communication but remained somewhat “soft” in group settings. Drew continued to speak with a monotone much of the time, but he varied intonation and stress when he was reminded to do so.

Oral Language

Drew’s language skills were evaluated using speech and sign approximately 2 months before implantation (chronological age = 7;3). Results from the Test of Language Development (TOLD; Newcomer & Hammill, 1982), the Woodcock-Johnson Psycho-Educational Battery–Revised (WJBP–R; Woodcock & Johnson, 1990), and the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1965) revealed age-equivalent scores ranging between 4;1 and 6:3. His relative strengths included Grammatic Understanding (6;3) (TOLD) and Antonyms and Synonyms (5;7) (WJBP–R). His lowest scores were in Analogies (4;1) (WJBP–R) and receptive vocabulary (4;10) (PPVT). Drew also scored at the 4;10 level on the receptive and expressive subtests of the Reynell Developmental Language Scales (RDSL; Reynell & Gruber, 1994). A language sample collected 2 months before Drew’s implant was activated revealed that only 4 of 59 utterances were correct, complete sentences when describing pictures and conversing. His mean length of spoken utterance was 2.86 morphemes at that time. These scores indicated that Drew’s language skills were well below expected levels for his chronological age.

Many language goals were addressed during Drew’s program. One of his most pressing needs was to increase his receptive and expressive vocabulary. Although Drew knew the signs for many words, he was initially unfamiliar with how they sounded. This deficit was addressed through picture dictionaries and theme-related picture books such as those mentioned above for synthetic auditory training. Drew also kept a personal dictionary so that definitions for new vocabulary could be written down and reviewed in a systematic way. Units on classification, description (e.g., name, colors, sizes, shapes, functions, composition, and associations), comparing and contrasting, synonyms, antonyms, and homonyms were introduced as his vocabulary increased. In addition, school-related vocabulary words were pre-taught to improve his chances for success in reading and other subjects. Drew’s parents and teachers conscientiously explained and reviewed unfamiliar words.

Syntax and grammar needs were also addressed during the first few months of intervention. Goals included comprehension and use of a variety of sentence structures and morphological markers (i.e., regular and irregular past tense verbs, present progressive constructions, copula and auxiliary verbs, question forms, and plurals). Rules for using each form were discussed, practiced, and then elicited in less structured activities. Generalization of different sentence types and grammatical constructions was often observed after a few practice sessions. Higher level language skills (e.g., inferences, oral and written narratives, and analogies) were introduced after approximately 1 year.

Language, listening, and speech were integrated and reinforced through less structured activities during the last quarter of each session. Question and answer games (e.g., Guess Who; Milton-Bradley, 1987) humorous books, computer software, and wordless comic strips provided fun and naturalistic opportunities to communicate. These kinds of activities served three main purposes. First, they provided an opportunity to monitor generalization of newly learned skills to conversations. Second, they helped to avoid overemphasis on “isolated, structured listening behaviors to the exclusion of other communication skills,” or “greenhousing” (Robbins, 2000, p. 328). Third, they helped to increase Drew’s confidence as an oral communicator by providing guided practice with activities similar to those that he experienced with friends and family.

In summary, although Drew made substantial progress in language skills during his first 2 years of implant experience (most of his scores increased by 2–3 years in the areas named above), his age-equivalent scores remained between 10 and 22 months below his chronological age. Improvements were most evident in syntax and morphology as Drew typically expressed himself with correct and complete sentences and used a variety of verb tenses appropriately. These improvements were also reflected in his written narratives. Drew’s vocabulary deficits continued to require special attention by his parents, teachers, and school speech-language pathologists.

Discussion

Drew’s experiences with normal hearing and the presence of some residual hearing after his illness appear to have supported his relatively rapid gains in oral communication after implantation. That is, his preimplant hearing experiences may have allowed him to associate the electrical signal provided by the implant with his memories of
speech sounds and to interpret them more readily. Analytic auditory training served to increase Drew’s awareness of the acoustic differences between phonemes and provided practice in recognizing fine acoustic distinctions. It was important to monitor his progress in speech perception so that intensive practice was provided only for contrasts that were not readily distinguished. Although Drew produced most speech targets correctly after short periods of instruction, generalization of fricatives and improved prosody remained a challenge throughout the first year of implant use. His lack of automaticity in speech highlighted the need to emphasize a conversational rate of production as well as accuracy. Delays in semantics, syntax, and grammar were addressed through direct instruction and reinforcement at home and school. Drew made steady progress in the latter areas once he understood the rules that governed the use of each construct. Although his vocabulary increased substantially, ongoing emphasis was needed to increase his lexicon and improve comprehension of literal and idiomatic language.

