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BETWEEN HARD-OF-HEARING AND DEAF CHILDREN.

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SPEECH AND HEARING SKILLS: A COMPARISON BETWEEN HARD-OF-HEARING AND DEAF CHILDREN

by

TONI GAIL GOLD

A dissertation submitted to the Graduate
Faculty in Speech and Hearing Sciences in
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CHAPTER I

INTRODUCTION

Normal speech and language development in the child is greatly dependent upon auditory input. The child normally learns to speak by understanding the speech that he hears from others and by imitating their output and devising new utterances of his own. When the auditory channel is defective due to hearing impairment, the normal process of speech and language development may be stopped or delayed. The speech which does develop is typically characterized by numerous articulatory errors, faulty rhythm and abnormal voice quality. The degree of difficulty that is manifested is in part related to the severity of the hearing loss incurred.

The frequency and nature of articulatory errors in the speech of the hearing-impaired has been studied rather extensively. As hearing loss increases, at least up to 90 dB HTL, it is generally believed that the number of segmental errors increases and intelligibility is reduced. However, this relationship is not a simple one. Smith (1972) noted that there were instances in which several of her deaf subjects had the same number of articulatory errors but differed greatly in the degree of intelligibility. She attributed this to differences in the children's prosodic skills, a factor whose contribution to intelligibility is not a new discovery. Yet since the turn of the century when Alexander Graham Bell (1916) noted the importance of natural "accent and rhythm" for the intelligibility of a speaker, only limited progress has been made in identifying and measuring these prosodic features and in isolating them from articulatory features.

Hudgins and Numbers (1942) determined that sentences produced with "normal rhythm" were four times more likely to be understood than those produced with incorrect rhythm. However, they also noted that those sentences spoken with normal rhythm generally had fewer articulatory errors while those with faulty rhythm generally had more articulatory errors. This suggests that the two factors of articulation and rhythm are closely interrelated and cannot easily be separated. Smith (1972) also evaluated "non-phonemic and suprasegmental aspects of speech" (p. 45) for her deaf subjects. She found that judgments on voice, quality, pitch, control, stress, fluency and rate were too highly variable to allow for a clear determination of the effects of these factors on intelligibility. Later, Levitt et al. (1975) devised a test of prosodic feature production which evaluated production of the features of stress, pause and question intonation in controlled test sentences. The test was administered to children in schools for the deaf and provided a measure of their ability to produce some of the more important prosodic features of speech.

Recognizing that intelligibility is dependent as much on good speech reception skills as on good speech production skills, Smith studied various measures of residual hearing as they related to intelligibility. Of the variables considered (including prosodic reception of tonal stimuli, phonemic reception, and pure tone thresholds for various frequencies alone and in combinations) the highest correlation was found between performance on the Phoneme Reception Test and speech intelligibility. Smith tested profoundly deaf children in schools for the deaf. Observations made about this population can not necessarily be extended to the less severely hearing-impaired. The effects of the degree of hearing loss on speech intelligibility and related skills is an important consideration in the education of children with milder hearing losses and these effects need to be investigated.

The primary aim of this study was to investigate the relationship between measures of residual hearing and speech production in hard-of-hearing children. These children are to be found almost exclusively in regular schools and not in schools for the deaf. Therefore, findings based on this population alone would reflect differences in educational settings as well as in degree of hearing loss. Since there are also a considerable number of deaf children who have been mainstreamed into the regular schools, this allows a more balanced study of both hard-of-hearing and deaf children within the same school system. In addition, differences between deaf children in schools for the deaf and in regular schools could also be studied.

A secondary aim of this study was to develop improved methods of testing prosodic feature reception and prosodic feature production skills since present measures of these skills appear to be inadequate.

The purpose of the present study is two-fold:

(1) to determine whether there are significant differences between hard-of-hearing and deaf children on various tests of phonemic and prosodic speech production and reception skills and
(2) to determine which of these skills correlate most highly with speech intelligibility.

CHAPTER II

REVIEW OF THE LITERATURE

Speech Production Skills

Overall Speech Intelligibility

One of the major considerations in the education of the deaf is that of achieving a level of speech competence such that the individual can make himself understood to the "person-on-the-street". Various investigations in recent years have indicated that only about 20% of the speech output of the deaf is understood by inexperienced listeners (Brannon, 1964; John and Howarth, 1965; Markides, 1970; Smith, 1972). In each of these studies severely to profoundly deaf children in the age range from six to fifteen years were asked to read test materials or to speak spontaneously about an event or a picture. Recordings were made of their verbal output. Later, inexperienced listeners wrote down the words they could recognize and a score was calculated from the number of intelligible words relative to the number of words produced.

Hudgins and Numbers (1942), who were the first to report data using this technique, had both hard-of-hearing and deaf children read special sentences and asked the children's teachers to listen to their speech and give them a score for the number of words correctly produced.

The mean score for the group of eight to nineteen-year-olds was about 29%. This slightly elevated score compared with that reported by the studies mentioned above is probably the result of a combination of the additional experience of the listeners and the less severe hearing losses of some of the subjects. When Markides (1970) asked inexperienced and experienced listeners to evaluate the speech of his deaf subjects, the mean intelligibility scores obtained were 19% and 31%, respectively. Mangan (1961) also found that scores given by experienced listeners were 10% to 15% higher than those given by inexperienced listeners, for the same deaf speakers. Thomas (1964) reported that scores were about 10% better for words and about 25% better for sentences when the listeners were experienced.

Mangan asked teachers to watch and listen to their children as they read fifty familiar phonetically balanced words. The mean intelligibility score was 65%. This 35% increase over the approximately 30% intelligibility score obtained from other experienced listeners in other studies is in accord with what Hudgins and Numbers predicted would occur when listening situations were most like face-to-face conversation. Thomas also reported scores of 59% for experienced listeners using a look and listen system for evaluating the words produced by deaf speakers.

Regardless of the degree of experience of the listeners or of the extent that conditions are like normal, face-to-face conversation, the average speech intelligibility score for deaf children is poor. A review of the relevant literature should give some insight into why these scores are so low.

Production of Segmentals

Much attention has been given over the years to the articulatory errors made by deaf children. A comprehensive analysis of the speech production skills of hearing-impaired children was reported by Hudgins and Numbers in 1942. The authors studied 192 students at two schools for the deaf where the orientation was towards strict use of an oral teaching method. The subjects were between the ages of eight and twenty years. Their hearing losses covered a range from hard-of-hearing to profound deafness. The students were recorded while reading ten simple sentences and evaluations were made of their skills at phrasing, accentuation and rhythm as well as articulation. Correlations were measured with severity of hearing loss, age, educational setting and overall intelligibility.

Consonantal errors

Articulatory errors were classified in terms of those involving consonants and those involving vowels and diphthongs. Consonantal errors fell into the categories of voicing confusions, substitutions of one consonant for another, added nasality, misarticulation of consonant blends, misarticulation of abutting consonants and omission of word initial or word final consonants. Hudgins and

Numbers found voicing errors, omission of initial consonants and misarticulation of consonant blends to occur most frequently. Voicing errors usually consisted of the substitution of a voiceless cognate for the intended voiced one.

Voicing errors

Since that classic investigation, numerous other studies have been concerned with the nature of the hearing impaired child's articulation. Voicing errors are reported frequently. Markides (1970) tested eighty-three hard-of-hearing and deaf children at five schools for the deaf and partially-hearing in Manchester, England. All of the children were either seven or nine years old. They took an articulation test consisting of twenty-four pictorially presented monosyllabic words. Test results showed that when voiced stops were intended, the voiceless cognate was frequently substituted. Mangan (1961) had both experienced and inexperienced listeners evaluate the speech production ability of twenty-one deaf and nine hard-of-hearing children reading a list of familiar phonetically balanced words. A common error reported was that of devoicing of the final voiced consonants. Nober (1967) studied forty-six hard-of-hearing and deaf children between the ages of three and fifteen years at the Mill Neck Manor School for the Deaf. He reported that intended voiceless sounds were more often produced correctly than intended voiced sounds. Although this is not the same as the finding that voiceless sounds are substituted for voiced ones, it still implies that voiced sounds are harder to produce.

Contrary to these findings, Smith (1972) reported a reverse tendency of a greater proportion of substitutions of voiced sounds for their voiceless cognates as opposed to voiceless for voiced substitutions. She tested forty deaf children at the Lexington School for the Deaf, a strictly oral school. The children were asked to read twenty specially designed sentences which incorporated all of the most frequently used phonemes of English and included, whenever possible, transitions to and from the vowels /i/, /æ/ and /u/ with each of the seven places of articulation. The words were in the expected vocabulary range of eight year old deaf children (Smith, 1972, p. 39). Voicing errors were found to be very numerous in this deaf population. Heider et al., (1941), in a study of spontaneous speech vocalizations of hard-of-hearing and deaf children ages three years-ten months to six years-ten months, reported a greater tendency to use voiced sounds than their voiceless cognates. Carr (1953) also reported the tendency for young deaf children to produce more voiced sounds than voiceless ones in spontaneous speech. Neither of these reports indicated whether the voiced sounds were appropriate to the utterance or whether they may have been replacing intended voiceless ones.

If the predominance of voiced phonemes over voiceless ones is generally the case, then it may be a manifestation of the problem of continuous phonation attributed to many severely hearing impaired individuals. This condition is characterized by voice continuing after the completion of a phrase or starting before an utterance (Millin, 1971). This tends to make all phonemes sound voiced. Another explanation for the high incidence of voicing errors may be that the problem is not due so much to the lack of voicing distinctions in consonants. Instead, the duration of the preceding vowel may affect the listener's perception of the presence of voicing in the consonant (Denes, 1955; Raphael, 1972). Although voicing errors were numerous, there was only a modest correlation between the number of voicing errors and overall speech intelligibility in Smith's study (1972). Hudgins and Numbers had reported voicing errors along with errors in consonant blends and omission of the initial consonant to have an important effect on intelligibility.

Omissions

Several researchers (Hudgins and Numbers, 1942; Markides, 1970; Smith, 1972) have reported that omission of the intended consonant is a frequent error type in the speech of the deaf. Hudgins and Numbers noted a difference in the significance of these omissions to intelligibility based on whether the omissions occurred in initial or final position in the word. Although the error type occurred frequently in both locations, there was a correlation of -.56 between intelligibility and omissions in initial position and a correlation of only -.16 for omissions in final position. In contrast, both Markides and Smith reported high correlations between intelligibility and omissions in final position (r=-.87, -.65, respectively). Caution must be exercised in interpreting correlations. Although a particular error may occur frequently as intelligibility decreases, one can not be certain that correction of the particular error would improve intelligibility significantly. There are frequently interrelationships between error types which are not entirely apparent on the surface. For example, Error A causes a substantial reduction in intelligibility whereas Error B has little effect on intelligibility. However, Error B occurs almost every time Error A occurs. There will thus be a large negative correlation between Error B and intelligibility as there is between Error A and intelligibility. Despite the high correlation between Error B and intelligibility, correction of Error B will have little effect on intelligibility.

Position of error in word

Whereas Hudgins and Numbers reported a high incidence of consonant errors in initial position in the word, in more recent years, a greater frequency of errors on consonants in word final position has been reported. Nober (1967) found the order of consonant errors to increase according to position in the word from initial to medial to final. For both the partially-hearing and deaf children studied by Markides, errors involving the final consonants were more numerous than errors involving initial consonants. Although both kinds of errors correlated highly with intelligibility (r=-.87 for each), final consonant errors were reported in the three highest ranking articulatory error categories affecting speech intelligibility. Smith's subjects also had a marked increase in the number of errors for consonants in final position over initial or medial position.

Consonant blends

Production of consonant blends was not always tested by the numerous examiners of deaf speech. Hudgins and Numbers reported that the frequency of errors in consonant blends had an important effect on the listener's ability to understand the child. The children were reported to add an additional vowel, usually /ə/, between the two elements of the blend, thus changing the rhythm of the utterance, or else they eliminated one of the elements. Correlations of intelligibility with errors in consonant blends were -.47 and -.41, respectively, for the two schools tested. Brannon (1964) tested twenty deaf children on the Templin-Darley Screening Test of articulation and found misarticulation of consonant blends to be an important error. Smith tested /p,t,k/ and /s/ in blends for older children only and found omission of one element or the other of the blend to occur frequently.

Place of articulation

There is general agreement in the literature regarding better production of bilabial sounds than other consonants both in isolated words and in sentences (Nober, 1967; Huntington et al., 1968; Levitt et al., 1974) and in spontaneous speech of young deaf children (Heider et al., 1941; Carr, 1953). Carr reported her deaf children to use more front consonants than back consonants and more front vowels than normal hearing children used. Nober, testing consonant production in isolated words, found that as the place of consonant production moved further back in the mouth, the chances of it being produced correctly decreased with the exception of glottal sounds. The order of correct production of consonants which he reported was as follows: bilabials, 59%; labiodentals, 48%; glottal, 34%; linguadentals, 32%; lingua-alveolars, 23%; linguapalatals, 18%; and linguavelars, 12%. These findings are in fairly good agreement with the concept that those sounds which are more visible are easier for the deaf child to produce since he can rely on a sensory avenue which is functioning normally to supply him with input. Huntington et al. (1968) made EMG measurements from the oral articulators of two normal subjects and two deaf adults who had had consistent speech therapy since the detection of their hearing problems before they started school. Although they found that the deaf were more likely to produce a consonant correctly if they had a visual model to follow (i.e., the more visible sounds

/b,m,w/) they suggested that visibility itself was not the crucial factor determining why bilabial sounds were more often correct than other consonants. They proposed that tongue movements were actually harder than lip movements and therefore, lingua-alveolars, linguadentals and linguavelars would be hard to produce. This interpretation is also consistent with the observation cited above (Nober) that the frequency of correct production of the glottal consonants is greater than that of the linguadentals, lingua-alveolars, linguapalatals and linguavelars.

Errors in vowels and vowel-like sounds

Basic error types

Hudgins and Numbers classified vowel and diphthong errors into five categories: (1) substitution of one vowel for another, (2) distortion of diphthongs, (3) neutralization, (4) diphthongization and (5) nasalization of vowels. In terms of absolute numbers of errors, there were far more vowel substitutions than any other category of error. However, when comparing the number of distortions of diphthongs with respect to the number of times a diphthong was the intended sound, the relative frequency of this error type is much greater than of any of the categories of vowel errors. In 1970, Markides also reported diphthongs to be harder than vowels for the deaf children to produce.

Diphthong errors in the deaf have been reported to be prolongation of both phoneme parts (Hudgins and Numbers), elimination of the second element (Hudgins and Numbers, Markides, Smith), omission of the first element (Mangan) or substitution of the neutral schwa for the intended diphthong (Markides).

Vowel errors

With respect to vowel substitutions, Hudgins and Numbers and Markides reported the tendency for the deaf speakers to substitute vowels that were not closely related in terms of articulatory position to the intended one. Other investigators found a high incidence of tense-lax confusions (Smith) and substitutions from adjacent sounds on the Northhampton Chart (Mangan). In fact, Mangan took this as encouragement that only small modifications were needed in order to train the deaf to produce the correct target sound.

Although not considered highly significant vowel errors by Hudgins and Numbers, other investigators have reported the problems of neutralization (Heider et al., 1941; Markides, 1970; Smith, 1972), diphthongization (Boone, 1966; Markides, 1970) and nasalization (Martony, 1965, 1966) of vowels.

Back vowels, as a rule, were produced correctly more often than front ones (Mangan, 1961; Nober, 1968) and vowels with low tongue position were correct more often than those with mid or high tongue position (Nober). This supports Boone's theory (1966) that the deaf have different resonance patterns because they tend to keep their tongues too far back and too low in their mouths, thus interfering with correct production of front and high vowels but achieving better production of back and low ones.

Some studies report a predominance of neutral vowels in the deaf child's speech (Heider, Smith). Further evidence in support of this finding is furnished by Angelocci, Kopp and Holbrook (1964) who studied spectrographs made by eighteen eleven to fourteen-year-old males reading CVC words. Fundamental frequency and formants were analyzed. Results showed that the ranges of frequency and amplitude for the first three vowel formants for the deaf subjects were smaller than for the normal subjects of the same age. A plot of the frequency of F_1 against F_2 showed a high degree of overlap among the vowels produced by the deaf speakers. Also F_1 and F_2 values for each vowel tended toward those for the neutral vowel.

Relative frequency of consonant and vowel errors

Regardless of whether children were tested on speech production in continuous speech or on isolated test words, researchers have found that consonants are more often in error than vowels and diphthongs. For test words in sentences, Hudgins and Numbers reported 21% consonant and 12% vowel errors for their deaf subjects, while Smith found 53% consonant errors and 39% vowel and diphthong errors for her deaf population. Both Brannon (1966) and Markides found more consonant than vowel errors when the phonemes appeared in isolated test words. Markides' hard-of-hearing subjects produced 9% error for vowels and 26% error for consonants while his deaf group had 56% error for vowels and 72% error for consonants.

Several explanations have been offered for the higher incidence of errors reported for consonants than vowels. Brannon claimed that vowels are actually produced correctly more often than consonants since vowels carry more energy, are easier to hear and require less difficult tongue adjustments than consonants. On the other hand, Hudgins and Numbers noted:

> ...experimenters were less critical in determining the degree of vowel accuracy than that of consonants. The justification for this lies in the nature of the vowel itself and in degree of tolerance of the normal ear for a wide degree of vowel distortion (p. 321).

Moreover, Monsen (1976) suggested that because listeners perceive more consonant than vowel errors, it is not true that the articulation of consonants per se is worse than that of vowels. He writes:

> If we may assume that vowels in general convey to the listener more consonantal cues than consonants do vocalic cues, then it is reasonable that a reduction in effects of transition from one speech sound to the next may result in fewer consonants being correctly perceived than vowels (p. 288).

Finally, since more consonants than vowels are generally produced in running speech, there is a greater likelihood of there being more errors on consonants than on vowels.

In addition to the frequency of occurrence of consonant errors compared with vowel errors, consonant errors are generally believed to be more directly correlated with overall intelligibility than vowel errors are. Hudgins and Numbers reported rhythm and consonant articulation to be more important than vowel articulation in overall intelligibility. Markides found a correlation of -.87 between consonant errors and intelligibility and only -.66 between vowel errors and intelligibility. Although both error types correlated significantly with intelligibility, consonant errors were felt to play a more important role. However, caution must be exercised in interpreting these correlations. The frequency of occurrence of a particular error type must be taken into consideration when interpreting its effect on intelligibility. An error type which does not occur frequently may fail to show a significant correlation to intelligibility. However, when that error type does occur, it may contribute to a significant reduction in intelligibility. For example, omission of the intended vowel does not appear to correlate highly with intelligibility. This is due to the fact that it does not occur often. Yet when it does occur, it is generally an error of major size since it usually entails omission of an entire syllable (Levitt, 1977).

In general, correlations of phonemic errors to overall intelligibility are high and are fairly consistent across studies: Brannon (1964) -.79, Montgomery (1967) -.80, Markides (1970) -.87 and Smith (1972) -.80.

Summary: production of segmentals

There appears to be fairly good agreement in the literature that voicing errors and omission of consonants in word final position occur frequently in the speech of the deaf individual. However, there is less agreement with respect to the effects of these errors on overall speech intelligibility. Although Hudgins and Numbers reported voicing errors among those most important to intelligibility, Smith found that in spite of the high incidence of this error type, only a modest correlation (-.36) was found between voicing errors and intelligibility. Where Markides found a correlation of -.87 between final consonant omissions and intelligibility, Smith found a correlation of only -.65, and Hudgins and Numbers found a correlation of -.16.

Typical kinds of vowel errors reported are substitutions of another vowel made with very similar placement of the articulators as the intended vowel or substitution of a neutral /ə/ or /ʌ/. Consonantal errors are reported to occur more frequently than vowel errors and also appear, at least at first glance, to show a higher negative correlation to intelligibility than are vowel errors.

Production of Suprasegmentals

Although much attention has been given to the segmental errors made by the deaf, it has long been recognized that suprasegmental deficiencies contribute as much or more to the problem of poor intelligibility in the speech of the deaf. Hudgins and Numbers (1942) reported that those utterances marked by faulty rhythm (55% of all utterances) accounted for only 26% of all of the intelligible sentences read by their deaf subjects. However, the remaining utterances which were characterized by good use of rhythm, regardless of whether there were numerous articulatory errors, accounted for 74% of all of the intelligible sentences read. Thus it would seem that if a sentence is produced with appropriate rhythm it stands a better chance of being understood. The proper rhythm or timing of speech is affected by such factors as overall rate, duration of phonemes, pausing and grouping of syllables.