Drew is currently in sixth grade and works closely with a teacher for children with hearing impairments who acts as a sign interpreter for most of his classes. This arrangement allows her to identify course material that may be difficult for Drew and to tutor him in a resource room setting. She estimates that Drew relies most on signs during classes in which new content and vocabulary are introduced frequently (i.e., science and social studies). Reliance on signs is minimal in classes where vocabulary is more common or predictable (i.e., English and math). Drew also uses a personal soundfield frequency-modulated (FM) system to improve signal-to-noise ratio in the classroom.

Speech therapy at school was discontinued in fourth grade when articulation goals were met. Drew’s parents report that they routinely helped him with homework and preparation for tests in previous grades but that this year he has become more self-organized and has needed much less assistance. Drew made the “all A” honor roll for the first semester of sixth grade. He is active in sports and was elected to student council. His speech is readily intelligible and he communicates freely in face-to-face conversations, although he still experiences difficulties comprehending speech in noisy situations. Recently, Drew’s cochlear implant, which had two nonfunctioning channels, failed completely after approximately 4 years of use. It was surgically explanted and replaced with a Clarion MultiStrategy implant with a Hi-focus electrode array soon after the failure was detected. After an adjustment period of approximately 3 weeks, Drew reported that he could understand speech better than with his previous implant.

**CASE 2: A CHILD WITH PRELINGUAL ONSET OF DEAFNESS**

**Background Information**

Bobby suffered a profound bilateral sensorineural hearing loss secondary to an attack of spinal meningitis at 5 months of age. He experienced seizures and a regression in motor skills at that time and received physical and occupational therapy soon after his illness. Seizures have not been observed since he was released from the hospital, and his motor skills returned to normal. Bobby also received family-centered speech and language intervention for approximately 1 year after his hospitalization. Although manual signs were used to communicate with Bobby at home, he mainly expressed himself through gestures and pointing. Bobby had only a few weeks of hearing aid experience following his illness.

Bobby received a Nucleus 24 cochlear implant at 3:0. Because of ossification of the cochlea, only 11 of 22 electrodes were inserted and activated. His audiometric information can be found in Table 1. A psycho-educational evaluation completed at 3:1 determined that Bobby’s nonverbal intellectual abilities were higher than expected for his age group, although his visual motor skills were in the low average range and his adaptive behaviors (daily living and socialization) were in the moderately low range for his age. Communication development was severely delayed because of his hearing impairment. It was reported that Bobby “warmed up” easily and was friendly and cooperative during this evaluation.

Bobby’s mother first contacted the M.D. Steer Audiology and Speech-Language Center at Purdue University approximately 1 year after implantation because she was concerned about his lack of progress in speech and language. At that time, Bobby attended a self-contained special education classroom 4 half-days per week with speech-language consultation for his teacher. He was the only child with a hearing impairment in the class and received instruction through an interpreter who used Manually Coded English, a system his family also used at home. Bobby’s mother reported that he wore his cochlear implant most of his waking hours but removed it when playing outside. A communication evaluation was completed at our clinic in the fall of 1999, when Bobby was 4:2. Bobby was scheduled for one 90-minute intervention session per week thereafter. More frequent intervention was not possible because the family lived relatively far from the clinic. A dually-certified clinician (CCC-A and -SLP) and a certified audiologist, the second and third authors, supervised two graduate students who provided intervention each semester.

**Communication Abilities at the Start of Intervention**

From the first session, Bobby was an attentive yet highly cautious child. He was often reluctant to interact with clinicians and usually responded through eye gaze, pointing, or single signs—sometimes made under the table. Bobby’s participation usually improved when his mother was in the room, and he often looked to her for reassurance and encouragement. Parent reports, clinician observations, and assessment results from Bobby’s implant center indicated that he had made very limited improvements in auditory perception during his first year of implant use. His mother reported that he alerted to some environmental sounds (e.g., telephone, running water, television), but that
he seldom responded to speech in a meaningful way or to his name when called. Overall, Bobby's closed-set speech perception scores remained at chance levels on the Minimal Pairs Test (Robbins et al., 1988).