Timing

Rate

On the average, deaf speakers speak at a much slower rate than normal speakers (Rawlings, 1935, 1936; Voelker, 1938; Calvert, 1961; Boone, 1966; Brannon, 1966; Hood, 1966; Martony, 1966; Colton and Cooker, 1968; Boothroyd, Nickerson and Stevens, 1974; Nickerson, Stevens, Boothroyd and Rollins, 1974). In 1938 Voelker compared ninety-eight deaf and thirteen normal hearing children in grades one through three on reading rate. He found that the fastest deaf reader was slightly slower than the average normal reader. The average reading rates for the two groups were 69.6 and 164.4 words per minute for the deaf and normal hearing children, respectively. Nickerson et al. (1974) tested slightly older deaf and control groups on reading rate and still found large differences between the groups, although the mean rate for the deaf group was as high as 108 words per minute. This seems in keeping with Boone's (1966) findings that the rate of the speech of the deaf increases with age but still remains considerably slower than that of normal speakers. In addition to measuring the number of words per minute, Nickerson et al. studied their subjects' utterances in terms of number of syllables per second. They reported an average of 2.0 syllables or 4.7 phonemes per second for the deaf as compared with 3.3 syllables and about 8.0 phonemes per second for normal speakers. The number of syllables per second for the normal group is identical with the predicted number suggested by Pickett (1968).

The problem of reduced speaking rate for the deaf individuals seems to be related to the two separate problems of increased duration of phonemes and improper and often prolonged pauses within utterances.

Increased duration of phonemes

The duration of a phoneme bears important information in the perception of a speech message. Durational changes in vowels serve to differentiate not only between vowels themselves but between similar consonants adjacent to those vowels. Vowels are generally longer in the presence of voiced stops and continuants (House and Fairbanks, 1953; Denes, 1955; Raphael, 1972). This lengthening of the vowel contributes to the perception of the consonant. Unfortunately, however, the duration of phonemes is distorted in the speech of the deaf. There is a general tendency towards a lengthening of vowels and consonants (Angelocci, 1962; Calvert, 1962; John and Howarth, 1965; Boone, 1966;

Levitt, Smith and Stromberg, 1974). Angelocci claimed that his deaf subjects took four to five times as long to produce fricatives as did his normal subjects. The closure periods for plosives were also considerably prolonged. According to Hood (1966), training on duration of phonemes would improve intelligibility significantly if articulation was good.

Monsen (1974) studied twelve deaf and six normal hearing adolescents as they read fifty-six CV(C)'s containing the vowels /i/ or /I/. He found that the deaf subjects tended to create mutually exclusive durational classes for the two vowels such that the duration of one vowel could not approximate that of the other even when they occurred in the presence of different consonants. For the normal subjects, the duration of /i/ was always longer than /I/ for a particular consonant environment but the absolute durations of the two vowels could overlap if the accompanying consonants differed. Thus although the vowels produced by the deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely on normal decoding strategies to interpret what he heard.

Another manifestation of the problem of duration of phonemes relates to the differentiation between stressed and unstressed syllables. Nickerson et al. (1974) measured the duration of syllables in four short utterances read by twenty-five deaf and twenty-five normal hearing children.

They calculated the ratio of the duration of the stressed syllable to that of the unstressed syllable adjacent to it. The results showed that the deaf children failed to produce differences between the durations of the stressed and unstressed syllables that were as great as those produced by the normal hearing children. Although both the deaf and the normal children tended to prolong the syllable in phrase or sentence final position, the deaf subjects also produced the unstressed syllables with increased duration. Boothroyd, Nickerson and Stevens (1974) reported the unstressed syllables to take twice as long for the deaf as for the normals. Angelocci (1962) found that the durations of the unstressed vowels produced by the deaf speakers in his study were four to five times as long as the average of that produced by hearing speakers. This lack of differentiation between length of stressed and unstressed syllables contributes to the listener's perception of improper accent or stress in the speech of the deaf as reported by Hudgins (1946) and Levitt (1971). McGarr (1976) noted that when her one hundred and twenty-five deaf subjects read test sentences designed to evaluate their ability to produce stress, pause and rising intonation, one out of four subjects gave equal stress to all words, reading in a staccato fashion.

Duration is not only increased for unstressed syllables but for stressed syllables as well. John and Howarth (1965) found that the duration of monosyllabic words spoken by their deaf subjects was nearly twice that for the same words spoken by hearing children. A study is presently in progress in which recorded speech of deaf children is being manipulated by computer to alter deviant timing patterns (Osberger, 1977). Pauses are eliminated, and both absolute and relative duration of syllables are changed in an effort to produce more intelligible speech. Preliminary results show that for some subjects there were small improvements in intelligibility as the ratio of the duration of stressed to unstressed syllables was altered.

The overall tendency for increased duration of all phonemes in the speech of the deaf (Calvert, 1961; Hood, 1966) is felt to be related to the teaching of articulation of individual isolated elements rather than longer more meaningful units of speech (Rawlings, 1935, 1936; John and Howarth, 1965; Boone, 1966). Although the articulation of individual phonemes is extremely important for speech intelligibility,

> ...unless the proper relationships between sounds in sequence exist in the speech of deaf children it will be no more intelligible than were the results of synthesizing speech by stringing together isolated elements (John and Howarth, 1965, p. 129).

Normal transitional elements between phonemes and between syllables are necessary for the smooth flow of speech.

Interphonemic transitions

The deaf do not move their articulators correctly in proceeding from one phoneme to the next (Angelocci, 1962; Calvert, 1961, 1962; John and Howarth, 1965; Martony, 1965, 1966; Brannon, 1966; Levitt and Nye, 1971; Smith, 1972; Stevens, Nickerson, Boothroyd and Rollins, 1976). Calvert selected ten experienced listeners who said they could identify a deaf speaker by voice quality alone. He exposed them to recordings of vowels, diphthongs, mono- and bisyllabic words and sentences read by deaf and normal hearing speakers, speakers with harsh and breathy voices and speakers simulating deaf speech. For utterances involving vowels alone, the listeners achieved only 5% accuracy in judging what group the speaker belonged to. As the length of the utterance increased to include transitional elements between phonemes and words, accuracy of judgments improved until a score of 70% was achieved for sentences. Calvert concluded that identification of the deaf speaker is dependent upon dynamic factors of speech, the movement from one articulatory position to the next.

Intrusive elements are often joined to the intended vowel or consonant. Smith (1972) noted the presence of added attack consonants on vowels and added release vowels on consonants. Calvert (1962) referred to an intrusive glide, usually a /ə/, to describe the audible on and off glides of vowels in deaf speech. He noted that in normal speech these glides are clearly visible on Sonagrams but they occur rapidly and are inaudible. Rawlings (1935, 1936) proposed that part of the problem had to do with the fact that all phonemes were learned as releasing sounds and this adds extra syllables when the sounds should be arresting. Levitt (1971) suggested that while moving from one articulatory position to the next, the deaf child unintentionally emits extra sounds. Other kinds of transitional problems include the timing of voice onset relative to release of voiceless stops (Angelocci, 1962), of the onset of nasalization for nasal consonants (Stevens et al., 1976), and of the end of nasalization on nasal consonants (Martony, 1965, 1966).

Pauses

In addition to the altered durational patterns of the speech of the deaf, there are noted increases in within- and between-phrase pauses which contribute to overall rate problems and thus to decreased intelligibility (Hudgins, 1946; John and Howarth, 1965; Boone, 1966; Boothroyd et al., 1974; Levitt et al., 1974; Nickerson et al., 1974; Forner and Hixon, 1977). Stark and Levitt (1974) reported that their deaf subjects tended to pause after every word and to give stress to almost every word in specially prepared sentences designed to test the use of pause and stress. According to John and Howarth (1965) the silences between words often accounted for one half the total time taken in saying test sentences.

As early as 1946, Hudgins noted that part of the problem of pausing was related to its inappropriate placement. Boothroyd et al. (1974) found within-phrase pauses to be a more serious problem than between-phrase pauses when they compared deaf to normal hearing speakers. On the average, within-phrase pauses lasted eight times longer for deaf than normal subjects. Nickerson et al. (1974) reported that total pause time for hearing children constituted 25% of the time required to produce their test sentences while pause time for the deaf was 40%.

Boothroyd et al. (1974) set up a visual training program consisting of 450 hours of individual tutoring on nonsense syllables and meaningful words and phrases with emphasis on reducing the duration of unstressed syllables and within-phrase pauses. Raters noted significant improvements in these areas when the subjects read the same set of sentences after training that they had read before training. Improvements on unrehearsed speech were not as apparent. The authors were somewhat surprised at first to discover that in spite of the temporal improvements, the subjects as a group showed no significant increase in intelligibility. This seemed to be in direct contrast with John and Howarth's report (1965) of mean increase in intelligibility of 56% for their subjects after training. Boothroyd et al. suggest that the differences in findings may be due to the fact that some of John and Howarth's subjects had more residual hearing and,since an auditory training program had been used, the subjects may have learned better pitch and intonation as well as timing which would have contributed to their overall intelligibility.

Levitt, Smith and Stromberg (1974) looked at a combination of pauses and phoneme duration as these factors affected intelligibility. They created a measure of deviant duration

> ...in which pauses and excessive prolongation of voiced segments were weighted in inverse proportion to the variation in duration for corresponding sections in the hearing children's speech.

When this measure was compared to intelligibility scores, the authors found a trend toward the reduction in intelligibility as the weighted deviant duration increased.

The excessive and inappropriate use of pauses leads to the perception of improper grouping of syllables (Hudgins, 1946; Nickerson et al., 1974). Hudgins (1937) blamed these problems on poor breath control. He claimed that the deaf used too much breath per syllable and that they did not group syllables into breath groups and phrases as normals would. Rawlings (1935, 1936) found no significant differences between deaf and normal individuals for breathing in quiet, but that the deaf used more breath in speaking than did normal hearing individuals and that the amount of breath used increased with increasing severity of hearing loss. Recently, Forner and Hixon (1977) reconfirmed the fact that muscle activity is normal for deaf individuals during quiet breathing but noted that they do not take in enough air when breathing for speech. Therefore, they must rely on tidal air and must combat the forces of recoil throughout speech. Hudgins (1937) claimed that there was a lack of coordination between the movements of the respiratory muscles and the articulators and proposed training programs to improve voice and breathing. He warned (1946) that speech rhythm has to be taught from the start and not superimposed on an existing pattern of isolated sound production. Phoneme duration changes depending upon the stress in the sentence and thus because sounds vary, they cannot be taught in isolation.

Tests of timing and related prosodic skills

There does not seem to be much dispute that deaf speakers do not use stress and pause appropriately in their speech. However, little has been done until recently to determine whether the deaf are capable of using these prosodic features appropriately when they are called for in specifically designated locations in a sentence. Levitt and others have undertaken a longitudinal study of children in schools for the deaf in New York State. In the first years of the study (Stark and Levitt, 1974) the children were asked to read each of four simple sentences marked in five different ways: as a statement, as a question with final rising pitch, with pause in specified locations and with different stress patterns. The children read the sentences in random order and the recorded utterances were evaluated to determine whether the intended features were produced. The children produced stress and pause but not only in the intended location. In other words, they tended to put equal stress on most words and to pause between most words. The children were also rather unsuccessful at producing question intonation. Inadequate variation in intonation is often described as a characteristic problem in the speech of the deaf (Voelker, 1938; Peterson, 1946; Green, 1956; Calvert, 1962; Martony, 1968; Levitt, Smith and Stromberg, 1974; Stratton, 1974). Phillip, Remillard, Bass and Pronovost (1968) noted that deaf subjects had particular difficulty in using rising intonation at the ends of sentences to mark question. They found that both rising and falling intonation at sentence end were not successfully produced because of poor pitch changes.

In later years of the study by Levitt et al., revisions were made in the test materials (McGarr, 1976) so that the prosodic production test items would more closely match those on the prosodic feature reception test. This was important since the investigators were interested in comparing reception and production ability for prosodic features. The new test utterances were shorter and only stress, pause and question were tested. The results of the test showed a definite feature effect. Pause was correctly produced about 70% of the time and stress about 65% of the time. Rising intonation in question was correct only 4% of the time (Levitt, Stark, McGarr, Carp, Stromberg, Gaffney, Velez, Osberger and Freeman, 1976). When the features of stress and pause were called for later in the utterance they were more likely to be produced correctly than if they appeared early on in the sentence. When question was intended, the children often produced the test utterances in statement form or with staccato errors, i.e., with equal stress on all syllables. There was improvement in overall scores over the years of the study. A comparison of performance on the reception and production tests revealed that some children who had good reception ability still did not produce the features correctly. This was taken as support for the idea that these children should be trained in the use of prosodic features and major improvements in this area should be apparent.

Voice quality

Aside from the problems of timing (rate, duration and pauses) in the speech of the deaf, there seems to be much agreement that there are voice quality problems as well. Those experienced in working with the deaf claim that they can readily identify the speech of deaf individuals (Bodycomb, 1946; Boone, 1966) and differentiate it from that of a normal speaker (Calvert, 1962). However, in a study by Calvert where teachers of the deaf were asked to mark a check list of the characteristics they felt most closely described the voice quality of the deaf, there was much variety among the fifteen teachers in the adjectives they chose. Of fifty-two suggested terms, thirty-three were checked. Thus, although it would seem that the voice quality is highly recognizable for running speech, the attributes which contribute to the perception are not clearly definable. The teachers chose such terms as tense, harsh, flat, breathy and throaty. Unfortunately, many of these terms are not easily measured or accurately defined, thereby making diagnostic and consequently remedial techniques difficult to develop.

Nasality

Perhaps the most frequently noted problem of voice quality is that of nasality. Boone (1966) described the speech of the deaf as having a different resonance which he felt was due to the tongue hump being kept too far back in the mouth. Colton and Cooker (1968) suspected that the nasal quality of deaf speech might be related to slow speaking rate. They had seven normal speakers read some utterances in a slow, word by word fashion. When thirty college students listened to these recordings played backwards to avoid judgments on articulation, they reported more nasality in the slow speech of normals than in their normal speech.

Today sophisticated equipment is available for the physical measurement of nasalization. Stevens et al. (1976) used a small accelerometer attached to the nose and an accompanying visual display of the accelerometer output to monitor velopharyngeal opening for voiced sounds. The results showed that 76% of the deaf subjects had excessive nasalization on vowels. The device proved to be reliable as a measure of nasality. The authors reported a good correlation between velopharyngeal adequacy and intelligibility of read speech as determined by experienced listeners.

Pitch

Another prominent quality problem in the speech of the deaf relates to pitch. Several investigators have noted that the pitch of the deaf speaker's voice is somewhat higher than that of normals of comparable ages (Angelocci, 1962; Calvert, 1961, 1962; Engleberg, 1962; Angelocci, Kopp and Holbrook, 1964; Boone, 1966; Martony, 1968). Boone noted that the problem is most apparent for adolescent males. Younger deaf children do not seem to differ as much from normal hearing youngsters, and adolescent females have similar mean pitches to their comparably aged controls.

Willemain and Lee (1971) hypothesized that the reason for the high pitch in the speech of the deaf is that the deaf speaker uses extra vocal effort to give him an awareness of the onset and progress of voicing. Pickett (1968) suggested that the increased pitch was due to increased subglottal pressure and tension of the vocal cords. These authors seem to feel that the increased vocal effort is directed at the laryngeal mechanisms for kinesthetic feedback. Martony (1968), however, proposes that this laryngeal tension is a side effect of the extra effort put into the articulators. He claimed that since the tongue muscles are attached to the hyoid bone and the cricoid and thyroid cartilages, extra effort in their use would result in tension and a change of position in the laryngeal structures and therefore a change in pitch.

In addition to higher pitch on the average, there is also a wider range of pitch for the deaf subjects (Green, 1956; Angelocci et al., 1964; Boone, 1966; Martony, 1968).

Some deaf speakers have speech patterns characterized by excessive pitch changes (Martony, 1968; Willemain and Lee, 1971; Smith, 1972). Frequently the speaker will start an utterance at a high pitch level and drop sharply after 100-200 msec (Martony, 1968). Willemain and Lee reported that pitch usually goes up as the complexity of the speech message increases. They had twenty-six deaf teenagers use a tactile device to monitor their pitch. The subjects used higher pitch before training. The task went from humming to repeating their names to reading a passage. The authors felt that there was an element of nervousness or tension which contributed to the pitch being high. They noted that as the children performed the tasks in subsequent weeks there was less nervousness involved and pitch was lower. These observations were made when the display rate of the pitch information was slowed down. When this happened, the subjects had to rely on kinesthetic feedback and their pitch problems were more apparent. When the tactile display occurred soon after the production of the fundamental pitch was begun, the subjects were able to use the device to monitor and adjust their pitch output. The authors hoped that a miniaturized version of the equipment could be developed for more ready use by deaf individuals.

Voice quality and intelligibility

At present, although there appears general agreement about some of the major voice quality disorders of the speech of the deaf, there is still little concrete evidence of the correlation of these deviations to overall intelligibility. Although Stevens et al. (1976) were able to measure velopharyngeal adequacy and intelligibility, we have no proof as yet that the more the nasal emission the greater the disturbance to intelligibility since it is possible that inadequate velopharyngeal control affects articulation and that contributes to intelligibility problems. There is a need for more work comparing nasality problems to intelligibility.

It appears that excessive pitch variation has an obvious detrimental effect on intelligibility. Smith (1972) found that spasmodic variation in pitch shows a high negative correlation with intelligibility. McGarr, Osberger and Gold (1976) used the NTID rating scales for intelligibility and for pitch in rating 57 deaf children on spontaneous speech production. They found that for those children with the number 1 pitch ratings (those who could not sustain phonation), there was extremely poor intelligibility. There was a significant interaction between pitch deviancy and intelligibility when pitch was considered in terms of its appropriateness for the age and sex of the speaker. Although the correlation was significant, the relationship was not a simple one. There was a bimodal distribution for those with natural pitch. Some were very intelligible and some were very unintelligible.

Summary: production of suprasegmentals

The speech of the deaf is characterized by distinct problems of timing, intonation and voice quality. Frequently, speech is described as slow, with prolonged duration of both stressed and unstressed syllables, poor transitions between words often characterized by intrusive sounds and excessive and inappropriately placed pauses within phrases and sentences. In spite of the rather conclusive quantitative results of measurements of timing problems in the speech of the deaf, little definitive information is available on correlations of these problems to intelligibility. Boothroyd et al. (1974), who noted significant improvements when their subjects were trained to reduce the duration of unstressed syllables and within-phrase pauses, failed to find a significant increase in intelligibility as a result of these temporal improvements. Levitt et al. (1974) proposed a more complex relationship in which there was some interaction between intelligibility and pauses and duration of voiced segments.

Tests of prosodic feature production showed that deaf children tended to produce equal stress on all words in an utterance and to produce pauses between most words. In addition, test results showed that the children had little success at producing different intonational patterns, particularly rising intonation as in yes/no questions. Monsen and Leiter (1975) tried to use narrow band spectrograms to measure the intonational changes in deaf subjects' speech. Although there were obvious differences between the spectrograms of normal and deaf subjects, the authors could not find a consistent pattern of pitch variability in their subjects which could correlate well with reduced intelligibility.

Although there is much variability, there does appear to be a voice quality which is identified with the deaf. Excessive nasality and inappropriate pitch are two of the factors which account for the abnormal quality of the speech of the deaf. There is some evidence that these factors do reduce intelligibility. Stevens et al. (1976) reported a good correlation between the degree of measured nasality and reduced intelligibility. McGarr et al. (1976) found a significant correlation between intelligibility and deviation of pitch from that expected for an individual's age and sex, although the relationship was not found to be a simple one. In addition, excessive pitch changes have been found to detract significantly from overall intelligibility (Smith, 1972; McGarr et al., 1976).

Speech Reception Skills

Reception of Segmentals

In order to better understand the speech production errors made by the deaf, it is necessary to determine precisely what information they are capable of receiving through their impaired auditory systems. Although overall test scores are frequently referred to in traditional speech discrimination testing, a more valuable approach is that of specifying and interpreting the kinds of errors made. Smith (1972) designed a phoneme reception test based on typical kinds of articulatory errors in the speech of the deaf. She found performance on this test to be a very good predictor of overall speech intelligibility.

Reception of consonants

One major finding consistently reported in the literature is the relatively poor performance of hearing impaired subjects on items testing discrimination of place of articulation and especially good recognition of the feature of voicing (Siegenthaler, 1949; Oyer and Doudna, 1959; Owens and Schubert, 1972; Bilger and Wang, 1976). What is most striking about this finding is that it is true for normal subjects listening under conditions of low-pass filtering or competing noise, for subjects with adventitious losses and for individuals with congenital, bilateral hearing losses. Miller and Nicely (1955) found that under conditions of noise and with low-pass filtering, the features of voicing and nasality were most recognizable to normal subjects, whereas affrication and duration suffered and place of articulation was least able to withstand the competition.

Siegenthaler (1949) tested five normals, five subjects with flat sensori-neural hearing losses and five subjects with sloping losses on a paired word discrimination test presented at SRT, SRT+5 dB and SRT-5 dB. The word pairs were based on contrasts of voicing (/tɔk/ vs /dɔg/), place (/bæd/ vs /dæb/) and manner (/ti/ vs /si/). The normal hearing subjects had most difficulty identifying manner items, those with flat losses performed about as well on all features and the subjects with sloping losses identified voicing contrasts better than contrasts of manner or place. In a study by Oyer and Doudna (1959) where subjects with conductive and sensori-neural losses were given W-22 tests at 40 dB re SRT, place appeared to be most difficult and voicing easiest for the group as a whole. Owens and Schubert (1968) also reported place and manner to be the source of most of the discrimination problems for their subjects taking a closed set CVC test. Bilger and Wang (1976) found the perception of nasality and voicing easiest for a group of sensori-neural subjects with high frequency losses, some of whom had moderate losses as low as 250 Hz.

Whereas some of the previously mentioned studies dealt with adults with unilateral and/or adventitious losses, the following studies report similar findings for young subjects with severe to profound bilateral losses of early onset. The similarity in findings is important in understanding the auditory information available to deaf children because these latter subjects could not rely on previously learned phonemic or linguistic information in operating on these tests. Similarly, because of the low correlation between performance on discrimination tests and on duration of hearing-aid use, Pickett et al. (1972) concluded that the test results reflect effects of inherent auditory factors and not experience with amplification.

Schultz and Kraat (1971) tested five ten- to thirteen-year old subjects with bilateral sensori-neural hearing losses. The examiner created a closed set CV test consisting of one of eight consonants /s,d,f,v,m,p,k,g/ and either the vowel /ɑ/ or /u/. The vowels were never interchanged as foils within a test; each vowel was tested separately. The authors looked at consonant confusions in terms of distinctive feature breakdowns and found the order of correct perception of features to be nasal, voice, grave, continuant and diffuse. This again is in agreement with previous reports that voicing and nasality are more perceptible and place (diffuse) contrasts are most difficult. Pickett et al. tested ninety-nine Gallaudet students, for whom an SRT could be measured, using a special version of the Rhyme Test. Place features were much more poorly received than voicing and lowcontinuant features (strong low-frequency energy as in nasals, liquids and glides). Smith (1972) created a fifty item closed set phoneme reception test. Each of the thirty-six consonant items had three choices based on place, manner, place-manner or voicing contrasts. She found that manner and voicing were recognized best and place and place-manner contrasts were most difficult. Smith found manner cues more perceptible than voicing cues. When tested in initial consonants, Pickett et al. also reported higher scores on reception of lowcontinuants than on voicing.

Explanations are offered for the rank order of recognition of test features by the hearing impaired. It is generally agreed that some cues for voicing and manner are dependent upon low frequency information (Cooper et al., 1952; Delattre et al., 1955). If this is the case, then it is more likely that the hearing-impaired should perform well on features which are audible in their range of residual hearing. Aston (1972) concluded that cues for manner and cues for nasals were in the frequency range below 1k Hz because her deaf subjects with no hearing above 1k Hz showed no difference in performance on items presented with and without 1k Hz low-pass filtering. She also claimed that most place cues were not in this frequency region because after training, the subjects improved on recognition of manner and nasality and not place.

Pickett et al. claimed that subjects had difficulty on place items because they could not detect F_2 transitions. Danaher and Pickett (1975) later noted that recognition of F_2 transitions alone were not the problem. Their subjects were able to discriminate changes in F_2 which were as small as those noted by normal subjects as long as F_1 was not present. However, place was particularly difficult to recognize when F_1 was present since F_2 transitions could be masked by F_1 when presented at high intensities such as those at which deaf subjects listen. They found evidence of both an upward and backward spread of masking from F_1 to the F_2 transitions. Pickett et al. explained that the deaf did better on recognition of the features of voicing not only because it is dependent on low frequency information but because it is also dependent on vowel duration - a discrimination that should not be exceptionally hard for the deaf. Erber (1972) claimed that the deaf are only capable of using time and intensity cues as evidenced by the fact that there is little difference in performance by deaf subjects when amplified speech or amplified low-pass filtered speech-modulated noise were supplemental cues to a lipreading task.

Regarding specific consonantal errors of discrimination, Rosen (1962) tested 251 adults with varying degrees of sensori-neural hearing loss on PB word lists. He reported fricatives to be hardest for their subjects and found recognition of front sounds to be poorer than back sounds. Oyer and Doudna's (1959) subjects had the greatest difficulty discriminating blends, followed by plosives, then fricatives and then nasals. There is general consistency in the literature that consonants in final positions in words are more difficult to discriminate than those in initial position (Oyer and Doudna, 1959; Rosen, 1962; Owens and Schubert, 1968; Pickett et al., 1972; Jones and Studebaker, 1974; Sher and Owens, 1974; McGarr et al., 1977). Only Smith (1972) failed to find a significant difference based on position of the target phoneme in the word.

Danaher and Pickett (1975) theorized that discrimination of voiceless consonants in prevocalic position should be better than discrimination of voiced consonants because for voiceless phonemes the delay of the onset of F_1 causes less masking of the F_2 transition. Yet, Siegenthaler (1949) and Smith (1972) found that hearing impaired subjects performed better on voiced than voiceless test items. Perhaps these test results do not match the predictions of Danaher and Pickett because overall scores for voiced and voiceless items on these tests do not take into consideration the effects of the differences between the vowels from one set of foils to the next.

Effects of vowels on consonant discrimination

As has been reported in the literature on normal speech perception, consonant discrimination is often dependent upon the accompanying vowel (Cooper et al., 1952; Raphael, 1972). Lawrence and Byers (1969) tested five adults with sharply sloping, high frequency, sensori-neural hearing losses above 1k Hz on a closed set CV test. The items were made of the four fricatives /ʃ,s,f,θ/ and four vowels /i,e,o,u/. They found that fricatives were more often correctly identified when accompanied by a back vowel than a front vowel. They explained that this was true because F_2 transitions for back vowels are lower in frequency than F_2 transitions for front vowels and are therefore in the audible frequency range of these hearing-impaired subjects. Schultz and Kraat (1971) also found that the vowel accompanying the test consonant contributed to the kinds of confusions made once the consonant was misidentified. They found more consistency in confusions when /ɑ/ was the test vowel than when /u/ was. As a result they concluded that we deal with the syllable and not the phoneme as our minimal unit of perception.

Bennett (1973) also found an interaction between consonant identification and the accompanying vowel. He measured the VOT (voice onset time) necessary for normal and deaf children to differentiate between voiced and voiceless stops in the presence of the vowels /i,u,ɑ/ and found that the deaf children had more difficulty properly identifying the presence or absence of voicing when the vowels /ɑ/ or /u/ were present compared with /i/. He theorized that since F_2 for /i/ was higher than for /u/ or /ɑ/ and was thus inaudible, the deaf children were better able to attend to the voicing cues than when they had competing information from the accompanying vowel. In addition, and perhaps as a result, the deaf children made more place errors when /i/ was present than when /u/ or /ɑ/ were, since they did not have the F_2 information to cue them on place of articulation. Of interest is the fact that Bennett found that special auditory training was helpful both in recognition and production of voicing contrasts.

Vowel confusions

The incidence of vowel discrimination problems is subject to some disagreement in the literature. Oyer and Doudna (1959) reported that the number of vowel errors was fewer than consonant errors for their 400 subjects listening to W-22 word lists. However, taking into consideration the fact that there are fewer vowels than consonants in the test, the relative proportion of errors on vowels was actually greater than the relative proportion of consonant errors. Schultz (1964) who also used W-22 tests on his ninety-three subjects with sensori-neural hearing losses, found that vowel errors constituted twenty-five percent of all of the errors made. Several other studies have placed less significance on the incidence of vowel errors (Rosen, 1962; Pickett et al., 1972; McGarr et al., 1977). Owens et al. (1968) claimed that the reason for these differences in results was the kind of test given. They compared performance of twenty subjects with sensori-neural losses on W-22 tests and on a CVC closed-response set test where only vowels differed in the four foils given. Their subjects did well on the vowel test. They explained this good performance on vowels by saying that in the open set tests errors in consonant perception could affect the vowel perception, whereas in a closed set test the identity of the final consonant is not in question. Smith (1972) found as much error for vowel contrasts as for place contrasts. This may be a function of the severity of the hearing losses in her population or of the nature of the foils given.

Pickett et al. reported that their subjects did better when back vowels were the target sounds and worse when front vowels were the target on the Rhyme Test used. This would seem likely since the back vowels contain low second formants which are more likely to be audible to a deaf population.

The general consensus regarding the kinds of vowel confusions made is that a near neighbor in the vowel quadrilateral will be reported if the intended vowel is not correctly identified (Peterson and Barney, 1952; Oyer and Doudna, 1959; Rosen, 1962; Owens et al., 1968; Smith, 1972) and that the confusion is likely to be on the same side of the quadrilateral but towards the mid-height position (Oyer and Doudna, 1959). One slight deviation from this trend was reported by Smith. She tried to get more specific information about vowel confusions by setting up a set of foils whereby first formant confusions and tense-lax confusions were available. She found that when /u/ or /ʊ/, having low F_2's were presented, they were likely to be confused with each other but that if /i/ or /I/ were the target, they were frequently thought to be the corresponding back vowels, /u/ and /ʊ/, respectively. This confusion is understandable because without the second formant information which is not audible with a high frequency hearing loss, the first formants of the high front and back vowels are similar and easily confused.

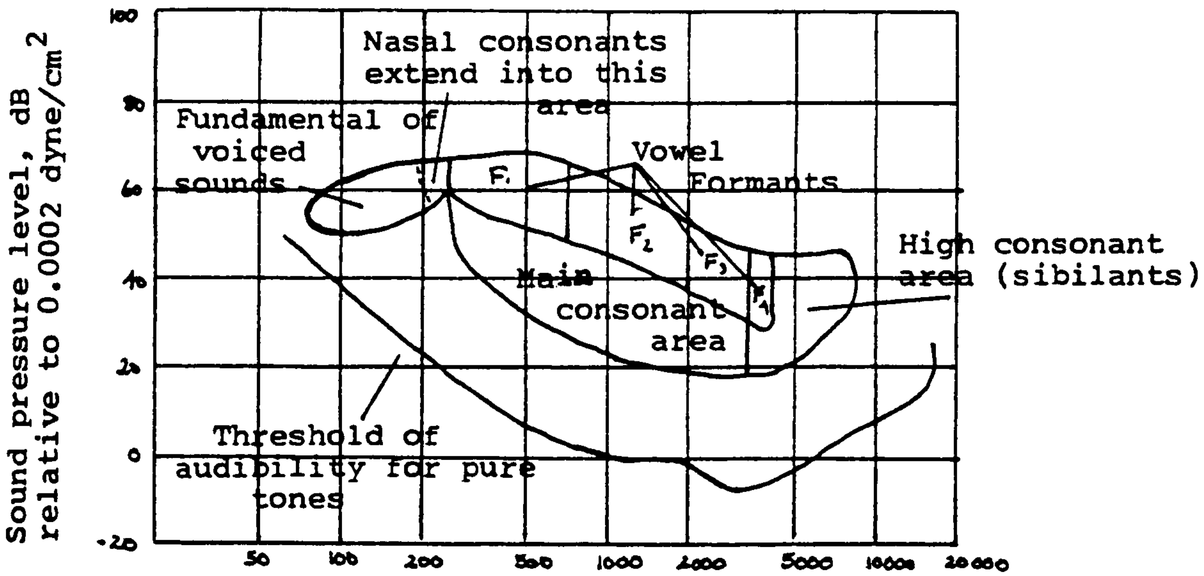
Summary: reception of segmentals

Discrimination of the features of voicing and nasality is easier than that of place of articulation. Voicing in consonants is believed to be easy to discriminate because of the high intensity, low frequency energy, as well as the cues presented by the duration of the preceding vowel. Similarly, the nasal sounds contain substantial low frequency energy. On the other hand, place of articulation is hard to discriminate because not only are the F_2 transitions often in the higher frequency range, but also because F_1 masks F_2 information at times. Figure 1 is a plot of the power/frequency distribution of speech signals (Richards, 1964). The pattern of perception of segmentals differs somewhat from that of production in the deaf population. This may be because of the visibility of some articulatory movements and the lack of visibility of others which affects one's ability to learn to produce phonemes but would not contribute to the ability to perceive these features on an auditory test.

Although there is disagreement as to the frequency of vowel discrimination errors, most likely because of the differences in the test materials used, the general consensus is that vowel confusions are with a near neighbor in the vowel quadrilateral and that the confusion is likely to be on the same side of the quadrilateral but towards mid-height position or with vowels having similar F_1's, if F_2

FIGURE 1

A plot of the distribution of power versus frequency for speech signals. The closed curves indicate the approximate range of sound pressures in free air at 1m from the talker's lips (Richards, 1964).



Frequency in Hz

is not audible. This is quite similar to the kinds of errors made in vowel production except that the mid-central vowel is often substituted for the intended vowel in production and confusions based on similar F_1's are seldom produced.

Reception of Suprasegmentals

Although there has been much research regarding phonemic discrimination ability in the hearing-impaired, litle attention has been paid to their prosodic feature reception skills. Smith (1972), noting the prevalence of stress, timing and intonation errors in the speech of the deaf, designed a test to evaluate the reception of these features. The five part test consisted of tonal stimuli differing in duration, frequency, timing patterns or intensity. The children were trained to recognize pictorial representations of each of the test features. Each stimulus was represented by a box on the response sheet. The size of the box indicated duration, the proximity of the boxes represented timing, and frequency was represented by the height of the box on the page. A closed-response set test was used in which two or three choices were given for each test item. There were various levels of complexity for each of the subtests. In addition, the fifth part of the test consisted of recorded sentences that had been passed through a 390 Hz low-pass filter. Subjects were asked to differentiate between three sentences which differed based on intonation (question, statement or question and pause), duration (number of words), location of stress or phrasing. The purpose of the low-pass filtering was to minimize the phonemic cues that were present in the sentences.

The results of this test showed that scores on the tonal portion correlated well with thresholds at 500 Hz and moderately well with intelligibility scores, although there was not the close correlation to speech production skills that was anticipated. Generally, the children performed relatively well on the test, scoring close to 100%, and as a result it was not a good differentiator between subjects.

In 1974, Stark and Levitt reported on prosodic feature reception testing for seventy-one 10 and 11 year olds attending schools for the deaf in New York State. The fifty-six item test consisted of pairs of sentences which tested recognition of pause, addition of syllables, question vs statement and location of stress. The task was to indicate whether two utterances in a pair were the same or different. Differences between sentences were based on the above-mentioned features.

Results of the test showed that many of the children responded at a chance level for most of the test items. Pause was the feature most often correctly discriminated, while performance on the question items was the worst. The relatively poor performance of the children on features which contain a good deal of low frequency information (which should be within their range of residual hearing) suggests that much can be done to improve the auditory training provided to these children.

The above test used a same-different task, which introduces the problem of differences in response criteria between subjects. A new prosodic feature reception test was thus devised to test recognition of the features of stress, pause and question in a closed-response set format (McGarr, 1976). The test contained balanced sets of three and five syllable utterances for a total of thirty-six test items. Four choices were available to the subject. All choices consisted of the same simple utterances but each was marked by a different prosodic feature, e.g., stress early in the utterance, stress late in the utterance, pause early in the utterance and pause late in the utterance. In addition, for the two syllable utterances (for which only one pause condition was possible) a question vs statement intonation was included as one of the choices. The child heard a recording of the test stimulus at MCL and circled the choice which most closely corresponded to what was heard.

The feature of pause, as in Stark and Levitt's findings, was most often identified correctly. Early stress was somewhat less difficult to recognize than late stress, and question was the most difficult item for the group. McGarr noted that some subjects had difficulty in detecting pause and in locating stress and found this surprising since these features are contained in low frequency information. One possible interpretation is that certain sounds in the utterance fall below the child's threshold of hearing resulting in many breaks or pauses in what is heard and an additional pause is thus not easy to identify.

Summary: reception of suprasegmentals

Detection of pause and location of stress, features thought to be conveyed by low frequency information audible to the deaf subjects, was not as good as anticipated. Pause was identified correctly most often, and early stress was somewhat less difficult to recognize than late stress. Recognition of yes/no questions which seems to rely on pitch change was especially poor, though this was not surprising. In addition, those children who performed well on prosodic feature reception tests did not always do well on the production of these same features.

Relationship between Measures of Residual Hearing and Speech Intelligibility

Conventional Three-Frequency Average

It is generally agreed that as the severity of the three-frequency pure tone hearing loss increases (until about 90 dB HL), there is a corresponding increase in the number of phonemic and rhythmic errors and a decrease in overall speech intelligibility (Hudgins and Numbers, 1942; Mangan, 1961; Brannon, 1964; Markides, 1970; Smith, 1972). The nature of the phonemic errors seems to be similar for all degrees of hearing loss (Heider et al., 1941; Mangan, 1961; Markides, 1970) but the numbers increase with increasing loss. Markides reported 9% vowel and 26% consonant errors for his hard-of-hearing subjects and 56% vowel and 72% consonant errors for his deaf subjects. While the hard-of-hearing children had mean intelligibility scores of 76%, the deaf children averaged 19% intelligibility.

As the severity of the three-frequency pure tone hearing loss increases above 90 dB, the relationship between hearing level and intelligibility appears to break down. Some children with severe losses have moderately good speech. It is evident that the pure tone audiogram alone is not enough to predict those who will have success at speech production and those who won't. Other factors must be responsible for explaining the functioning of these children as well as of some others with better hearing whose audiograms do not seem to reflect their true ability to use auditory information. Some of these factors are age of onset of deafness, degree of special education and educational setting.

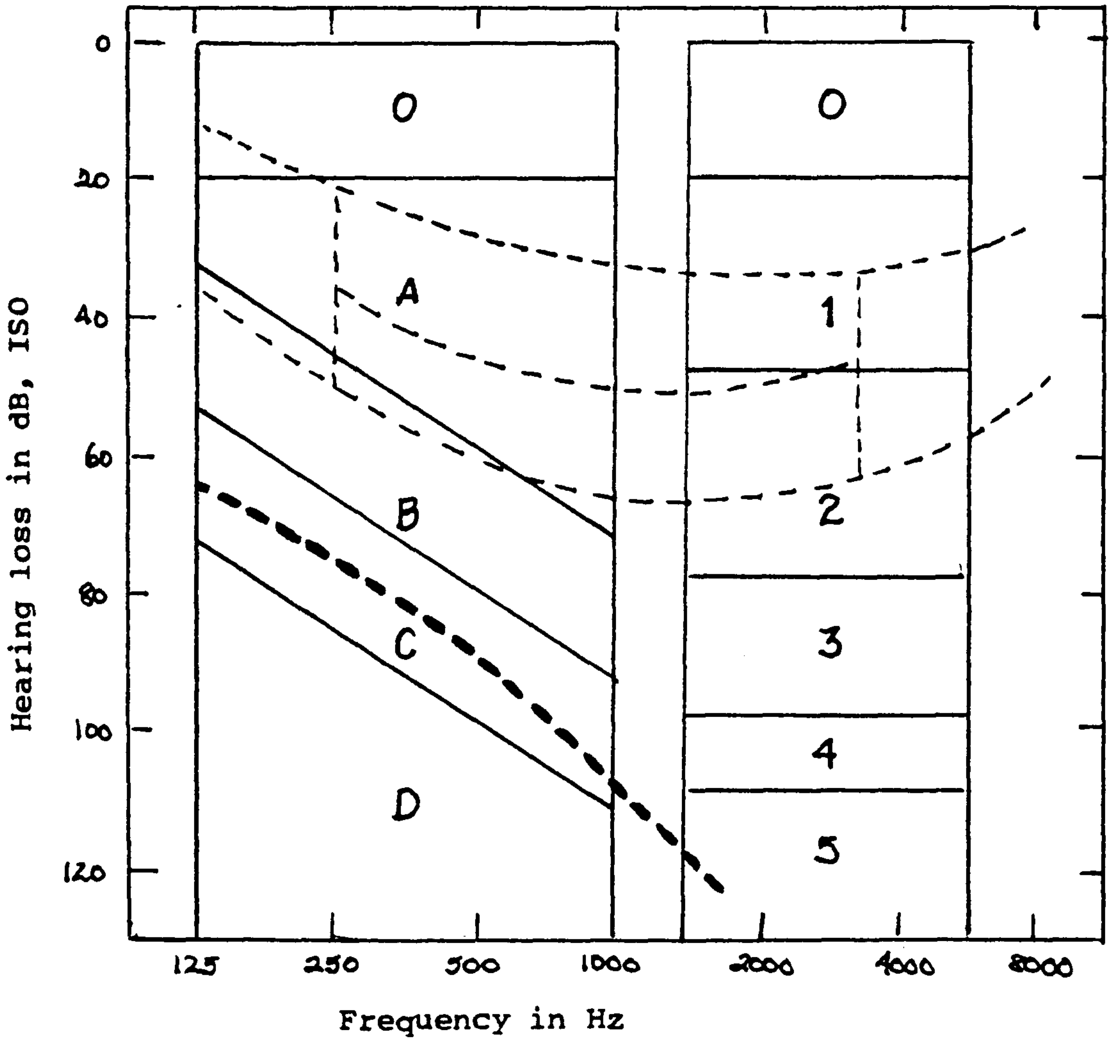
Other Pure Tone Measures

Dissatisfaction with the three-frequency pure tone average as a measure of auditory sensitivity led to other classifications of the audiogram. Wedenberg (1954) created a system whereby the audiogram was referred to both in terms of severity of loss (a letter system was used) and configuration (a number system was used). In 1972, Risberg and Martony modified these classifications to meet the needs of describing a more profoundly deaf population. They divided the frequency range into 125-1000 Hz (represented by the letters A-D) and 1500-6000 Hz (represented by the numbers 1-5) (Figure 2). The first division corresponded to areas containing F_0 and F_1 information and the second to F_2 and information in voiceless sounds. Using this system to describe children in Swedish schools for the deaf, they found that the majority of the children have thresholds in the low frequencies that may be due to tactile sensations (areas C and D) and responses in the high frequencies were often not measurable. This still left a large portion of the population with little usable information about their potential auditory skills.