Bobby’s mother reported that he had become more vocal at home after his implant was activated, producing a variety of nonmeaningful sounds such as [m:m:m:], [babababa], and [ːːːː]. He rarely attempted to initiate communication, answer questions, or call by using his voice during early intervention sessions. His mother indicated that he had attempted to tell her something through speech for the first time soon after intervention started.

To further assess Bobby’s spontaneous speech, audio and video recordings were made while he and his mother played with an assortment of toys on three occasions during his first 3 months of intervention. A total of 141 vocalizations from the three half-hour interactions were categorized as precanonical, canonical, or postcanonical by two judges using the procedures described by Ertmer et al. (2002). The two judges were in agreement for 90% of their decisions. Each judge also reclassified 10% of the sample to assess intra-judge reliability. Agreement scores between their original and second classifications were 88% and 97%.

Listener judgments revealed that approximately 80% of Bobby’s spontaneous vocalizations from these recordings were classified as precanonical, 15% as canonical, and 5% as postcanonical. These findings indicated that Bobby remained at an early stage of vocal development more than 1 year after he received his implant. His lack of progress in vocal development was in contrast to other young deaf children who produced mainly speech-like vocalizations after a similar length of implant experience (Ertmer & Mellon, 2001; Ertmer et al., 2002; McCaffery, Davis, MacNeilage, & von Hapsburg 1999). However, because approximately 20% of his utterances were classified as canonical or postcanonical, Bobby appeared to be poised to increase his production of more speech-like vocalizations.

Bobby’s phonetic inventory was also assessed. Consonants and vowels were included in his inventory whenever both judges independently transcribed the same phone for a given utterance. A total of five vowels (number of transcription agreements in parentheses): /a/ (16), /u/ (1), /æ/ (14), /ə/ (1), and /i/ (1)) and three consonants (/b/ (11), /l/ (2), and /d/ (6)) were identified in canonical and postcanonical vocalizations during the first month of intervention. This quantity was similar to that observed in deaf children with hearing aids (Stoel-Gammon, 1988), but was less than that seen in other young cochlear implant recipients (Ertmer & Mellon, 2001; Ertmer et al., 2002; McCaffery et al., 1999), indicating that Bobby had a very limited repertoire of speech sounds.

Bobby’s language comprehension and expression skills were also severely limited at the outset of intervention. Tests administered at Bobby’s implant center via simultaneous communication revealed receptive and expressive language scores at the 1- to 2-year-old level (chronological age = 4;1). Observations in our clinic revealed that he comprehended and used signs for family members (e.g., mom, dad), common items (e.g., car, cow, bed, bird), some familiar commands (e.g., sit down, come here), and some concepts (i.e., two, same). He also matched objects to corresponding pictures, associated colors with items (e.g., red nose), and pointed to facial parts to direct an adult to complete a drawing (i.e., eye, nose, mouth). The MacArthur Communicative Development Inventory (MCDI; Fenson, Dale, Resnick, & Bates, 1993) was also completed by Bobby’s mother. She reported that Bobby understood 182 signs and understood and expressed himself with 6 signs (chronological age = 4;7).

Bobby typically used eye gaze to make requests, to respond to requests, and as social initiations. When he did not understand a request or task, he often looked away or simply waited for additional information from the adults. When he did comprehend, he smiled and imitated the actions of his clinicians. Bobby enjoyed repetitive, structured activities with interesting visual materials. He did not often create symbolic scenarios during play, but rather pursued mechanical activities, such as hooking vehicles together, crashing them, and building passageways for them. Bobby’s mother reported that he enjoyed outdoor play, particularly bike riding, swimming, and going to the park.

Communication Intervention and Progress

Communication intervention with Bobby has been eclectic, involving structured auditory and speech training activities and experiential play activities to stimulate language development. Language facilitation strategies for preschoolers with language delays and approaches designed for children with hearing impairments were integrated into Bobby’s sessions (Bricker & Cripe, 1992; Lowell & Stoner, 1963; Robbins, 1994; Vergara & Miskiel, 1994). Simultaneous communication was used during all sessions because Bobby showed almost no spoken language skills.

Because much of Bobby’s progress depended on the effectiveness of communication models at home (Rossetti, 2001), new signs and language stimulation strategies (Camarata, Nelson, & Camarata, 1994; Fey, 1986; Leonard, 1992) were shared with his mother on a regular basis. These strategies included speaking slower, more distinctly, and slightly louder than normal; repeating new vocabulary and functional phrases many times; modeling responses to sounds and speech; varying intonation to highlight new words or phrases; recasting Bobby’s verbal and nonverbal attempts to communicate into spoken and signed language; and encouraging Bobby to attend to speechreading cues. In addition, clinician-made materials were sent home to reinforce learning.

Auditory Training

Bobby’s initial auditory training goals targeted consistent identification of nonspeech sounds, such as hitting a drum or ringing a bell, and the recognition of the sounds associated with objects pictured in “talking” books (i.e., books with sound-producing computer chips). Improved speech perception was initially addressed by asking Bobby to identify words varying in syllable number and to recognize frequently occurring words (e.g., Bobby’s name, ...
family and clinician names, favorite toys) and short phrases (e.g., *sit down, red car*). Many of these items were suggested by his mother to address communication needs at home and at school.

An analytic approach was used to highlight differences in suprasegmental and segmental speech features (see Appendix). During these activities, minimal pair pictures or objects were introduced in three ways: first with auditory, sign, and speechreading cues; then with auditory and speechreading cues; and finally with auditory cues only. This progression provided Bobby with many opportunities to hear and remember the names of the target words. Initially, Bobby did not respond consistently to a two-choice listening task, and so his clinicians had to demonstrate the task repeatedly. Praise, encouragement, and tangible reinforcers (e.g., game or puzzle pieces) were needed to maintain Bobby’s attention and motivation.

Several techniques were helpful for improving Bobby’s listening skills. These included repeating new vocabulary words several times using a distinctive and consistent intonation pattern, choral word productions, and sabotage (Robbins, 2000). Sabotage was used to make sure that Bobby was listening attentively. For example, following a correct identification of an object by Bobby, the clinician would mislabel the item to see if Bobby would recognize the “mistake.”

Although Bobby was sometimes distracted or resistant, he was usually attentive during short periods of auditory training. He readily gave responses when his confidence was high, but required many models and much encouragement when new word pairs were introduced. During the latter times, he would often not make a choice rather than risk a mistake. When he did misidentify an item, the clinician repeated the target word with speechreading cues to provide a multisensory model. Auditory-only models were then presented again to reinforce the target contrast through hearing alone.

Word pairs differing by the number of syllables were introduced early in intervention because these words can be recognized on the basis of speech timing, a relatively gross acoustic cue. Most cochlear implant users are able to identify suprasegmental cues (i.e., stress and timing patterns) soon after implantation (Fryhauf-Bertschy et al., 1997). Word pairs with one versus three and one versus two syllables (e.g., *orange* vs. *strawberry, pig* vs. *donkey*) were introduced and practiced for approximately 10–15 minutes during each session. At the end of Bobby’s second semester in the clinic (22 sessions), he identified words differing by number of syllables with better than chance accuracy (75%–81%) in the auditory-only condition and 100% accuracy with auditory and speechreading cues.

Contrasts between phonemically dissimilar words with the same number of syllables (i.e., words with different consonants and vowels, such as *car* vs. *sheep*) were targeted next. These kinds of words were selected to begin auditory training at the segmental level because they provide grossly different acoustic waveforms but similar timing and stress characteristics. After two semesters of practice, Bobby identified phonemically dissimilar words with 60%–70% accuracy on two-choice, auditory-only tasks and 90%–100% accuracy when both speechreading and auditory cues were provided.

Bobby’s program also sought to increase auditory comprehension in meaningful contexts. Synthetic auditory training activities included practice in name recognition, recognition of phrases in routines (e.g., “Get your shoes,” “Take a bath,” “Time to eat”), and statements and questions (e.g., “No more monkeys,” “Whose turn?,” “Where’s the swing?”). “Predictable” books (e.g., *Brown Bear, Brown Bear*; Martin & Carle, 1967) seemed particularly useful for stimulating auditory skills and language comprehension. They were used in the following way. Bobby’s mother and the clinicians would take turns reading pages from a selected book. At the end of each page, Bobby would provide a signal to turn to the next page by tapping a toy xylophone or cymbal. The entire book was read in this way while it was audio-recorded. Bobby then took the audiotape and book home so that he could listen to the story by himself or as an adult pointed to each word. Bobby’s mother reported that he enjoyed these stories and would often listen to them by himself.