Several investigators have tried to determine whether thresholds at particular frequencies might be better predictors of a child's functioning, specifically his speech intelligibility. For the most part, the more high frequency hearing a person has, the better his speech intelligibility is likely to be (Montgomery, 1967; Ling, 1968; Boothroyd, 1970). For those with predominantly low frequency hearing due to sharply sloping losses, Montgomery (1967) found that thresholds at 125 and 250 Hz may be used as indicators of "potential speech ability". Boothroyd felt that hearing sensitivity at 1000 and 2000 Hz was especially good at predicting speech intelligibility when 90 dB was used as a cut-off. For the Clarke School students whom he tested, if a child had thresholds at 1000

FIGURE 2

The classification of audiograms according to Risberg and Martony (1972). The heavy dashed line indicates a C5 audiogram.



and 2000 Hz better than 90 dB, he had a 75% chance of having good intelligibility but if his thresholds at those frequencies were worse than 90 dB there was only a 10% chance of being intelligible. Smith compared hearing at various test frequencies with overall intelligibility scores for her 40 deaf children. The best correlation (-.65, $p<.001$) was obtained for the average of 125, 500 and 1000 Hz. She also found a breakdown in the linearity of the relationship between hearing level and intelligibility above 90 dB.

Non-Tonal Measures

Boothroyd (1972) proposed using a more complex stimulus than pure tones in order to learn more about the child's auditory sensitivity. He suggested using phonemes to test these frequency ranges: /u/ -500 Hz, /ɑ/ -1000 Hz, /ʃ/ -2000 Hz, /s/ -4000 Hz. He also proposed the creation of tests based on pairs of stimuli which could be differentiated by detection of differences in duration, number of syllables, presence of voicing or formant contrasts. In this way we would have more meaningful information on what auditory stimuli the children were processing.

Erber (in Stark, 1974) claimed that performance on a closed-set spondee test was a valid way of determining which subjects were using low frequency information. He classified some severely deaf children as profoundly impaired because they scored between 0 and 30% on his test. He felt that the audiogram was not as sensitive as this test in recognizing which children could utilize low frequency information and which could not, i.e., those who truly possess residual hearing. The profoundly deaf group use vibrotactile cues and can perceive time and intensity changes but can not deal with rapid frequency changes in normal speech.

A still better predictor of the child's speech performance than any pure tone measures was the Phoneme Reception Test that Smith devised (1972). The test results showed that those children who were better able to discriminate such features as manner, voicing and place of articulation (in a closed-set response test) were generally children who had more intelligible speech. The correlation of performance on this test to intelligibility ($r=.78$, $p<.001$) was greater than that for any individual frequency or combination of frequencies with speech intelligibility. Thus, it appears that for stimuli that are closer to real speech there are better correlations to speech intelligibility than for tonal stimuli.

Suprasegmental reception skills have also been measured and correlated with intelligibility. At present, specific information on these correlations is limited. Smith found a "moderate" correlation between intelligibility and performance on discrimination of prosodic features on tonal stimuli. However, the test was not felt to be a good differentiator between subjects since most of them did quite well. It would appear that further research on reception of prosodic skills may lead to an important link in the total picture of the relationship between residual hearing and speech intelligibility.

Summary

Various factors have been considered in trying to determine which auditory skill correlates most closely with intelligibility. While the pure tone average falls short for hearing losses greater than 90 dB, the Phoneme Reception Test designed by Smith is reported to be better than any pure tone information as a correlation to intelligibility. At present, information on correlations of prosodic feature reception ability to intelligibility is limited. Tests of reception of suprasegmentals appear to show some correlation to intelligibility; however, at present, the relationship is not clear. To date, these tests of residual hearing have been administered only to profoundly deaf children in schools for the deaf. Predictions of performance of the hard-of-hearing on these tests can not be made without further research in this area.

CHAPTER III

METHODOLOGY

Subjects

Forty-three hearing impaired children between the ages of nine and twelve served as subjects for this study. There were twenty-four girls and nineteen boys all born between 1962 and 1964. The range of ages was from nine years and five months to twelve years and four months with a mean age of ten years and two months. The children were pupils in the New York City Public School system and received additional assistance from the resource room teachers in their schools. The resource room program, under the auspices of the Bureau for Hearing Handicapped of the Board of Education of the City of New York, is designed to maintain severely hearing-impaired children in a regular school setting by means of supportive instruction in all subject matter including language and speech skills. The hearing-impaired children are seen daily on an individual or group basis.

A list of all nine- to twelve-year old, hearing-impaired children known to attend resource room classes in the New York City Public Schools was provided by the Bureau. Of the thirteen schools included on the list, the seven that were chosen represented a distribution of geographic areas and socio-economic levels of the city. Three schools were in Brooklyn, three in Queens and one in Staten Island. The schools covered a range of socio-economic levels from low (some on Welfare) to middle income. None of the children were from high income families since few high income families in New York City send their children to public schools. The number of children sampled from each of the seven schools ranged from two to nine. Once the schools were chosen, permission was obtained from the parents before any testing was begun. Appendix A contains a listing of the data related to the schools chosen.

The severity of the hearing losses characteristic of this group of children ranged from pure tone averages of 40 dB to 110 dB+ HTL in the better ear. The pure tone averages were calculated at 500, 1000 and 2000 Hz. Where there was no response at one or more of these frequencies, a value of 110 dB+ was assigned as the pure tone average. There were twenty-three children with pure tone averages better than 80 dB HTL and twenty with average hearing losses equal to or worse than 80 dB HTL. This cut-off point was chosen because this level is used as a criterion for entry into a school for the deaf in New York. Audiological data on these children were obtained from the Board of Education records and whenever possible, from clinical files at individual hospital centers where the children were seen for hearing aid evaluations. The children were all fitted with monaural or binaural amplification. Descriptive audiological, listening and background data for each of the subjects appear in Appendix B.

Equipment

Speech production testing was accomplished using a Wollensak tape recorder (model 1520) and accompanying microphone to record the children's spoken output.

Speech reception materials were played on the Wollensak tape recorder and passed through the Hewlett Packard attenuator (model 350 C) and the Grason-Stadler impedance matching transformer (model E 10589 A) to a single TDH-39 earphone housed in an MX 41/AR cushion. This earphone was placed in a full head set with a dummy ear piece on the other side. A set of AKG G 60 headphones was connected directly to the tape recorder for the purpose of monitoring the output at a constant comfortable level.

Listeners

Several different groups of listeners were required for evaluating speech production skills. Those listeners with substantial previous exposure to the speech of deaf children were classified as experienced listeners. A total of eleven experienced listeners participated in the study; five were from the Communication Sciences Laboratory of the City University of New York and six were from Johns Hopkins University. Listeners with negligible or no previous exposure to the speech of the deaf were classified as inexperienced listeners. Most of these listeners were college students.

The tests of speech production took four basic forms: scores of intelligibility, ratings of intelligibility, identification of prosodic features and transcription of phonemic production. For the intelligibility scores, the listeners were required to write down what they heard from the recordings of sentences produced by the children. (See Appendix C-1 for instructions to listeners.) The listeners' notations were scored in terms of the proportion of the words correctly identified. This objective measure was referred to as the intelligibility score.

In order to avoid learning effects on test materials, it was important that no sentence was heard more than once by a listener. Similarly, to avoid the listener learning the speech patterns of the individual children, each listener heard several different children on a single tape. Also, because of the probability of between-listener differences, it was necessary to have several listeners for each tape recording. For statistical reliability at least three listeners were required for each tape. In order to meet these requirements, a total of 111 listeners were needed; three listeners for each of thirty-seven tape recordings. Each tape recording consisted of the twenty test sentences produced by four different children and recorded in semi-random order. On each tape, no speaker read two sentences in a row and no sentence was repeated. It was not difficult to find a group of 111 inexperienced listeners. However, it would have been impractical to obtain a set of experienced listeners equal in size since not that many experienced listeners are available. Consequently, only inexperienced listeners were used to obtain the intelligibility scores.

Ratings of intelligibility were given by both experienced and inexperienced listeners, henceforth referred to as <u>raters</u>. Those inexperienced listeners used for obtaining intelligibility scores were also asked to provide a rating of intelligibility using the NTID rating scale to be described in the next section. Intelligibility ratings on the same scale were obtained from a group of three experienced raters, each of whom rated the first four sentences on each tape. The experienced raters were familiar with the speech of the deaf in general but not with the speech of the specific children being studied. These raters were also familiar with the test materials. Familiarity with the test materials was necessary prior to testing since the few experienced raters were exposed to the same sentences repeatedly. The use of familiar materials was less likely to interfere with ratings of intelligibility than with intelligibility scores.

Intelligibility ratings were also obtained for "spontaneous" speech samples, i.e., the speech produced by having the child describe a picture sequence. For practical reasons only experienced listeners provided these ratings.

In order to evaluate prosodic feature production skills, two groups of experienced listeners were used. One set of three listeners knew in advance the prosodic features that the child was attempting to produce on each utterance. The second set of six listeners did not know in advance which prosodic features were intended on individual utterances, although they were familiar with the test materials as a whole. The use of two groups of listeners allowed for a determination of the effects of prior knowledge of the test materials on the evaluation of the child's effectiveness at producing the test features.

In a second test of prosodic feature production, only experienced listeners with prior knowledge of the intended features were used. One of these listeners had also been among the three listeners of the earlier test.

In order to determine the segmental errors made by the hearing-impaired children, it was necessary to make transcriptions of their utterances. Two listeners made broad phonetic transcriptions of all of the phonemes for all of the children reading the twenty test sentences. These two listeners are referred to as transcribers.

Inter-Transcriber Consistency

A special coding system designed by Smith (1972) and modified for this study (see Appendix C-2) was used to prepare the transcriptions for computer analysis. In Smith's study, several listeners made transcriptions of different portions of the sentences read by her deaf subjects and inter-transcriber consistency was checked by comparison of their transcriptions of a pool of common sentences. In the present study, the use of two transcribers each of whom transcribed all of the sentences guaranteed consistency of criteria across subjects and helped to separate between-listener and between-speaker differences.

Two checks were made on the consistency of the transcriptions. Since one of the transcribers was among the group of trained phoneticians used in Smith's study and one was not, the latter listener transcribed ten utterances which had been transcribed by Smith's trained phoneticians. A comparison was made on a phoneme by phoneme basis and a score was given for the proportion of phonemes transcribed in agreement. An agreement score of 65% was obtained which is quite close to the 67% agreement obtained between trained phoneticians on their common pool of utterances.

As a second check, a confusion matrix was drawn up comparing the transcriptions of the first transcriber to that of the second (see Appendix C-3). Each entry on the diagonal represented the number of times the two transcribers reported the same observation. Other entries indicated the differences between the two transcribers in their reports of the phonemes produced. If the transcriber felt that the intended phoneme was not produced, he could indicate that he heard the substitution of another phoneme, a mild or severe distortion of the intended phoneme or the absence of that phoneme. Disagreements between transcribers were recorded as a proportion of the number of observations. Results of the comparison showed that the bulk of the transcriptions were identical. In fact, the overall agreement rate of 78.9% was better than for Smith's trained phoneticians (67%).

When the first transcriber reported hearing a particular vowel, the second transcriber heard the same vowel 82.4% of the time. When they disagreed it was generally due to confusions based on small differences in tongue height and advancement, e.g., I/i, ʌ/ə, ɚ/ə. There was 85.4% agreement for consonant transcriptions. The overall agreement rate of 78.9% was lower than the average of vowel and consonant agreements because there was some disagreement between transcribers on the occurrence of omissions or distortions of the intended phoneme. There was an average of 40% disagreement between transcribers on the occurrence of omissions. There was 95% disagreement on whether sounds were distorted but still recognizable.

Differences in the identification of omissions occurred frequently on phonemes in word final position. This is felt to be a subtle judgment even for the speech of normal children and does not appear to be an important factor for intelligibility. The very large differences between transcribers in the report of recognizable distortions reflects different criteria for the boundaries of acceptable production of a phoneme. One transcriber either accepted the sound as intended or labelled it as completely distorted and the other transcriber called it recognizably distorted. In all, recognizable distortions constituted only a small part of all of the phonemic errors.

The differences between transcribers which were reported were for the most part subtle and were not felt to be factors which contribute significantly to a reduction in overall intelligibility. However, because of some inconsistencies at this point, caution was used in interpreting these differences. Also, unless otherwise stated, all information regarding phonemic errors in sentences is based on an average of the transcriptions made by the two listeners.

Test Materials and Procedures

In each school an effort was made to find a relatively quiet area where there would be a minimal amount of interference from outside activities. However, since the testing was done in the schools, some background noise was present. The signal-to-noise ratios as measured from tape recordings of the subjects' speech were roughly 30 dB. These levels were not felt to be significant enough to affect the test results.

Each of the forty-three children was seen separately for a maximum of two individual sessions each lasting forty-five minutes. Those of the children who could work at a more rapid rate did all of the tests in one session lasting approximately one hour and ten minutes. The test battery consisted of five tests of speech production ability and three tests of speech reception ability. Speech production tests were always administered before speech reception tests because it was felt that less time overall would be spent in training if concepts were taught before production tasks and simply reviewed before reception tests. Less time was required to orient the children to tests of prosodic reception if they had already learned the written codes for production, i.e., three dots means pause, underlining and capitals mean stress, etc. (to be discussed below).

Speech Production Tests

Phonemic production - sentences

This test consisted of twenty sentences constructed so as to contain all frequently used consonants in initial, medial and final position in a word and to contain a transition to and from the vowels /i,æ,u/ for the seven places of articulation (Smith, 1972, p. 39). These vowels were chosen because they represent the extremes of the vowel triangle. /æ/ was used instead of /ɑ/ because it was easier to find words with this vowel which met the specified criteria and which were also in the vocabulary of young deaf children. /æ/ like /ɑ/ is also a low vowel. The vocabulary used in these sentences was designed to be appropriate for deaf children at least eight years of age. The test sentences appear in Appendix D-1.

A tape recording was made of each child reading these twenty sentences. If a child was unfamiliar with one of the words in the sentences or if he did not appear to be reading the sentence as best he could (i.e., words omitted or word order changed), he was asked to read that sentence a second time and was helped with the word that he did not know. Six of the forty-three subjects were not included in the analysis of the data on this and the following test because of severe reading problems which were thought to interfere with the interpretation of phonemic errors. These children will be referred to as non-readers.

The tape recordings of the thirty-seven children reading the twenty sentences were recorded in semi-random order such that thirty-seven tapes were prepared. On each tape four speakers were heard; no speaker read two sentences in a row; no sentence was repeated. All twenty sentences appeared in order on each tape. Each of 111 inexperienced listeners (see description above) listened to one of the thirty-seven recordings and wrote down what he thought the speaker was saying. He was allowed to listen to each sentence twice and to write down as many words as he thought he recognized. The number of words correctly identified yielded an intelligibility score. In addition, after hearing each sentence twice, the listener was asked to rate its intelligibility using the 1-5 rating scale developed at the National Technical Institute for the Deaf (Johnson, 1975):

1. Listener cannot understand the message
2. Listener understands little of the content of the message, but does understand a few isolated words or phrases
3. Listener understands with difficulty about half

of the message. (Intelligibility may improve after a listening period.)
4. Listener understands most of the content of message
5. Listener understands the complete message

In this way, each tape was heard by three inexperienced listeners and each child was represented on five different tapes. Thus, fifteen different listeners contributed to the eventual average intelligibility scores and ratings for each child. In addition, experienced listeners heard the first four sentences of each of the thirty-seven tapes and rated them on intelligibility using the NTID 1-5 scale described above. Two separate intelligibility ratings were derived for each child based on the ratings of the experienced listeners and the inexperienced listeners.

Finally, broad phonetic transcriptions were made of the children reading the test sentences. Where a sentence was read twice, the better version was transcribed. The transcriptions were then subjected to further analysis.

Phonemic production - words

This test consisted of 56 target words taken from the twenty sentences described above. They were selected for the purpose of allowing a comparison of production of isolated words with production of the same words in the context of a sentence. Standard articulation tests were avoided because of the overlearning of the test words due to frequent usage of the materials and because of the poor correlation between performance on those tests to overall intelligibility. Within the present test list, all American English phonemes were included with the exception of the vowels /ʌ,ʊ/, the diphthongs /ɔI, ɑI, ɑʊ/ and the final consonants /ʒ,v/. The list of test words appears in Appendix D-2.

Each of the fifty-six words was printed on a separate card and the children were asked to read them aloud. If a child was not familiar with a test word, he was encouraged to try to read it and if he could not, he was given the proper model to imitate. A notation was made whenever a word was imitated. As mentioned above, six of the forty-three children did not take this test because of severe reading problems.

The reading of the words was tape recorded and was later transcribed, using broad phonetic transcription, by one of the experienced listeners who transcribed the twenty sentences.

Spontaneous speech samples

In order to gain information on the overall speech intelligibility of the children, "spontaneous" speech samples were obtained by having the children describe two different picture stimuli. A picture sequence developed by Stuckless (1962) for this purpose showed a family going on a picnic. The second picture was a large cartoon from a magazine featuring family members and friends engaged in various unrelated activities in a large and messy house. The children's oral descriptions were recorded. Copies of the picture stimuli appear in Appendix D-3.

Three experienced listeners who were familiar with the test pictures rated the intelligibility of each of the forty-three speakers on both spontaneous speech samples using the NTID 1-5 rating scale for intelligibility described above. Average ratings were determined for each child on each sample.

Prosodic feature production - Test I

This test was designed to evaluate the child's ability to use the prosodic features of stress, pause and rising intonation as in yes/no questions. Six simple utterances were constructed: three were two syllables long and three were five syllables long. Each of the utterances when read with appropriate stress, pause or question intonation made up utterances which could occur meaningfully in speech. The test consisted of eighteen items in which each of the six simple utterances appeared with each of the three prosodic features tested. The test was designed by Stark and Levitt (1974).

Six randomizations were made of the order of presentation of the eighteen sentences; three variations of the order of the feature presented and two combinations of the order of the six sentences within each feature group. The eighteen utterances were printed on separate cards. The feature of pause was indicated by three dots, stress by capital letters and underlining and question by a question mark at the end of the sentence. A listing of the test items appears in Appendix D-4.

The six basic sentences were printed as statements on separate cards. Each child was asked to read these cards aloud before the test began in order to familiarize himself with the test vocabulary. Then according to the randomization chosen, two practice items were selected and the first feature was taught. After the child demonstrated that he was capable of producing the feature being taught or that he understood what was expected of him even though he was not able to produce it, he was asked to read the six test sentences using the same feature he had just been taught and his utterances were recorded. He was then taught and tested on the second and third features in the same fashion. All forty-three children took this test.