In summary, after 2 years of implant experience, Bobby was just beginning to recognize and discriminate relatively gross acoustic patterns consistently. His awareness of speech and environmental sounds had improved, but his association of speech with meaning was emerging slowly. His limited progress and the large number of remaining goals in the Appendix suggest that Bobby needed more intensive auditory training to distinguish the acoustic features of English.

### Speech Production Training

Three main speech goals were selected for Bobby: (a) increased quantity and complexity of vocalizations, (b) expansion of consonant and vowel inventories, and (c) increased word production. These goals were addressed by modeling vowels and canonical vocalizations for imitation (e.g., *CV, CVCV* syllables, and babbling) and by encouraging Bobby to imitate and say key words and phrases during all activities. Target words contained consonants and vowels that were spontaneously produced in order to simplify the transition to meaningful speech. Bobby’s relatively rare spontaneous productions were reinforced through repetition, meaningful responses, and encouragement. His mother was shown how to reinforce Bobby’s speech at home by restating the intended meanings of his vocalizations and responding to them.

Real-time spectrographic displays (Sensime trics Speech Station 2.1, 1989; SpeechPrism, 1999) were used to provide an instantaneous visual feedback/reinforcement for speech, to increase vocalizations, and to expand phonetic inventory (Ertmer & Stark, 1996). Bobby enjoyed watching the display to see how his vocalizations affected the spectrographic pattern on the computer monitor. He was also surprisingly accurate in imitating a variety of isolated vowels and canonical syllable strings when the display was used. For example, he produced stops, fricatives, affricates, nasals, and a wide range of vowels in syllables following a

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clinician’s model. He also attempted approximations of words such as three, witch, puppy, and butterfly. His imitations of words of one to three syllables in length usually contained the appropriate number of syllables. Four-syllable words were usually produced with only three syllables. Velar consonants were typically imitated as alveolars. His vocal pitch and voice quality seemed appropriate for his age during these activities.

Despite Bobby’s relatively good imitative skills, little change was noted in his spontaneous speech. A 30-minute mother–child play session recorded approximately 1 year after he began intervention revealed that more than 90% of his vocalizations were precanonical in nature. Although his mother reported that he said the words mom, bye, and bus on request, Bobby produced little meaningful speech at home or in the clinic.

Language Stimulation

Initial language goals for Bobby focused on improving receptive and expressive vocabulary through the use of sign and speech together. New vocabulary words were introduced in semantic categories such as foods, furniture, and animals so that they could be associated and remembered more easily and reinforced in thematic activities. “Wh” questions were modeled and used to check comprehension (“What is that?” or “Where is the giraffe?”). Verbs were introduced and demonstrated and then applied to “following direction” activities. Clinician models emphasized single words and semantic relations that were at or slightly above Bobby’s mean length of utterance (MLU) (i.e., 1–3 signs/spoken words).

Bobby usually required many demonstrations before he would try new activities but responded cooperatively to game-like activities once he understood them. Several strategies appeared to be particularly useful for language stimulation. New vocabulary and phrases were modeled several times in an emphatic, melodic manner during experiential play or structured teaching activities. Pictures and objects were held near the speaker’s face to encourage the use of speechreading cues. Functional phrases (e.g., “I want __.”, “Your turn.”) were emphasized in relevant contexts. “Hide and Seek” activities were highly motivating and allowed practice with two- and three-word phrases (e.g., “Get big boat.”) and questions (e.g., “What’s inside?”).

After 1 year of intervention and 2 years of implant experience, Bobby continued to express himself mainly through gestures, eye gaze, and single signs during intervention sessions and at home. Two sign combinations were observed infrequently but appeared to be increasing. Bobby appeared to understand most practiced vocabulary words and “what” and “where” questions in a variety of contexts. Recent testing resulted in a single word/sign receptive vocabulary age of 3:7 on the Peabody Picture Vocabulary Test–Third Edition (Dunn, Dunn, & Dunn, 1997). This score reflected a gain of 22 months in a 6-month period. Comprehension and expression age-equivalent scores from the RDLS were lower, at 2;4 and 1;11, respectively. These test results suggested that Bobby was making greater gains in comprehension than in expression. As with auditory perception skills and speech production skills, his language skills showed a slow rate of increase when compared with the average performance of other children with cochlear implants (Robbins, Svirsky, & Kirk, 1997; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999).

Discussion

Although Bobby’s communication skills emerged slowly following implantation, it should be remembered that his improvements exceeded those that could be reasonably expected through the continued use of hearing aids. In particular, his increased potential for oral communication was seen in his responses to environmental sounds, his discrimination of suprasegmental contrasts, and his speech imitation abilities. Bobby’s limited progress in associating sound with meaning, however, provides an opportunity to consider some of the factors that might promote or impede communication development after implantation. These can be sorted into three main categories: within-child factors, technological factors, and intervention efficacy. It seems likely that aspects of each of these categories combined to affect Bobby’s progress.

Within-child factors. Bobby’s limited communication gains may be related to an expressive language disability that affected both sign and oral communication. This possibility is supported by three pieces of evidence: (a) much higher receptive than expressive scores on the RDLS, (b) a large discrepancy between comprehended and produced signs reported on the MCDI, and (c) his extremely limited signed and spoken output in everyday situations. Although recent increases in receptive vocabulary are encouraging and might translate into improved expressive vocabulary in the future, Bobby’s expressive signing skills remained much poorer than would be expected given his high nonverbal intelligence scores and his long-term exposure to signs.

Bobby’s communication difficulties also extended to spoken language. His slow rates of improvement in auditory perception and speech production suggested that speech models were difficult to recognize or comprehend via his implant. Children with language disabilities in addition to hearing impairments may have considerable difficulty processing and interpreting the electrical signal provided by cochlear implants. Improving speech perception is likely to require intervention that is more intensive than that needed by children who have no secondary disabilities.

Finally, Bobby’s personality may also have contributed to his slow development of communication skills. Two of the most prevalent impediments to learning in Bobby’s sessions were his shyness and his reluctance to try new tasks. These behaviors reduced the efficiency of many activities because clinicians had to wait for Bobby to respond and were required to present new vocabulary and concepts many times before he ventured a reply. In short, Bobby seemed to be an insecure, limited communicator who exhibited little self-motivation to expand his communication skills. One encouraging exception to this situation is Bobby’s emerging interest in printed words. He has
begun to ask for written labels for objects at home, school, and in the clinic. Reading and writing may eventually help to promote further gains in spoken and signed communication.

**Technological factors.** Three technology-related concerns might also have influenced the rate of Bobby’s progress. First, Bobby’s aided thresholds ranged between 35 and 50 dB HL for the frequencies 0.5–4 kHz (three frequency PTA = 42 dB HL). At this level, conversational speech was likely to be detectable, but not easily perceived, and masking of speech by background noises may have been common. Thus, ambient speech models may have been perceived only intermittently. In addition, Bobby appeared to be especially sensitive to sounds of seemingly moderate loudness. For example, startle-like responses involving jerking of the torso and, occasionally, falling on the floor, were observed when pure tones louder than 65 dB HL were presented in soundfield. These reactions suggested the presence of a small dynamic range and recruitment. These conditions may further reduce opportunities to process and comprehend speech.

Because of cochlear ossification, only 11 of 22 electrodes were inserted and activated. Although partial insertion means that a smaller section of Bobby’s auditory nerve was stimulated than is typical for children with implants, research has indicated that gains in speech perception are still possible. Findings from a recent study by Kirk, Sehgal, and Miyamoto (1997) showed that, after 1½ years of implant experience, children with 9–13 active electrodes achieved closed- and open-set speech perception scores comparable to those of age-matched peers with full insertions. Taken together with Bobby’s relatively strong imitation ability, this finding suggests that partial insertion of the electrode array is not a major contributor to his delay in developing speech perception skills.

The third technological concern involved the frequent breakdowns of his device. Bobby’s implant was broken at least six times in 2½ years. The memory of his processor was erased by static electricity discharge several times. This problem was sometimes solved by an immediate trip to his implant center (80 miles one way) for remapping. On other occasions, the trip was delayed and Bobby was without his implant for several days. Cords for his implant have broken four times and replacement has taken between 3 and 17 days each time—mainly because the family could not order parts by phone without a credit card. Such extended periods without auditory stimulation certainly had negative consequences for oral communication and language development. These problems could have been circumvented or lessened by avoiding plastic play equipment and other sources of static electricity, and by keeping spare parts on hand.