As described above, two sets of listeners evaluated the tape recordings of the children's performance on this test. Both groups consisted of experienced listeners who were familiar with the test materials. However, one group knew which features were intended for each test item, while the other group did not. The listeners who knew which feature was intended, indicated whether the feature was produced correctly and if not, which feature was produced in its place. Those listeners who did not know the specific feature intended, indicated which of a series of possible features had been produced.

Prosodic feature production - Test II

This test, created for the present study, was designed to evaluate the children's use of stress, pause and question intonation in a more natural setting than the previous test. The target features appeared in the context of a sequential question and answer unit. Each of the three units began with a question which was answered by the second utterance in the unit. If the sentence was read properly as an answer to the question, stress had to fall on a specific syllable. For example,

> What color is the apple?
> The apple is green.
> What is green?
> The apple is green.

In this way the features of early and late stress and pause in a statement or a question were tested. The test materials appear in Appendix D-5.

A second purpose of the test was to determine the effects of training on the production of the target features. For this reason the test was administered twice, before and after training. For the first version the children were presented with a set of three cards each having one question and answer unit printed on it. There were no special markings to indicate which features were being tested. The children read the cards to familiarize themselves with the materials and then read the units aloud and were recorded. This test portion was always administered before the Prosodic Feature Production Test I, described above. After completion of Prosodic Feature Production Test I, which involved training of the children on the specified features, the three test units of the present test were presented again. This time the items were marked by capitals and underlining to indicate stress and by three dots to indicate pause. Prosodic Feature Production Test I was always administered between the two parts of Prosodic Feature Production Test II because training was needed for Prosodic Feature Production Test I and for the second part of Prosodic Feature Production Test II, but would have interfered with administering the first part of Prosodic Feature Production Test II.

Two experienced listeners listened to the tape recordings and noted whether the children produced the features intended and if not, what features were being produced. No attention was paid to the Wh questions because they were not intended as test items, but rather as prompts to lead into the appropriate responses. Only thirty-two children took this test because it was added to the test battery after testing had begun.

Speech Reception Tests

All speech reception tests were presented monaurally to the child's better ear. Better ear was selected based on the better SRT if available. If no better SRT could be found the better pure tone average was used. When no better ear data were available, the right ear was chosen. However, whenever a preference was stated on the child's part, that ear was tested. This occurred for seven of the forty-three children. In none of these cases did the audiometric data reveal a difference of greater than 10 dB between the two ears.

Prior to the beginning of the testing, an MCL was established for each child using recorded sentences. Sentences were used because it was felt that the conventional methods using words would require a higher setting which would be likely to be uncomfortable for listening to sentences later on. Since more time would be spent listening to sentences than words, the MCL for sentence materials was used. Most children were satisfied with this presentation level throughout the testing. Only five of the children requested increased intensity once the testing had begun. They all waited until the last of the reception tests was administered to request a change. For three of the five children the last reception test was the phonemic reception test.

The output levels of the apparatus used in reception testing were calibrated at the start of testing in every school. A General Radio sound level meter (model 1562-Z) was used for this purpose.

Phoneme Reception Test

This test was developed by Smith (1972) to evaluate phonemic discrimination ability in deaf children down to eight years of age. It was a closed response test consisting of fifty sets of three monosyllabic words. In each set, the words differed from each other by one phoneme. The phonetic contrasts used in these sets were based on differences in place of articulation or manner of articulation or voicing-manner contrasts for consonants. Vowel contrasts were based on tongue placement and/or tension of the tongue. The contrasts were based on typical kinds of phoneme substitutions appearing in the speech of deaf children.

A tape recording was made of the test words read by an adult male speaker with an educated New York dialect. The test tape was presented to each of the forty-three subjects and the children were asked to circle one of the three words on the answer sheet in front of them. Before the test began, there were three practice items presented. The test items appear in Appendix D-6.

Prosodic feature reception - Test I

This test was designed to investigate the child's ability to differentiate the features of stress, pause and intonation for yes/no questions through a strictly auditory channel. There were nine simple sentences divided equally into two, three and five syllable utterances. Each of the two, three and five syllable items was presented with a syllable stressed early in the utterance (early stress) and also with a syllable stressed late in the utterance (late stress). The three and five syllable items were also presented with pause after a syllable early in the utterance (early pause) and with pause after a syllable late in the utterance (late pause). The two syllable items were presented with pause between the two syllables or with question intonation as in a yes/no question. This test was developed by Stark and Levitt (1974).

The test consisted of a recording of ten practice and thirty-six test items read by the same male speaker who read the phonemic reception test. The answer sheet contained four written choices for each item, all containing the same simple sentence but differing by the prosodic feature indicated. A sample answer sheet appears in Appendix D-7. The choices included stress, pause or question with the additional factor of early or late stress or pause location. The child was asked to circle the appropriate choice after hearing the target item presented auditorially. At first, the practice items were reviewed verbally by the examiner to familiarize the child with the task. When it was felt that the child understood the task involved, the first ten practice items were presented via tape and earphones and further assistance was given as the children often found the transition from live voice to tape recording somewhat difficult. Assistance was given up to the eighth item and then the children were encouraged to work on their own for the rest of the practice and test items. All forty-three children took this test.

Prosodic feature reception - Test II

This test was designed for the present study to determine how well the hearing impaired child could discriminate place of stress in an utterance, a feature which could easily change the meaning of an utterance. In this test, place of stress was the target feature in both statements and questions. Most of the questions were Wh and used the same intonation pattern as the statements. Two of the questions used rising intonation and allowed for a comparison of recognition of place of stress within different intonation contours. In addition to stress, emphasis (extra stress) was used to determine whether greater use of intensity, duration and/or pitch change would make this feature more easily recognizable to the hearing impaired population.

The test consisted of twelve simple sentences, six questions and six statements. Within each group of six, three were three syllables long and three were five syllables long. Each of the simple sentences was presented once with stress and once with emphasis, constituting twenty-four items on the test. Because of an error made during the production of the master tape, stress or emphasis was tested seven times in early location (always sentence initial), eight times in mid-location and nine times in late location in the utterances, rather than an equal number of times (8) in each location as had been intended. However, the extra item of stress in late position allowed for useful additional comparisons. For each test item read there were three written choices differing only in place of stress or emphasis. The word group was always the same; stress and emphasis were not compared within a test item. The test items appear in Appendix D-8.

Four practice items were used to teach the child to associate the auditory stimulus with the written representation. Practice was done without earphones at first and later with the tape recorded practice items. The children were instructed to circle the sentence they heard. Because the test was introduced after overall testing had begun, only thirty-four subjects took this test.

CHAPTER IV

RESULTS

This chapter will focus on the results of the phonemic and prosodic tests and intelligibility scores and ratings for the hard-of-hearing and deaf groups of children. Particular emphasis will be placed on differences in mean scores and differences in the patterns of confusions for the two groups. In addition, scores on each test will be correlated with the pure tone average and with overall intelligibility scores for each child. Appendix E contains listings of each of the scores and ratings obtained by each of the children.

Speech Production Skills

Speech Intelligibility

Read sentences

Intelligibility scores for all words in the twenty test sentences were derived for each child based on the average number of words which the inexperienced listeners could identify correctly from the recordings of the children's speech. Table 1 shows that scores for all subjects ranged from 1.3% to 96.6% with a mean of 53.9%. (Percentages referred to in the text, and proportions listed in the tables are used interchangeably throughout the

TABLE 1

Means, standard deviations, standard errors and ranges of intelligibility scores for hard-of-hearing, deaf and both groups of children for the total corpus of words and for selected words in the twenty test sentences. Scores are indicated in terms of proportion correct.

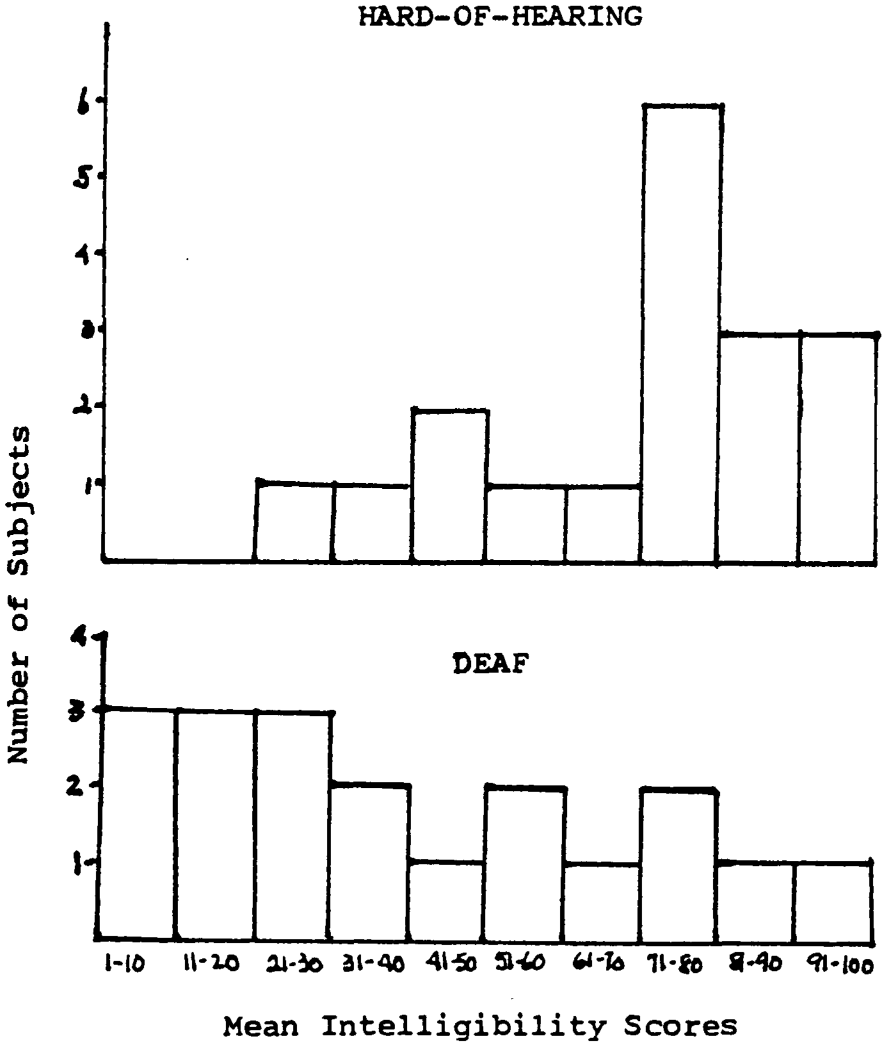
Word Group	Hard-of-Hearing	Deaf	Both
All words			
Mean	.696	.391	.539
Standard deviation	.203	.290	.304
Standard error	.048	.067	.050
Range	.281-.966	.013-.921	.013-.966
Selected words			
Mean	.682	.385	.529
Standard deviation	.207	.293	.293
Standard error	.049	.067	.048
Range	.276-.955	.016-.926	.016-.955
N=	18	19	37

chapter. Percentage = 100 X proportion.) Scores for the hard-of-hearing group (HOH) ranged from 28.1% to 96.6% with a mean score of 69.6% while the deaf group (DF) had scores ranging from 1.3% to 92.1% with a mean of 39.1%. A t-test showed that the average scores for the two groups of children differed significantly ($t=3.68$, $df=35$, $p<.001$). The distribution of scores appearing in Figure 3 shows that most of the hard-of-hearing children had high intelligibility scores while the deaf children's scores were spread over the entire range with a heavier concentration toward the lower end. Seventy-eight percent (14) of the 18 hard-of-hearing children had scores greater than 50%, while only 37% (7) of the 19 deaf children scored that high. Only 4 deaf children had intelligibility scores greater than 70%, whereas 12 of the hard-of-hearing children exceeded that amount; and only two of the hard-of-hearing children had scores lower than 40% while 11 deaf children had scores that low.

A comparison between intelligibility scores for the 81 key words studied by Smith and for all of the words in the 20 sentences showed essentially the same scores for the two methods of scoring. The mean scores for the key words were 68.2% and 38.5% for the hard-of-hearing and deaf groups, respectively. These scores are almost identical with those for all words in the test sentences. As a matter of convenience, scores for all words will be used from this point on in the discussion.

FIGURE 3

Distribution of mean intelligibility scores for hard-of-hearing and deaf subjects for all of the words in the twenty test sentences. Scores are based on the number of words correctly identified by inexperienced listeners.



In addition to intelligibility scores, ratings were obtained for each speaker using the 1-5 rating scale for intelligibility developed at the National Technical Institute for the Deaf (Johnson, 1975). The scale, shown in Table 2, ranks the speaker's intelligibility in steps from 1 meaning speech cannot be understood, to 5 meaning speech is completely intelligible. One hundred and eleven listeners with essentially no experience in listening to deaf speakers, rated the intelligibility of the sentences read by the thirty-seven hearing impaired children. The average intelligibility ratings for the entire group, as determined by these inexperienced listeners, was 3.05 with a range from 1.28 to 4.82. The hard-of-hearing group averaged 3.60 and ranged from 2.37 to 4.82. The deaf group ranged from 1.28 to 4.60 and averaged 2.52 (Table 3). These mean ratings were found to be significantly different ($t=3.74$, $df=35$, $p<.001$). Fourteen of the 18 (83%) deaf children had average ratings lower than 3.0 while 4 of the 19 (21%) hard-of-hearing children had ratings lower than 3.0 (Figure 4).

Three experienced listeners rated the intelligibility of the 37 readers on a portion of the 20 sentences using the same 1-5 scale. The children averaged a rating of 3.78, the hard-of-hearing group averaged 4.20 and the deaf group averaged 3.38 (Table 3). These mean ratings were found to be significantly different ($t=3.32$, $df=35$, $p<.002$). These averages were considerably higher than those obtained by the inexperienced raters. The distribution of ratings by

TABLE 2

National Technical Institute for the Deaf rating scale for overall speech intelligibility.

Rating	Description of Speech
1	Listener cannot understand the message
2	Listener understands little of the content of the message, but does understand a few isolated words or phrases
3	Listener understands with difficulty about half of the message. (Intelligibility may improve after a listening period.)
4	Listener understands most of the content of message
5	Listener understands the complete message

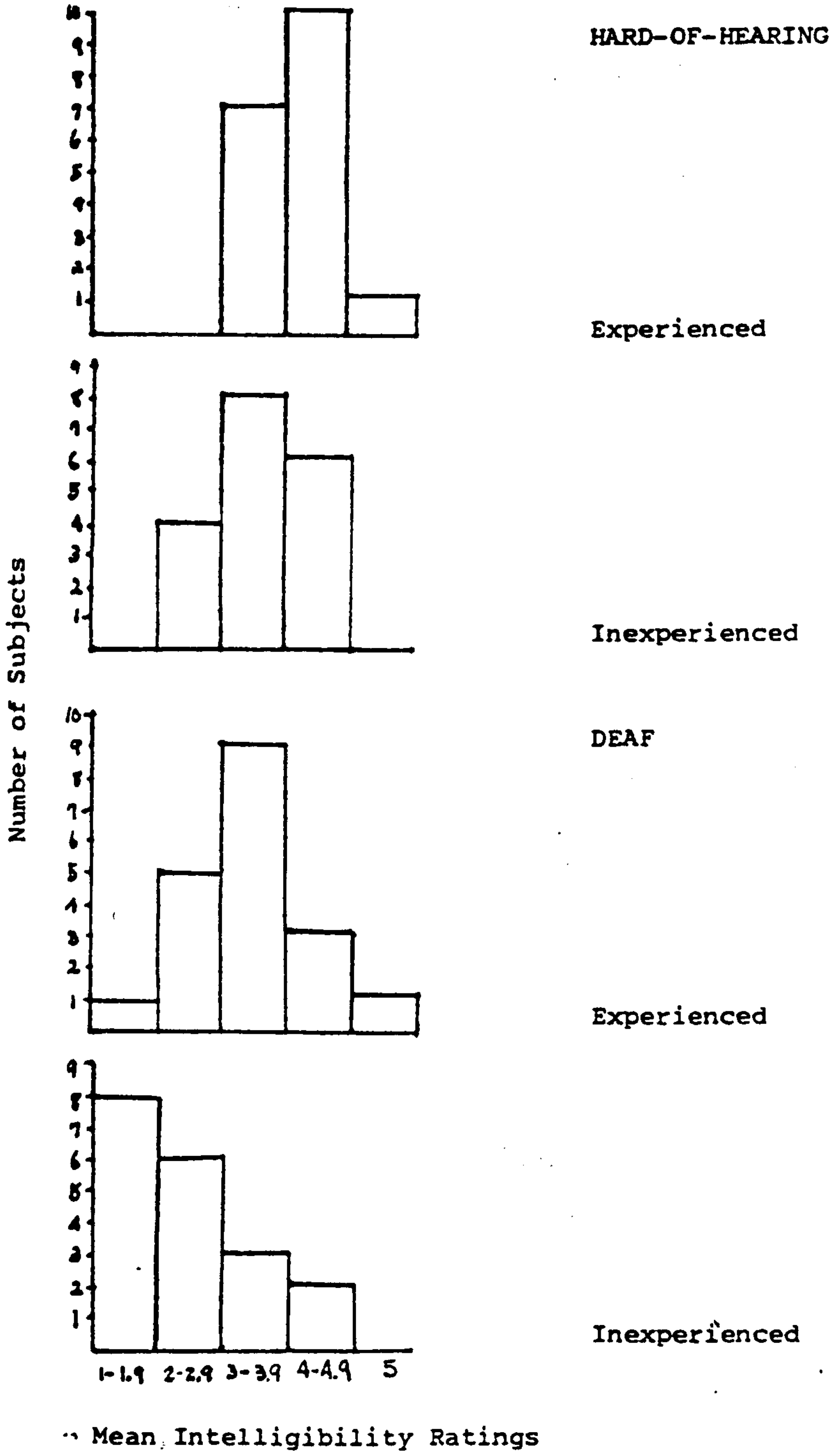
TABLE 3

Mean intelligibility ratings, standard deviations, standard errors and ranges of ratings based on NTID 1-5 rating scale for hard-of-hearing, deaf and both groups of children as determined by inexperienced and experienced listeners for the same read materials.

Listeners	Hard-of-Hearing	Deaf	Both
Inexperienced			
Mean	3.60	2.52	3.05
Standard deviation	.07	1.02	1.02
Standard error	.17	.23	.17
Range	2.37-4.82	1.28-4.60	1.28-4.82
Experienced			
Mean	4.20	3.38	3.78
Standard deviation	.50	.93	.85
Standard error	.12	.21	.14
Range	3.33-5.00	1.33-5.00	1.33-5.00
N=	18	19	37

FIGURE 4

Distribution of intelligibility ratings for hard-of-hearing and deaf children as determined by experienced and inexperienced listeners for read speech materials.



experienced raters (Figure 4) shows the corresponding shift towards higher ratings compared to those from the inexperienced group. A t-test comparing the mean ratings given by experienced and inexperienced raters showed a significant effect of experience on intelligibility ratings ($t=-10.90$, $df=36$, $p<.001$), with the deaf showing larger differences than the hard-of-hearing children and both groups having higher mean ratings when experienced listeners rated. Caution must be exercised when interpreting the effects of experience on intelligibility ratings since the experienced raters in this study were also familiar with the test materials and knew in advance which sentences were being read as they rated the child's overall speech intelligibility.

The correlation between the ratings given by the experienced and the inexperienced raters for these recordings was statistically significant ($r=.92$, $p<.001$). High correlations were also obtained between the intelligibility scores and the intelligibility ratings given by the inexperienced listeners ($r=.99$, $p<.001$) and between the intelligibility scores given by inexperienced listeners and intelligibility ratings given by the experienced raters ($r=.92$, $p<.001$).

An analysis of variance was carried out for the factors of Child and Sentence. Between-listener differences were treated as part of the replication error. This was done because each listener did not listen to all of the children reading all of the sentences. Every listener heard four children reading five sentences each, in a way that each utterance was heard by three different listeners. The results of this ANOVA showed significant effects due to the child reading the sentence, and to the sentences themselves (Table 4). The interaction between Sentence and Child was statistically significant but was not very large compared to the main effects. Although listener variability was a significant factor, it did not contribute as much to the eventual differences in scores per child as did the Child or Sentence.

Spontaneous speech

Three raters, experienced in listening to the speech of the deaf, rated the intelligibility of each of the forty-three children on each of the two spontaneous speech samples. An average of these six ratings was obtained for each child. There was a significant difference between the mean ratings of the hard-of-hearing and deaf groups ($t=2.99$, $df=41$, $p<.005$). The mean intelligibility ratings were 4.35 for the hard-of-hearing and 3.55 for the deaf children.