**Intervention efficacy.** The three main settings for Bobby’s habilitation were the home, his preschool, and our clinic. Whereas many aspects of these settings promoted communication skills, others were less than optimal for language learning. Bobby was clearly a happy child who was talked to, played with, and included in family activities. His needs were a high priority for the family, as evidenced by the parent’s involvement in educational planning and in seeking services through our clinic. As with other young children who have communication impairments (Rossetti, 2001), even supportive parents need to learn and apply special strategies to facilitate language development as efficiently as possible. Although Bobby’s implant center provided counseling and lists of strategies for stimulating listening and spoken language, it was observed that many of these suggestions were not implemented consistently.

Three main concerns were identified when reviewing mother–child interactions soon after intervention was begun in our clinic. First, Bobby’s mother used signs infrequently (approximately 12% of the time), and her signing vocabulary was restricted mainly to single signs for nouns, a few verbs, and a few adjectives. This level of signing skill is understandable given that the family learned to sign through printed materials rather than formal instruction. Bobby’s family would have benefited to a much greater extent from family-centered sign instruction that included language facilitation techniques, signing role models, and opportunities to ask questions (Moeller & Luetke-Stahlman, 1990). A second concern centered on spoken communication. Bobby’s mother consistently used speech when communicating with him, and many of her utterances were appropriate, context-related single words or short phrases. Her speech, however, was often so low in intensity that it may not have been detected by him. Limited signing and soft speech, if also present in the home, suggest that neither communication modality was optimal on a regular basis. Finally, maternal requests for oral or signed communication were seldom observed during mother–child interactions. Without consistent expectations for the use of signs and speech, Bobby had little reason to go beyond eye gaze and gestures to communicate. These concerns emphasize the importance of ongoing family-centered intervention by professionals who are familiar with the needs of young children with implants. The fact that Bobby’s mother began to use more signs, speak louder, and require communicative responses after she received instruction shows that parents can become effective agents for language development when given adequate support.

Although Bobby’s rural special education cooperative attempted to provide appropriate services, his program was not sufficient to address his communication needs and take advantage of his improved hearing. For example, within Bobby’s multicategorical preschool classroom, he did not receive daily instruction from a teacher of the hearing impaired, the curriculum was not designed to address his functional communication deficits, and he had no exposure to signing peers. Even though Bobby was assigned an interpreter, she often signed without speaking. Such inconsistent emphasis on oral communication was not optimal for developing Bobby’s speech and oral language skills. Additionally, although Bobby’s teacher received consultation from a speech-language pathologist, Bobby himself received little, if any, individual speech-language therapy.

It was apparent after meeting with school personnel that they desired to know more about ways to help Bobby, but
they were unfamiliar with implant technology, the education of children with hearing impairments, and the processes of aural rehabilitation. They voiced a desire for ongoing and on-site guidance from cochlear implant professionals so that they could develop and implement an appropriate program for Bobby. Some implant centers now employ educational consultants and communication professionals to serve as liaisons with local service providers. Bobby’s situation underscores the importance of this service (Archbold, 2000).

The intervention provided in our clinic must also be scrutinized if a clearer picture of Bobby’s situation is to be gained. At least three aspects of our program could have been improved. As mentioned previously, Bobby was seen for only one 90-minute session per week. Children of preschool age typically respond better to shorter and more frequent periods of individual instruction. Given his severe language deficits and his increased potential for oral communication via his implant, more intensive intervention was warranted. Daily sessions of 30–45 minutes and close consultation with his classroom teacher would have improved his chances for success. Second, Bobby worked with different graduate students each semester. His progress may have been impeded by the time it took for him to adjust to them and cooperate fully. Finally, we used simultaneous communication with Bobby because of his family’s experience with MCE and because he exhibited such limited communication in any modality. This approach provided visual referents for spoken information; however, it may have promoted continued reliance on sign rather than speech for communication.

**SUMMARY**

One of the most consistent research findings for children with cochlear implants is that listening, speech, and language outcomes vary across children (e.g., Fryhauf-Bertschy et al., 1997; Zwolan & Ashbaugh, 1998). The two cases described here appear to represent the moderately high and low ends of the outcome spectrum—at least for the time period that was studied. As such, they required different strategies to stimulate learning at a level that was developmentally and functionally appropriate. Drew’s case highlighted the need to “keep up” with rapidly emerging auditory skills while addressing speech and language deficits. Bobby’s slow progress underscored the many challenges that confront parents, clinicians, teachers, and school personnel who have a limited understanding of implant technology and aural habilitation. Finally, it is important to remember that the described treatments were based on knowledge of speech acoustics, techniques that have been shown to be effective with children who have language disorders, and recommendations by experts who work with young implant recipients. A controlled evaluation of the outcomes of these treatments was not undertaken. Future treatment efficacy studies are essential for designing specialized interventions to meet the communicative needs of children with cochlear implants.

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APPENDIX. ANALYTIC AUDITORY TRAINING PROCEDURES AND GOALS

General Procedures for Auditory Training With Minimal Pair Words

1. Introduce minimal pair words by saying each word several times as you place pictures or printed words in front of the child. Encourage the child to pay attention to auditory and speechreading cues by holding the cards/objects close to your face as you name them. Discuss any unfamiliar words. Objects, rather than pictures, should be used whenever possible to hold the interest of toddlers and preschoolers.

2. After introduction, place picture or word cards representing two minimal pair words in front of the child. Present one of the words without speechreading cues by covering your mouth with a screen (a needlepoint hoop with two layers of loosely knit cloth). For example, say “Show me cat” while covering your mouth as the child chooses between “cat” and “rat.”

3. The child repeats the target word aloud and then points to the picture, printed word, or object that represents that word. Tokens and game pieces can be given as reinforcers to maintain interest.

4. The target word can be repeated with or without speechreading cues as a prompt whenever an incorrect choice is made. If speechreading cues are provided, allow the child to see you say the word and then say the word again while covering your mouth with a screen.

5. Randomize the order of the words as you say them. Work at a steady, brisk pace to present 10 trials for each pair of words. Three to five word pairs can be presented in 10 minutes, depending on the child’s concentration. Keep a tally of correct and incorrect responses to determine when criterion has been reached.

Modifications to Enhance Auditory Skills (Adapted From Robbins, 1990; Tye-Murray, 1993)

1. Include a variety of male and female “talkers” in auditory training.

2. Whenever possible, incorporate personally meaningful words in training. For example, family names, spelling words, numbers, and vocabulary words can be used in practice.

3. Include progressively longer and more difficult materials (e.g., three or more choices, sentences, multiple step directions).

4. Keep listening activities “light” by the use of positive feedback, encouragement, false assertions, and humor.

5. Allow the child to assume the role of the “talker” as you act as the listener.

6. Include contrasts in the final and medial, as well as initial, positions in words.

7. Emphasize listening practice during all activities (i.e., board games, stories, experiential play, conversations), as well as during analytic auditory training activities.

Sequence of Contrasts for Analytic Auditory Training

A. Identification of nonspeech sounds:
1. Determining the presence or absence of sound
2. Recognizing noise makers and musical instruments
3. Recognizing sounds associated with common household items

B. Identification of suprasegmental feature cues:
1. Long vs. short duration of sounds (e.g., /a:/ vs. /a/)
2. Continuous vs. interrupted sounds (e.g., /s/ vs. /سائل /س/ /س/ /س/ /س/)
3. Syllable number (e.g., 1 vs. 3, 1 vs. 2 syllable words)

C. Identification of phonemically dissimilar words:
1. Contrast words that have the same number of syllables but different vowels and consonants (e.g., shoe vs. tie, cupcake vs. pencil)

D. Identification of segmental (vowel and consonants) features:
1. Vowels in isolation and in minimal pair words
   a. Wide vowel contrasts: [i, æ, u, o, ə] (e.g., heat vs. hat, home vs. ham)
   b. Narrow vowel contrasts: /ɪ/ vs. /iː/ vs. /æe/ vs. /æ/, /ɑː/ vs. /oʊ/, /ɔː/ vs. /jɑː/ vs. /æ/, and /əʊ/ vs. /ʌ/ (e.g., beat vs. hit, hope vs. hop)

2. Consonant manner of production in minimal pair words:
   - stops vs. fricatives
   - stops vs. affricates
   - stops vs. nasals
   - nasals vs. fricatives
   - nasals vs. affricates
   - nasals vs. liquids
   - nasals vs. glides

3. Consonant voicing features with minimal pair words:
   - [f/s] vs. [t/v]
   - [d/z] vs. [p/b]
   - [θ/ð] vs. [t/d]
   - [k/ɡ] vs. [p/b]

4. Consonant place features (two or three word sets can be used):
   - [p/t/k] vs. [f/s/ʃ]
   - [j/w] vs. [θ/ʃ]
   - [b/d/g] vs. [m/n/ŋ]
   - [l/r] vs. [θ/ʃ]
   - [v/ʊ] vs. [θ/ʃ]

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