Figure 5 shows a distribution of the intelligibility ratings for the hard-of-hearing and deaf children. The NTID 1-5 rating scale for intelligibility (Johnson, 1975) was used. A rating of 5 represented highly intelligible speech, while a rating of 1 meant that speech could not be understood. The distribution shows a heavy concentration of 4 and 5 ratings for the hard-of-hearing groups, whereas there

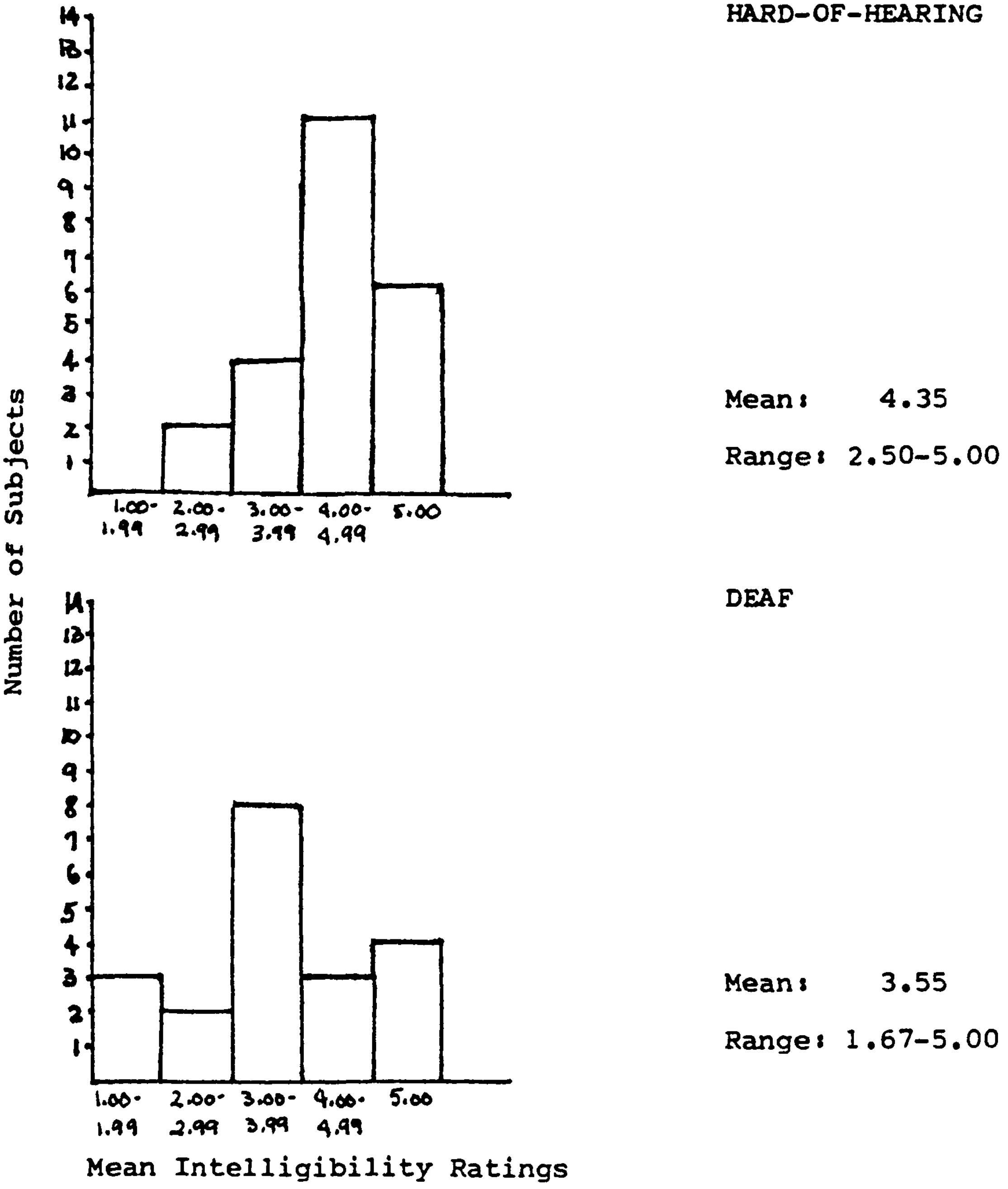
TABLE 4

Analysis of Variance between Child and Sentence with between-listener differences treated as part of the Replication Error.

Source	Sum of Squares	DF	Mean Square	F	Level of Significance
Child	1462.424	36	40.622	177.770	.001
Sentence	207.701	19	10.932	47.838	.001
Child x Sentence	536.876	684	0.785	3.435	.001
Replication Error	338.200	1480	0.229		

FIGURE 5

Distribution of mean intelligibility ratings for hard-of-hearing and deaf children for two spontaneous speech samples. Ratings were given by experienced listeners. Also included are mean ratings and range of ratings for the two test groups.



HARD-OF-HEARING

Mean: 4.35

Range: 2.50-5.00

DEAF

Mean: 3.55

Range: 1.67-5.00

is a wider distribution of ratings for the deaf group. Seventy-five percent of the deaf children had mean ratings between 3 and 5; 40% were between 3 and 3.99 and 35% were between 4 and 5. In comparison, 91% of the hard-of-hearing children had mean ratings between 3 and 5; 17% were between 3 and 3.99 and 74% were between 4 and 5.

The six non-readers in this study (see Chapter III for explanation) had an average intelligibility rating of 3.97, not significantly different from the average rating for the whole group of readers (3.98).

Experienced listeners' intelligibility ratings of read and spontaneous speech for the thirty-seven subjects who participated in both tests had a correlation of .87 ($p < .001$). Since no inexperienced listeners were asked to rate the intelligibility of these spontaneous speech samples, no comparisons are possible between ratings based on the experience of the listener for spontaneous speech. (See Chapter III for explanation.) Such information has already been discussed relative to read materials.

Phonemic Production

Phonemic production: sentences

Major error type

In the twenty sentences read by the thirty-seven children, there were 8,584 intended vowels and 11,618 intended consonants, creating a corpus of 20,202 intended phonemes for the 37 speakers. Examination of the broad phonetic transcriptions showed that the error rate for the intended phonemes was 24%. Table 5 contains a breakdown of the major categories of phonemic errors made by the hard-of-hearing and deaf children. The frequency of occurrence of these errors with respect to the total number of phonemes intended is indicated in the first, third and fifth columns in the table. In parentheses, in the even numbered columns, are entries showing the relative proportion of errors, i.e., the relative frequency of the indicated error category as a proportion of the total number of errors. For example, phonemes were omitted 9.6% of the time that they were intended (row 1, column 5). This constituted 39.8% of all segmental errors made by the children (row 1, column 6), and was the most common error. Within category substitutions made up another large proportion of the total body of errors. These were the substitution of an incorrect vowel for the intended vowel (23.7%) and substitution of an incorrect consonant for the intended one (19.9%). Distorted sounds that were nevertheless recognizable as the intended phonemes (recognizable distortions) constituted another 8.7% of the total error. This error type will be interpreted with caution due to the differences in criteria between transcribers. The remaining categories of severe distortions (i.e., distortions so severe that the intended phoneme was unrecognizable), diphthong errors, substitutions of non-English phonemes, misreading of words and substitutions of consonants for vowels and vowels for con-

TABLE 5

Relative frequency of articulatory errors for hard-of-hearing, deaf and both groups of children for all phonemes in the twenty test sentences. Two entries are shown for each group of children. The first is the proportion of error out of the total number of phonemes intended. The second (in parenthesis) is the relative frequency of the error type as a proportion of the total number of errors made. (See text for explanation.)

	Hard-of-Hearing		Deaf		Both	
Error Type	Proportion of error	Relative proportion of error	Proportion of error	Relative proportion of error	Proportion of error	Relative proportion of error
Omission	.076	(.392)	.116	(.406)	.096	(.398)
Vowel-vowel substitution	.050	(.258)	.065	(.227)	.057	(.237)
Consonant-consonant substitution	.035	(.180)	.060	(.210)	.048	(.199)
Recognizable distortion	.019	(.098)	.023	(.080)	.021	(.087)
Severe distortion	.007	(.036)	.013	(.045)	.010	(.041)
Diphthong	.004	(.021)	.004	(.014)	.004	(.017)
Non-English substitution	.002	(.010)	.004	(.014)	.003	(.012)
Other	.001	(.005)	.001	(.003)	.002	(.008)
Total	.194	(1.000)	.286	(.999)	.241	(.999)

sonants made up the remaining 7.8% of the errors; as shown in the fifth to seventh rows of the table.

As anticipated, the deaf children had more errors on a larger percentage of the intended phonemes than did the hard-of-hearing children (see confusion matrices in Appendix F-1 and F-2). Whereas 28.6% of the phonemes produced by the deaf group were in error, only 19.4% of the phonemes produced by the hard-of-hearing group were in error. A t-test showed that the average proportion of phonemes produced correctly by the two groups was significantly different ($t=1.998$, $df=78$, $p<.05$). However, the relative frequency of error types (after adjusting for total errors) reveals the following pattern: for both the deaf and hard-of-hearing children, omissions constituted approximately 40% of all errors and vowel-vowel substitutions made up 26% of the total errors for the hard-of-hearing and 23% for the deaf group. The deaf children had a larger proportion of consonant-consonant substitutions than did the hard-of-hearing children.

Consonantal errors

Table 6 contains a list of all of the consonants ranked according to the percent of correct production. Bilabial sounds, regardless of the manner of their production, headed the list as most often correct. The lingua-alveolar fricatives and the affricates were the most subject to error.

TABLE 6

Distribution of error types for consonants. Each entry is the relative frequency of that error type after adjusting for the total proportion of errors for the intended phoneme. The data are pooled across all children. Phonemes are presented in rank order of correct production.

		Error Types										
Phoneme	Proportion Correct	P	M	V	P-M	P-V	M-V	P-M-V	O	RD	SD	Other
b	.931	.228	.110	.136	.072	.000	-	.025	.127	.097	.087	.118
w	.923	.010	.084	-	.105	-	.000	.019	.037	.301	.084	.360
p	.921	.015	-	.126	.041	.000	.015	.041	.533	.115	.015	.099
f	.891	-	-	.129	.031	.000	-	.062	.455	.221	.091	.011
m	.886	.180	.241	-	.023	-	.015	.019	.326	.126	.029	.041
j	.874	.000	.000	-	.500	-	.000	.178	.143	.071	.036	.072
n	.872	.028	.040	-	.014	-	.019	.031	.748	.023	.045	.052
h	.856	.034	-	-	.181	.000	-	.122	.572	.011	.033	.047
l	.839	-	.045	-	.041	-	.003	.003	.545	.155	.089	.119
v	.820	.006	-	.136	.117	.006	-	.006	.477	.104	.071	.077
g	.752	.040	.020	.095	.055	.000	-	.047	.517	.028	.113	.085
k	.716	.068	-	.056	.037	.008	.004	.014	.600	.065	.080	.068
ð	.690	.007	-	.119	.744	.007	-	.030	.025	.051	.009	.008
r	.688	.039	.000	-	.009	-	.000	.015	.472	.234	.187	.044
t	.674	.008	.015	.081	.010	.001	.012	.022	.676	.057	.063	.055
θ	.644	.068	-	.066	.302	.000	-	.073	.192	.227	.056	.016
ŋ	.627	.318	.000	-	.006	-	.013	.000	.607	.028	.009	.019
tʃ	.527	-	.311	.015	.232	-	.000	.013	.201	.049	.126	.053
d	.520	.016	.028	.062	.002	.009	.005	.007	.785	.040	.019	.027
ʃ	.505	.010	.200	.000	.200	.000	.000	.092	.109	.094	.099	.000
dʒ	.344	-	.120	.049	.071	-	.047	.088	.489	.084	.036	.016
s	.341	.050	.152	.014	.006	.006	.014	.004	.492	.167	.066	.029
z	.237	.050	.075	.042	.007	.009	.020	.000	.589	.111	.085	.012
Mean of points where confusions could occur		.059	.089	.075	.120	.003	.010	.040	.422	.107	.066	.062

P= place substitutions M= manner substitutions V= voicing substitutions O= omissions
RD= recognizable distortions SD= severe distortions - = no possible confusions in American English

Consonants were in error on the average 28.5% of the time that they were intended. The major portion of the consonantal errors was due to the omission of the intended phoneme (Table 7). There were five phonemes for which omission constituted more than 60% of the total errors made (Table 6, column 10). They are /d/ 78.5%; /n/ 74.8%; /t/ 67.6%; /ŋ/ 60.7%; /k/ 60.0%.

Consonant for consonant substitutions were the second largest source of error. The other categories contributed minimally to the total error. The relative frequency of each type of substitution (e.g., place, manner, voicing) is shown in the bottom row of Table 6. Each entry in the row is the proportion of substitutions of the type indicated relative to all possible substitutions of that type. It was computed by summing all of the entries in the column above and dividing by the number of cases where such an error could occur. For example, in American English there are eight phoneme pairs in which the members of the pairs differ solely by voicing /p,b/, /t,d/, /k,g/, /f,v/, /tʃ,dʒ/, /θ,ð/, /s,z/, /ʃ,ʒ/. The sum of all entries under voicing is 1.126. This number divided by the number of phonemes involved (15 because /ʒ/ was not among the intended phonemes in the twenty sentences) yields .075, the entry in Table 6. The results show that place-manner errors occurred most frequently. This high incidence, however, seems to be due to one or two specific errors, such as /d/ for /ð/. Manner errors ranked second among con-

TABLE 7

Relative frequency of consonant errors for hard-of-hearing, deaf and both groups of children for all of the consonants in the twenty test sentences. Two entries are shown for each group of children. The first is the proportion of error out of the total number of consonants intended. The second (in parenthesis) is the relative frequency of the error type as a proportion of the total number of consonantal errors made. (See text for explanation.)

	Hard-of-Hearing		Deaf		Both	
Error type	Proportion of error	Relative proportion of error	Proportion of error	Relative proportion of error	Proportion of error	Relative proportion of error
Omission	.116	(.520)	.182	(.529)	.149	(.523)
Consonant-consonant substitution	.060	(.269)	.104	(.302)	.082	(.288)
Recognizable distortion	.030	(.135)	.031	(.090)	.031	(.109)
Severe distortion	.011	(.049)	.020	(.058)	.016	(.056)
Non-English substitution	.002	(.009)	.007	(.020)	.005	(.018)
Other	.004	(.018)	.000	(.000)	.002	(.007)
Total	.223	(1.000)	.344	(.999)	.285	(1.000)

fusions, followed by voicing then place and place-manner-voicing errors. Substitutions involving manner-voicing and place-voicing were minimal. There were few major differences between the kinds of substitutions made by the hard-of-hearing and deaf children. The only exceptions were the tendency for the deaf children to make more confusions of place-manner-voicing and the hard-of-hearing children to make more errors of place.

When errors were viewed in terms of the manner of production of the intended phoneme, the rank order of correct production was glides and laterals, nasals, stops, fricatives and affricates (Table 8). The rankings of proportion of correct production of consonants according to manner of production was the same for the hard-of-hearing and deaf groups.

The rank order of correct production of consonants according to place of articulation was bilabial, glottal, labio-dental, lingua-velar, lingua-alveolar and lingua-palatal (Table 9). Voiced sounds were correct slightly more often than voiceless sounds, but the proportions were not significantly different.

The most common kind of phoneme substitution for the fricatives was that of place-manner. A larger proportion of these errors was due to the substitution of /d/ for /ð/, a rather common occurrence in New York speech patterns. Stop substitutions usually consisted of errors of voicing. Errors for nasals were most often those of place substitu-

TABLE 8

Distribution of proportion of correctly produced consonants according to manner of articulation. Entries represent mean proportion correct across phonemes for hard-of-hearing, deaf and both groups of children.

Manner of Articulation	Hard-of-Hearing	Deaf	Both
Glides and lateral			
/w,r,j,l/	.867	.797	.830
Nasals			
/m,n,ŋ/	.879	.715	.795
Stops			
/p,b,t,d,k,g/	.816	.692	.752
Fricatives			
/f,v,θ,ð, s, z,ʃ,h/	.697	.553	.623
Affricates			
/tʃ, dʒ/	.513	.362	.436

TABLE 9

Distribution of proportion of correctly produced consonants according to place of articulation. Entries represent mean proportion correct across phonemes for hard-of-hearing, deaf and both groups of children.

Place of Articulation	Hard-of-Hearing	Deaf	Both
Bilabials			
/p,b,m,w/	.937	.894	.915
Glottal			
/h/	.924	.793	.859
Labio-dental			
/f,v/	.879	.834	.856
Lingua-velar			
/k,g,ŋ/	.811	.715	.763
Lingua-dental			
/θ,ð/	.728	.610	.667
Lingua-alveolar			
/t,d,s,z,n,l,r/	.670	.525	.595
Lingua-palatal			
/ʃ,tʃ,dʒ/	.648	.482	.563

tions. There were no consistent patterns of error for glides and laterals.

The confusion matrices for the hard-of-hearing and deaf children were compared in terms of a statistic known as G^2 (Appendix F-3) which was designed specifically for comparing data from discrete multivariate distributions (Bishop et al., 1975). This statistic compares confusion matrices on a row by row basis and takes into account differences in overall error rate between matrices. Using this method and counting the diagonal, i.e., the number of times the intended phoneme was produced correctly, nine consonants emerge as being produced significantly differently by the two groups of speakers ($G^2 > 17$, $p < .05$). These consonants are /t,d,k,s,z,h,m,n,ŋ/. This inventory contains samples of stop, fricative and nasal phonemes which the deaf and hard-of-hearing groups produce differently. When the G^2 was computed eliminating the diagonal, i.e., setting aside the fact that the hard-of-hearing children produced the sound correctly significantly more often than the deaf children, only two consonants remain as sounds for which the two hearing impaired groups had significantly different ($p < .05$) patterns of errors. These two sounds are /z/ and /ŋ/. In both cases, the deaf omitted the sound more often than did the hard-of-hearing group. The hard-of-hearing children tended to substitute a closely related sound, e.g., /s/ for /z/, /n/ for /ŋ/.

Vowel errors

Table 10 shows the vowels and diphthongs tested ordered according to the proportion correctly produced. Also shown in the table is the system of articulatory features used in classifying the vowels for the purposes of this study (Bronstein, 1960). The vowels /i,æ,u/ were of particular concern in Smith's (1972) construction of the twenty test sentences. They were embedded in various phonemic environments to include transitions to and from the seven places of consonant articulation with each of these vowels. This table shows that of these three vowels, /u/ was produced correctly most often (91.5%) and /æ/ and /i/ were less often correct (88.2% and 83.3%, respectively) although there was little difference in the performance between the latter two vowels.

When /u/ was the intended vowel, the most common error was the substitution of the /ə/. This constituted 22.4% of the total error for that phoneme. /ʊ/ was also a common confusion. The greatest proportion of errors for the phoneme /i/ was attributed to the substitution of its lax counterpart /I/ (37.8%) and another large proportion was due to the use of the /ə/ (18.0%). When /æ/ was the intended phoneme, /ɑ/ accounted for 20.2% of the total error and /ɛ/ for 11.9%.

A view of all of the vowel sounds intended reveals that there was an error rate of 18.2%. The greatest proportion of these errors was due to the substitution of an

TABLE 10

Rank order of correct production of vowels for the hearing-impaired children on all words in the twenty test sentences. Also shown in the table is the system of articulatory features used in classifying the vowels for the present study (Bronstein, 1960). The diphthongs /aɪ/ and /aʊ/ are listed according to the first component; /ju/ according to the second.

		Articulatory Features			
Phoneme	Proportion Correct	Frontness	Height	Rounding	Tension
/ɝ/	.973	Central	Mid	Neutral	Tense
/ɛ/	.923	Front	Mid	Spread	Lax
/o/	.921	Back	Mid	Round	Tense
/ɔ/	.920	Back	Low	Round	Tense
/u/	.915	Back	High	Round	Tense
/ʊ/	.906	Back	High	Round	Lax
/æ/	.882	Front	Low	Spread	Lax
/aʊ/	.879	Back	Low	Neutral	Lax
/a/	.874	Back	Low	Neutral	Lax
/ɪ/	.872	Front	High	Spread	Lax
/e/	.868	Front	Mid	Spread	Tense
/aɪ/	.844	Back	Low	Neutral	Lax
/i/	.833	Front	High	Spread	Tense
/ʌ/	.818	Central	Low	Neutral	Lax
/ə/	.752	Central	Mid	Neutral	Lax
/ju/	.500	Back	High	Round	Tense
/ɚ/	.284	Central	Mid	Neutral	Lax

unintended vowel for the target one (72.5%). The remaining categories of error each contributed a much smaller proportion of the error. Omissions occurred at a rate of 13.2% (Table 11). These omissions generally occurred when parts of words were omitted.

A comparison of the relative proportion of error for the hard-of-hearing and deaf groups shows that vowel-vowel substitutions constituted 72-73% of the total error for each group. The pattern of vowel-vowel substitutions reveals that typically when an error was made, the vowel produced was a near neighbor of the intended vowel on the vowel quadrilateral, e.g., /i/ for /I/, /æ/ for /ɛ/, /ʌ/ for /ɔ/. Frequently, the vowel produced was correct with respect to frontness of the tongue but was made with the wrong tongue height. Usually, the incorrect tongue height was toward mid-position. Furthermore, a common error was substitution of the central /ə/ or /ʌ/ for the intended vowel.

Next, all of the simple stressed vowels /i,I,e,ɛ,u,ʊ, æ,o,ɔ,ɑ,ʌ,ɝ/ were analyzed in terms of the substitutions made based on the features of frontness, height, degree of lip-rounding and tension alone and in combinations. In addition, vowel confusions due to substitutions of /ə/ or /ɚ/, diphthongization, omission and severe distortions were also considered. Table 12 shows the relative proportion of errors for each of these categories across the twelve intended stressed vowels. Each entry represents an average

TABLE 11

Relative frequency of errors for hard-of-hearing, deaf and both groups of children for all vowels in the twenty test sentences. Two entries are shown for each group of children. The first is the proportion of error out of the total number of vowels intended. The second (in parenthesis) is the relative frequency of the error type as a proportion of the total number of errors made. (See text for explanation.)

	Hard-of-Hearing		Deaf		Both	
Error type	Proportion of error	Relative proportion of error	Proportion of error	Relative proportion of error	Proportion of error	Relative proportion of error
Omission	.021	(.135)	.027	(.130)	.024	(.132)
Vowel-vowel substitution	.111	(.712)	.151	(.729)	.132	(.725)
Recognizable distortion	.005	(.032)	.013	(.063)	.009	(.049)
Severe distortion	.001	(.006)	.003	(.014)	.002	(.011)
Diphthong	.009	(.058)	.008	(.039)	.009	(.049)
Non-English substitution	.000	(.000)	.000	(.000)	.000	(.000)
Other	.009	(.058)	.005	(.024)	.006	(.033)
Total	.156	(1.001)	.207	(.999)	.182	(.999)

TABLE 12

Distribution of errors for stressed vowels appearing in all words in the twenty test sentences. Entries represent the mean proportion of each error type after adjusting for the total number of errors made. Each entry is averaged over all stressed vowels where such errors could have occurred. Data are pooled over all children. Vowels included in the analysis are /i,ɪ,e,ɛ,æ,ɑ,ɔ,o,ʊ,u,ɝ,ʌ/.

Error type	Mean Proportion Error	Most common Substitutions
Frontness (F)	.105	ʌ ↔ ɑ
Height (H)	.121	/ɪ↔ɛ/ /ɔ→u/ /ɛ↔æ/ /u↔o/
Rounding (R)	-	
Tension (T)	.265	/i↔ɪ/ /ɛ↔e/ /u↔ʊ/
FH	.029	/ɛ→ʌ/
FR	.087	/æ→ɑ/ /ɑ↔ʌ/ /ɝ→o/ /ʌ→æ
FT	-	
HR	.024	/ʊ→ɔ/
HT	.081	/e↔æ/ /ʊ→ɑ/ /ʊ→o/
RT	.298	/ɑ↔ɔ/
FHR	.041	/ʊ→ʌ/
FHT	.009	/i→ʌ/
FRT	.052	/ɔ→ʌ/ /ɝ→ɛ/
HRT	.017	/ɑ→o/
FHRT	.048	/u→ʌ/ /ʌ→o/
Unstressed neutral	.098	/o.u.i.æ.ʊ→ə/
Diphthongization	.024	/ʊ,æ,ɛ,ɪ/
Omissions	.051	/i,ʌ,ɛ/
Recognizable distortions	.053	/ʌ,æ/
Severe distortions	.017	

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* A→B substitution of B for A A↔B substitution in both directio

of the relative proportion of errors across the points where such confusions could exist in the English language. For instance, there are eight vowels for which height of the tongue alone produces a different American English vowel. They are: /ɛ,I/ and /æ/ with each other and /o,ɔ/ and /u/ with each other and /i/ and /e/ with each other. In the category of tension, there are three vowel pairs for which change of tension alone creates the other member of the pair. These are: /i/ with /I/ and /u/ with /ʊ/ and /e/ with /ɛ/. Only these points where phonemic differences could occur were averaged to yield the entries in Table 12.

The table shows that when tension errors can occur phonemically, they constitute an average of 26.5% of all of the errors made for the intended phoneme. The vowels in question were the /i/ and /I/ and /u/ with /ʊ/ and /e/ with /ɛ/ which were frequently substituted for each other. No other single feature confusion occurred as often on the average as that of tension.

Errors due to improper production of the features of rounding and tension average 29.8% of all errors for phonemes for which this kind of error was possible. This kind of error manifested itself as the substitution of /ɔ/ for the intended /ɑ/ or /ɑ/ for the intended /ɔ/.

The stressed vowels were also studied in terms of degree of frontness, height, rounding and tension. Table 13 shows that back vowels were more often correct than central or front vowels; mid vowels were correct more often than

TABLE 13

Distribution of proportion of correctly produced vowels according to degree of tension, frontness, height and lip rounding. Each category represents the average proportion correct for the simple, stressed vowels having those features.

Feature	Mean Proportion Correct
<u>Tension</u>	
Tense /ɝ, u, o, ɔ, e, i/	.901
Lax /ɛ, ʊ, ɪ, a, æ, ʌ/	.880
<u>Frontness</u>	
Back /u, o, ɔ, ʊ, a/	.907
Central /ʌ, ɝ/	.896
Front /ɛ, e, ɪ, æ, i/	.876
<u>Height</u>	
Mid /o, ɝ, ɛ, e/	.921
High /u, ʊ, i, ɪ/	.882
Low /ɔ, a, æ, ʌ/	.874
<u>Rounding</u>	
Round /u, o, ɔ, ʊ/	.916
Neutral /ɝ, a, ʌ/	.888
Spread /ɛ, e, ɪ, æ, i/	.876

high or low vowels; round vowels were produced correctly more often than neutral or spread ones; and tense vowels averaged a higher proportion correct than lax ones. These values were obtained by averaging the percent correct production of vowels according to the category in question. None of the differences within categories was very large, e.g., although back vowels were produced correctly more often than front vowels, back vowels were correct on the average 91% of the time, while front vowels were correct on the average 88% of the time.

For the diphthongs /ɑI/, /ɑʊ/ and /ju/, the most significant confusions were the omission of one of the two elements of the sound.

A G^2 statistic comparing the confusion matrices of the hard-of-hearing and deaf children showed that for four vowels and diphthongs /i,ɑ,ə,ɑI/ there was a statistically significant difference in the production of these sounds by the hard-of-hearing and deaf groups of children ($p < .05$). Elimination of the diagonal, i.e., those instances where the intended phoneme was correctly produced, limited the number of vowels with different error patterns to /ə/ and /ɑI/. When /ə/ was intended, the hard-of-hearing children produced /eI/ more often than the deaf group and the deaf children omitted the sound more often than did the hard-of-hearing group. Although the G^2 indicates a difference in confusions for /ɑI/ the difference is based on a slight difference in perception and labelling on the part of the transcribers. For the hard-of-hearing group there was a greater tendency for the transcribers to note the absence of the off-glide while for the deaf group the perception of the produced sound was labelled as /ɑ/, essentially the same effect.

Phonemic production: isolated words

The purpose of this test was to allow a comparison of production of phonemes in isolated words with production of the same phonemes in words read in the context of a sentence. Scores, in terms of the proportion of phonemes correct, were compared for the isolated test words and for those identical words as they appeared in the context of the test sentences. The scores for the words in isolation were obtained from the broad phonetic transcriptions made by one of the transcribers mentioned above. Although the scores were slightly higher for the phonemes appearing in context (71.5%) than for the words in isolation (67.9%), a t-test did not show a statistically significant difference between the two groups of scores ($t=.0395$, $df=70$).

Prosodic Feature Production

Prosodic feature production: Test I

Three experienced listeners who knew the intended utterances rated the children on Prosodic Feature Production Test I. They listened to the tapes and indicated whether the utterance was characterized by early or late stress, early or late pause, rising intonation as in question or falling intonation as in statement. They could also categorize the utterance as staccato (equal stress on all syllables and equal pause between syllables) or unintelligible. (See Chapter III for a description of the test and the listeners.)

Overall scores for the hearing-impaired children ranged from 31.5% to 92.6%. The mean score was 60.7%. The hard-of-hearing children had a wider range of scores than the deaf children: 61 percentage points as opposed to 33 percentage points. The mean scores for the two groups were not significantly different; the hard-of-hearing group had a mean score of 62.3% and the deaf group had a mean score of 58.9% (Table 14).

The rank order of features produced correctly was the same for the hard-of-hearing and deaf children. Pause was most often produced correctly (90%), followed by stress (66%) (late stress, 72%; early stress, 58%) and then question (26%) (Table 14). This ranking was also found to be the same for a matched group of normal-hearing children. However, in all categories but that of question, the deaf children had higher mean scores than those of the hard-of-hearing children. Only in the case of late stress did this superior performance by deaf subjects reach a level of significance ($t=2.140$, $df=34$, $p<.025$). This trend was entirely unexpected. A closer look at performance on test items featuring late stress revealed that the deaf children frequently used exaggerated cues to mark stress. Excessive

TABLE 14

Means, standard deviations and ranges of overall test scores for hard-of-hearing, deaf and both groups of children on Prosodic Feature Production Test I. Scores are indicated in terms of proportion correct.

Score	Hard-of-Hearing	Deaf	Both
Mean	.623	.589	.607
Standard deviation	.184	.089	.147
Range	.315-.926	.370-.704	.315-.926

Mean proportion correct for each test feature for hard-of-hearing, deaf and both groups of children on Prosodic Feature Production Test I.

Feature	Hard-of-Hearing	Deaf	Both
Pause	.888	.917	.901
Late stress	.638	.822	.724
Early stress	.522	.650	.581
Question	.411	.094	.264

duration was one of these cues. Whereas the outcome of this effort was to produce an effect recognized as stress, the overall production did not usually sound normal. A second part of the problem is that some hard-of-hearing children did very poorly on the test. It appeared that some of these children were using their own rules in producing stress. Some seemed to disregard instructions and read the utterances as statements with stress placed on a word other than the target word. Others may have used a cue such as slight pause before the stressed word, which was not recognized by the examiners as a marker of stress.

For both the deaf and hard-of-hearing groups, errors made in the production of items testing early pause were roughly evenly divided between the possible alternatives available to the listener. When late pause was intended, the most common error was staccato production for both groups. The deaf children also read the items as statements occasionally. When stress was the intended feature, one error, that of staccato production, was significantly more frequent than other errors. Both the deaf and hard-of-hearing children had a great deal of difficulty on items testing question intonation. They frequently substituted late stress (hard-of-hearing, 22%; deaf, 33%) or produced statements (hard-of-hearing, 21%; deaf, 32%) in place of the rising intonation which was called for. In addition, 15.6% of the utterances produced by the deaf children were identified by the raters as staccato. This confusion occurred only 9.2% of the time for the hard-of-hearing group. For the deaf group, these three confusions occurred more frequently than the correct production of the feature (Figure 6).

In order to determine whether there was an effect of the sentence itself on correct prosodic feature production, means were calculated for the six simple sentences across the six test versions and across all of the children. The values appearing in Table 15 indicate that within the two groups based on sentence length, there were small differences between sentences. However, on the average, the five-syllable utterances were correct nearly 10% more often than the two-syllable utterances. This difference was statistically significant ($t=4.89$, $df=10$, $p<.001$).

Another set of listeners was used in order to determine the effects of prior knowledge of the intended feature on perception of prosodic feature production ability of hearing-impaired children. (See Chapter III for a description of the listeners and the rationale for their use.) This set of six listeners was asked to listen to the recordings of Prosodic Feature Production Test I. They were not told in advance which feature the child was attempting to produce, whereas the three listeners in the first group knew the intended feature in advance. Instead, they were given nine characteristics from which to choose the one they felt most appropriately labelled the prosodic feature used in the utterance.

FIGURE 6

Distribution of features produced on Prosodic Feature Production Test I for each of the four test features intended, for the hard-of-hearing (x) and deaf (o) subjects. The intended feature is marked on the top of each box. The most frequent features produced are marked on the x-axis.

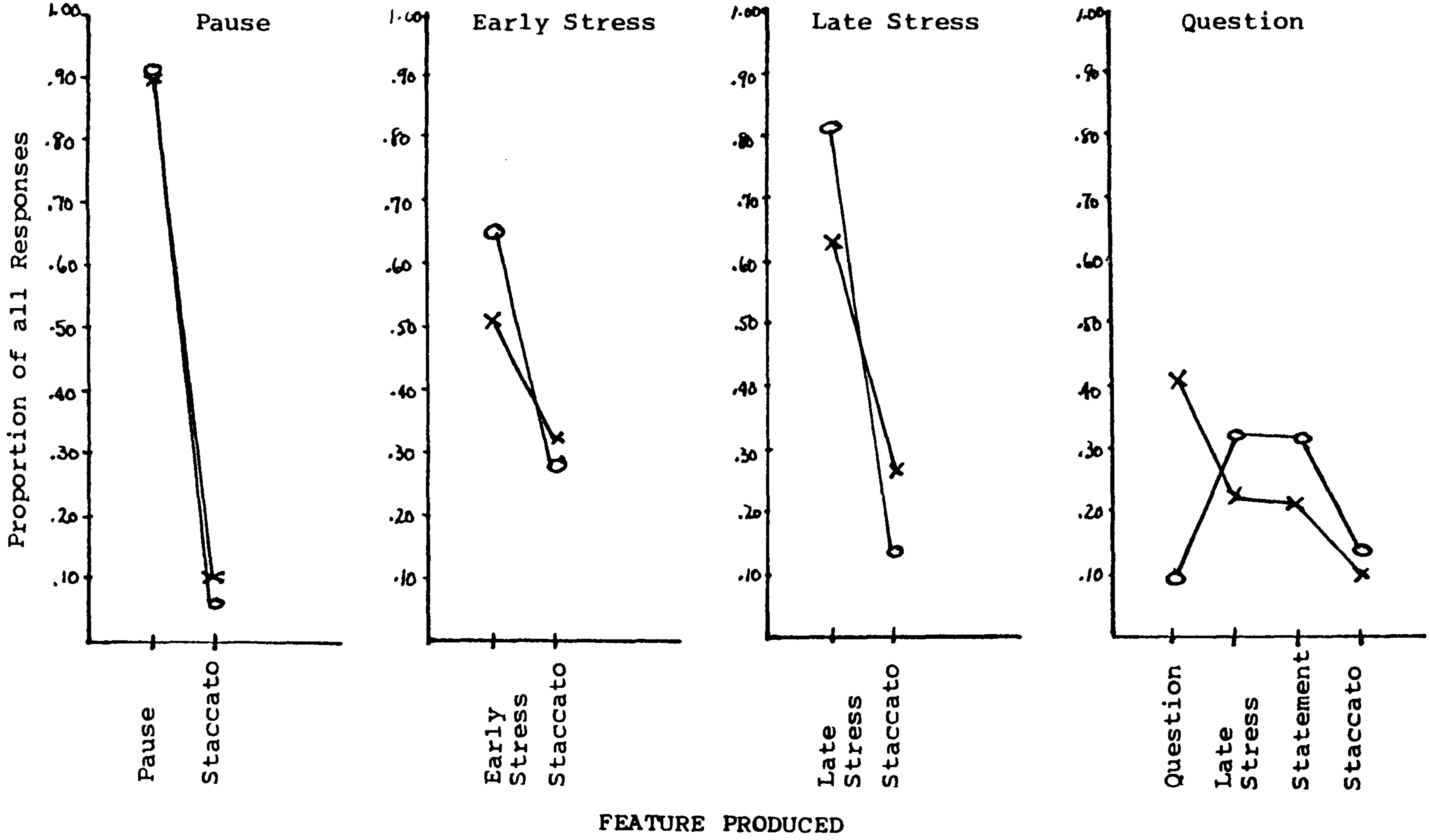


TABLE 15

Mean proportion correct for each of the six simple sentences on Prosodic Feature Production Test I. Scores are averaged over all test versions for hard-of-hearing, deaf and both groups of children.

Sentence	Hard-of-Hearing	Deaf	Both
Oh boy.	.548	.531	.540
Come here.	.566	.560	.563
Thank you.	.611	.544	.578
He has one big dog.	.609	.644	.626
My new hat is blue.	.682	.622	.652
I want to see it.	.689	.679	.684

An analysis of variance was carried out on the data for the two sets of listeners (Table 16). Of the three main factors, Feature, Listener-Group and Hearing-Group (i.e., hard-of-hearing vs. deaf), the Feature difference was most significant ($p < .001$) and the Listener difference was also significant, though less so ($p < .05$). There was no significant effect of Hearing-Group. There was a significant interaction between Feature and Hearing-Group ($p < .01$) due to the large differences in performance between the hard-of-hearing and deaf groups on the features of question, late stress and early stress (Table 17). For the features of early pause, late pause and late stress, there were large differences in the scores given by the two groups of listeners for the deaf children. The listeners who knew the intended feature in advance scored as much as eighteen percentage points higher than did the other group of listeners. A look at the pattern of confusions revealed that the group with no prior knowledge of the intended feature had a greater tendency to rate the badly produced utterances as unintelligible, thereby reducing the total number of correct items in the group.

Prosodic feature production: Test II

The major objective of this test was to evaluate the children's use of certain prosodic features in a more natural setting than in the previous test. (See Chapter III for description and rationale.) The features tested were early and late stress, pause in a statement and pause in a

TABLE 16

Analysis of Variance between Feature, Listener-Group and Hearing-Group for Prosodic Feature Production Test I. Only F values exceeding a level of .10 signicance are listed.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Level of Significance
Feature	5.562	4	1.390	174.153	.001
Listener-Group	0.064	1	0.064	7.959	.048
Feature x Hearing-Group	0.700	4	0.175	21.944	.008
Listener-Group x Hearing-Group	0.040	1	0.040	5.111	.086

TABLE 17

Comparison of mean scores for hard-of-hearing and deaf children for five test features on Prosodic Feature Production Test I. Scores were derived from two sets of listener, one with (*) and one without (**) prior knowledge of the target items.

	Hard-of-Hearing		Deaf	
Feature	Listener Group I*	Listener Group II**	Listener Group I	Listener Group II
Early pause	.906	.872	.946	.835
Late pause	.870	.852	.889	.704
Late stress	.638	.645	.822	.750
Early stress	.522	.594	.650	.675
Question	.411	.357	.094	.079

yes/no question. The target features appeared in the context of a sequential question and answer group. A second purpose of the test was to determine the effects of training on performance. The test was administered twice, once before and once after Prosodic Feature Production Test I, for which training was given.

Table 18 shows the mean proportion correct, standard deviation and ranges of scores for the hard-of-hearing and deaf children before and after training. Also shown in the table are the scores for each of the features tested. An analysis of variance was carried out for the factors of Training, Hearing-Group, Rater and Feature. The results showed that scores improved significantly with training ($p<.001$) (Table 19). The improvement with training was considerably greater for the hard-of-hearing than the deaf group ($p<.05$). In addition, the Feature effect was significant ($p<.001$). Performance on pause in a yes/no question was much poorer than on any other feature. Late stress items were produced better than early stress, as was true for Prosodic Feature Production Test I. Also, as was the case for the other prosody test, the deaf did better than the hard-of-hearing children on the production of stress. Once again, the differences between the hard-of-hearing and deaf groups were not significant for overall mean scores. The hard-of-hearing group had a mean score of 51% and the deaf group had a mean score of 51%. Rater differences were not found to be significant.

TABLE 18

Means, standard deviations and ranges of overall test scores pre- and post-training for hard-of-hearing and deaf children on Prosodic Feature Production Test II. Scores are indicated in terms of proportion correct.

	Hard-of-Hearing		Deaf	
Score	Pre	Post	Pre	Post
Mean	.319	.702	.371	.639
Standard deviation	.166	.194	.166	.217
Range	.000-.778	.222-1.000	.111-.667	.222-.889

Mean proportion correct for each test feature pre- and post-training for hard-of-hearing and deaf children on Prosodic Feature Production Test II.

	Hard-of-Hearing		Deaf	
Feature	Pre	Post	Pre	Post
Early Stress	.365	.771	.479	.844
Late Stress	.500	.885	.708	.865
Pause + Statement	.328	.859	.219	.781
Pause + Question	.000	.125	.000	.031

TABLE 19

Analysis of Variance between Training, Hearing-Group, Listener and Feature for Prosodic Feature Production Test II. Only F values exceeding the .10 level of significance are listed.

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F	Level of Significance
Training	0.352	1	0.352	189.753	.001
Training x Hearing-Group	0.017	1	0.017	9.449	.053
Feature	1.904	3	0.635	342.089	.001
Training x Feature	0.041	3	0.014	7.349	.068
Hearing-Group x Feature	0.049	3	0.017	8.953	.053
Listener x Feature	0.035	3	0.012	6.350	.082

Speech Reception Skills

Phonemic Reception

There was a significant difference between the mean scores for the deaf and hard-of-hearing children on the Phoneme Reception Test ($t=5.59$, $df=41$, $p<.001$). The mean for the deaf children was 47% while the mean for the hard-of-hearing children was 70%. In addition, there was a larger distribution of scores for the deaf children (22 to 74%) than for the hard-of-hearing children (46 to 86%).

Table 20 contains a listing of all of the test items and the test choices on the Phoneme Reception Test. The items are grouped according to the feature being tested. The target item is in the left most column of each row. Numbers near each item represent the number of times that that item was chosen as the response to the auditory stimulus.

Averaging the data over both groups of children, the test feature most often perceived correctly was manner (71%). This was followed by voicing (65%). Place-manner and place contrasts were correct 51% and 50% of the time, respectively (Table 21). The vowel category will be discussed separately below. This order of correct perception of test features seems compatible with the idea that recognition of place of articulation is generally dependent on more high frequency information which the hearing impaired children are less likely to have available to them and also with the idea that most manner cues are located

TABLE 20

Number of responses for the target and foils for each item on the Phoneme Reception Test. Items are grouped according to the feature tested. The target item is in the left-most column of each section.

PLACE CONTRASTS

sat$_{23}$	fat$_{15}$	hat$_{5}$
pea$_{9}$	tea$_{15}$	key$_{19}$
bum$_{7}$	dumb$_{11}$	gum$_{25}$
she$_{29}$	he$_{8}$	see$_{6}$
let$_{27}$	wet$_{6}$	yet$_{10}$
read$_{23}$	weed$_{11}$	lead$_{9}$
sit$_{21}$	sip$_{5}$	sick$_{17}$
big$_{33}$	bid$_{4}$	bib$_{6}$

MANNER CONTRASTS

new$_{8}$	zoo$_{34}$	do$_{1}$
bill$_{33}$	mill$_{4}$	will$_{6}$
lot$_{31}$	dot$_{4}$	not$_{8}$
zip$_{29}$	dip$_{10}$	lip$_{4}$
wet$_{29}$	bet$_{5}$	met$_{9}$
me$_{33}$	be$_{4}$	we$_{5}$ *
pan$_{29}$	pad$_{10}$	pal$_{4}$
buzz$_{26}$	bud$_{9}$	bun$_{8}$

PLACE-MANNER CONTRASTS

fair$_{24}$	chair$_{13}$	pair$_{6}$
mumps$_{28}$	dumps$_{9}$	jumps$_{6}$
gee$_{18}$	we$_{7}$	D$_{18}$
then$_{24}$	den$_{10}$	men$_{9}$
do$_{27}$	you$_{8}$	moo$_{8}$
hen$_{19}$	ten$_{21}$	when$_{3}$
bug$_{27}$	bum$_{8}$	buzz$_{8}$
mass$_{9}$	map$_{14}$	match$_{20}$

VOICING CONTRASTS

mat$_{33}$	bat$_{7}$	pat$_{3}$
bark$_{19}$	mark$_{7}$	park$_{17}$
pill$_{22}$	mill$_{6}$	bill$_{15}$
two$_{33}$	do$_{8}$	new$_{2}$
D$_{31}$	tea$_{5}$	knee$_{7}$
nip$_{30}$	tip$_{9}$	dip$_{4}$
sup$_{19}$	sub$_{11}$	some$_{13}$
rib$_{16}$	rip$_{16}$	rim$_{11}$
come$_{35}$	cup$_{6}$	cub$_{2}$
pat$_{36}$	pad$_{2}$	pan$_{5}$

VOICING CONTRASTS

seed$_{33}$	seat$_{1}$	seen$_{9}$
bun$_{30}$	but$_{5}$	bud$_{8}$

VOWEL CONTRASTS

beet$_{19}$	bit$_{9}$	boot$_{15}$
Pete$_{25}$	pit$_{16}$	pot$_{2}$
hot$_{23}$	hut$_{16}$	hoot$_{4}$
not$_{27}$	nut$_{11}$	neat$_{5}$
luck$_{18}$	lock$_{15}$	look$_{10}$
suck$_{23}$	sock$_{16}$	sick$_{4}$
hit$_{35}$	heat$_{1}$	hut$_{7}$
fit$_{19}$	feet$_{4}$	foot$_{20}$
fool$_{31}$	full$_{12}$	feel$_{0}$
pull$_{19}$	pool$_{17}$	pill$_{7}$
pal$_{31}$	pool$_{2}$	peel$_{10}$
lid$_{17}$	lead$_{14}$	led$_{12}$
full$_{28}$	fool$_{7}$	fall$_{8}$
pot$_{31}$	pet$_{9}$	put$_{3}$

* One child failed to respond. All otheritems total 43.

TABLE 21

Mean and range of proportion correct for the five test features on the Phoneme Reception Test. Proportions are given for hard-of-hearing, deaf and both groups of children. A separate listing is also given for the most intelligible children.

Feature	Hard-of-Hearing		Deaf		Both		Most Intelligible	
Feature	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Manner	.831	(.500-1.000)	.575	(.250-1.000)	.711	(.250-1.000)	.911	(.750-1.000)
Voicing	.783	(.420-1.000)	.504	(.250-1.000)	.653	(.250-1.000)	.892	(.580-1.000)
Vowel	.643	(.290- .860)	.496	(.140- .860)	.575	(.140- .860)	.779	(.640- .860)
Place-manner	.557	(.250- .750)	.438	(.130- .750)	.511	(.130- .750)	.675	(.500- .880)
Place	.652	(.250-1.000)	.313	(.130- .630)	.500	(.130-1.000)	.613	(.380- .880)

in the lower frequency range (Miller and Nicely, 1955; Aston, 1972). When performance for the hard-of-hearing children was compared with that of the deaf children, a difference was found both in the scores for each feature and in the rankings of correct perception of the features of place and place-manner. The hard-of-hearing children had the most difficulty with these items while the deaf group had more trouble with items testing place than with those testing place-manner.

The performance of the most intelligible quartile of the hearing impaired children reflected the same rank order of difficulty that was true for the overall group. Their scores were very high for manner and voicing items and were more than twenty points lower for place-manner and place items (Table 21).

Aside from information on the mean scores obtained by the hearing impaired group for the feature categories, Table 21 also shows the range of scores for each feature. These values indicate that some children were able to obtain a score of 100% on items testing manner, place and voicing but that no one scored higher than 86% on vowel items or 88% for place-manner contrasts. Whereas six or seven children got the top scores for items testing manner, voicing and vowels, only one child got 100% on place contrasts and only two children scored 88% on place-manner items. More than half of the children getting the highest scores were in the highest quartile of intelligibility and all ranked in the best 30% of the children taking the test.

Test items in which nasals and glides were the target were correct 65% and 64% of the time, respectively. When stops and fricatives were the target items, they were correct 56% and 53% of the time, respectively. Regardless of whether place, place-manner, manner or voicing was the classification of the test item, there was a tendency for the item to be perceived correctly more often if the target sound itself happened to be voiced. Voiced sounds were correct at a rate of 64% and voiceless sounds at a rate of 52%. Although the differences are large, they did not reach a level of statistical significance.

There was little difference in performance on items based on whether the sounds were in initial or final position in the test word. Initial items were correct at a rate of 59% and final sounds were correct at a rate of 61%. However, when the sound in either position was voiced it was perceived correctly more often.

The intended vowel was correctly identified 57.5% of the time. Several trends were apparent in the responses for items testing vowel recognition. Back vowels were correct more often (63%) than front vowels (59%), though the difference between the two groups did not reach a level of significance. Frequently vowels were confused with their tense-lax counterparts when they were available as foils, e.g., /I/ for /i/ and /ʊ/ for /u/, or with other vowels having similar first formants when the second formant was beyond the audible frequency range of the subjects, e.g., /i/ with /u/ (Figure 7). The more central-back vowels of /ʌ/ and /ɑ/ were frequently confused with each other.

Prosodic Feature Reception

Prosodic feature reception: Test I

Scores on Prosodic Feature Reception Test I ranged from 27.8% to 86.1% with a mean score of 55.9%. The range of scores for the hard-of-hearing group was somewhat larger than for the deaf group. Mean scores for the hard-of-hearing children (59.0%) and for the deaf group (52.8%) were not significantly different.

On the average, the children did best on items testing pause and worst on items testing stress. Their performance on question items was considerably worse than for pause but somewhat better than for stress (Table 22). The deaf children performed slightly better than the hard-of-hearing children on the recognition of the feature of early pause.

The kinds of confusions made for the intended features varied with target feature, number of syllables and degree of hearing loss. For target features of question, late stress, early pause and early stress, the hard-of-hearing and deaf groups both showed the same general patterns of confusions. In most cases, the deaf scored lower than the hard-of-hearing on the target item and made proportionately more errors in each confusion category (Figure 8). It was only for items containing late pause that the pattern of confusions differed between the test groups.

FIGURE 7

Vowel confusions on Phoneme Reception Test. Target vowel is in left most position in box. Numbers represent the number of times each of the test choices was chosen.

$\boxed{\text{i}_{25} \rightarrow \text{ɪ}_{16} \rightarrow \text{a}_{2}}$ $\boxed{\text{u}_{31} \rightarrow \text{ʊ}_{12} \rightarrow \text{i}_{0}}$

$\boxed{\text{ɪ}_{17} \rightarrow \text{i}_{14} \rightarrow \text{ɛ}_{12}}$ $\boxed{\text{ʊ}_{19} \rightarrow \text{u}_{17} \rightarrow \text{ɪ}_{7}}$ Tense-Lax confusions

$\boxed{\text{ʊ}_{28} \rightarrow \text{u}_{7} \rightarrow \text{ɔ}_{3}}$

$\boxed{\text{i}_{19} \rightarrow \text{u}_{15} \rightarrow \text{ɪ}_{9}}$

Front-Back confusions

$\boxed{\text{ɪ}_{19} \rightarrow \text{ʊ}_{20} \rightarrow \text{i}_{4}}$

$\boxed{\text{a}_{23} \rightarrow \text{ʌ}_{16} \rightarrow \text{u}_{4}}$

$\boxed{\text{a}_{27} \rightarrow \text{ʌ}_{11} \rightarrow \text{i}_{5}}$

Central-Back confusions

$\boxed{\text{ʌ}_{18} \rightarrow \text{a}_{15} \rightarrow \text{ʊ}_{10}}$

$\boxed{\text{ʌ}_{23} \rightarrow \text{a}_{16} \rightarrow \text{ɪ}_{4}}$

TABLE 22

Distribution of proportion correct for hard-of-hearing, deaf and both groups of children for each of the test features on Prosodic Feature Reception Test I.

Feature	Hard-of-Hearing	Deaf	Both
Pause			
late	.717	.600	.659
early	.690	.711	.701
Question			
	.594	.467	.531
Stress			
late	.556	.395	.476
early	.440	.456	.448

FIGURE 8A

Proportion of confusions made by hard-of-hearing (0---0) and deaf (●——●) children on Prosodic Feature Reception Test I. The intended feature is the left-most entry at the bottom of each graph. The number in the upper right hand corner of each graph indicates the number of syllables in the test items.

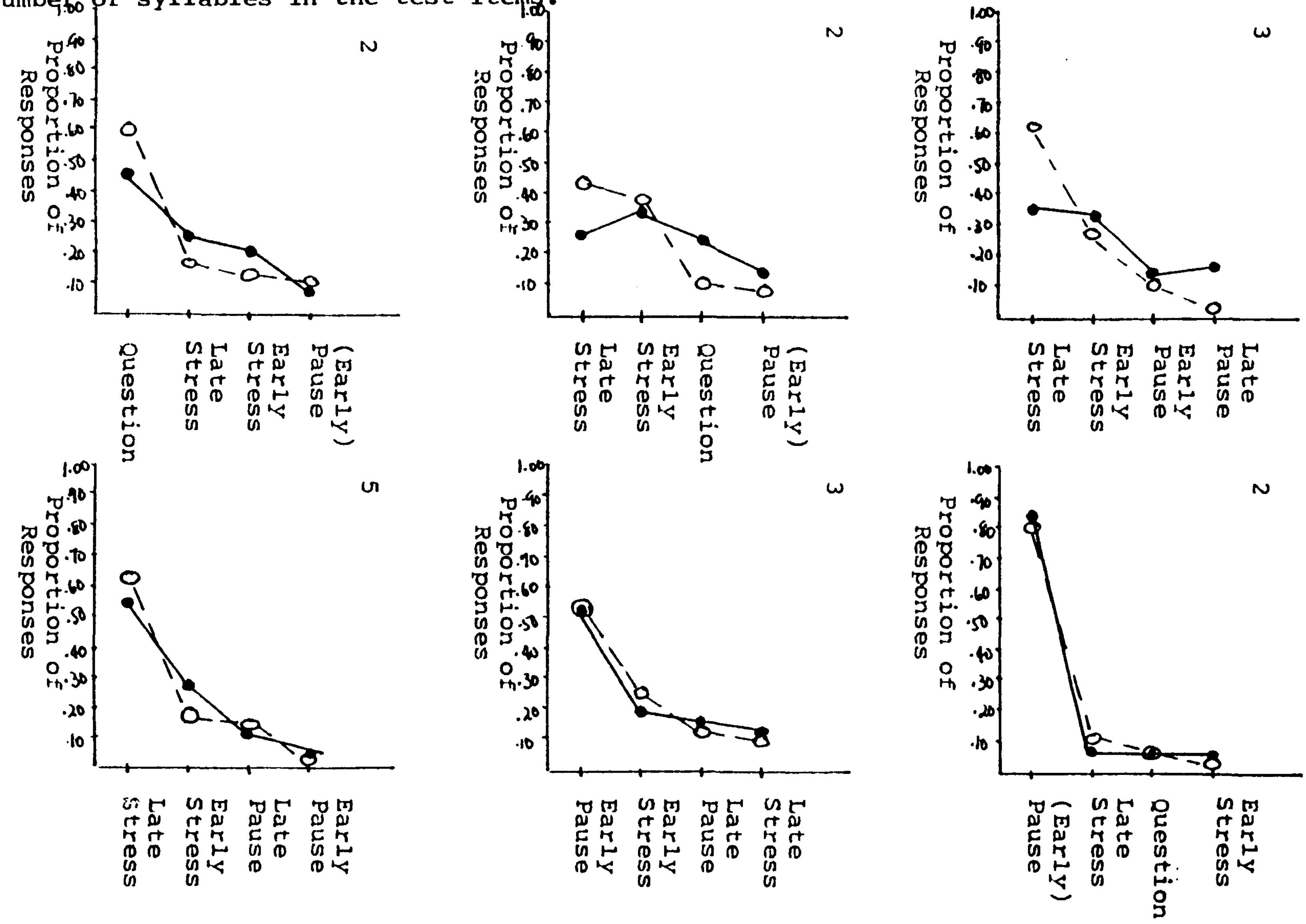
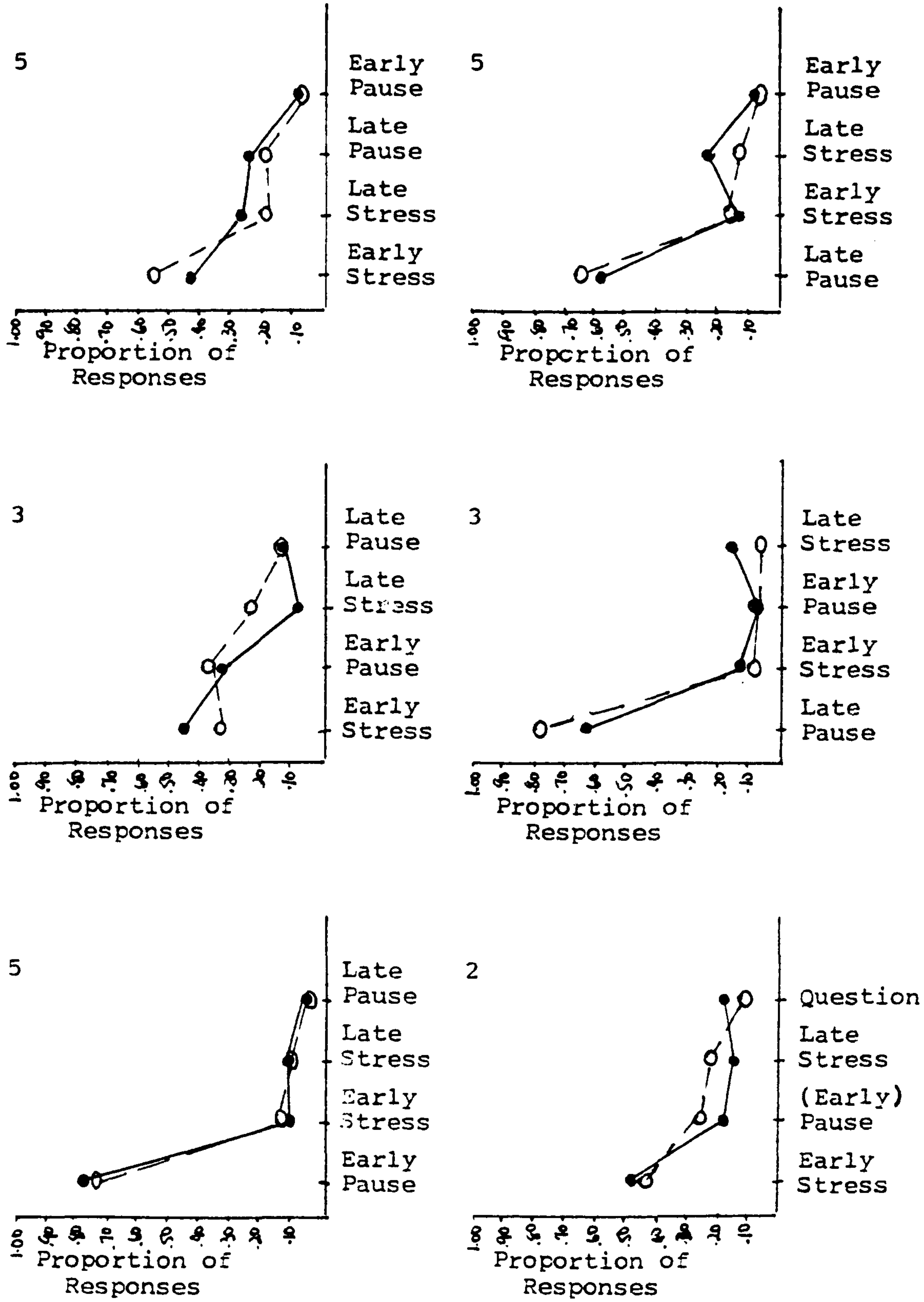


FIGURE 8B


5
Early Pause
Late Pause
Late Stress
Early Stress
Proportion of Responses
5
Early Pause
Late Stress
Early Stress
Late Pause
Proportion of Responses
3
Late Pause
Late Stress
Early Pause
Early Stress
Proportion of Responses
3
Late Stress
Early Pause
Early Stress
Late Pause
Proportion of Responses
5
Late Pause
Late Stress
Early Stress
Early Pause
Proportion of Responses
2
Question
Late Stress
(Early) Pause
Early Stress
Proportion of Responses
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10

When question was the intended item, it was frequently perceived as stress. When late stress was produced, the children often reported hearing early stress (regardless of the number of syllables in the utterance). Early pause was reported as early stress when it appeared in three syllable items. In two and five syllable items these confusions did not occur often. Three syllable items featuring early stress were frequently reported as early pause by the two groups. Early stress in five syllable items was said to be late pause. In two syllable items testing early stress, the hard-of-hearing group frequently circled the choice for early pause and late stress while some deaf children chose question and others chose early pause and late stress as their response.

Late pause was the feature for which there were obvious differences in the performance of the two groups of children. The deaf group had their greatest confusion with late stress when late pause was produced. The hard-of-hearing children did not have any major confusions in three syllable items but had early stress as the major confusion for five syllable items (Figure 8).

The overall pattern was for five syllable items to be perceived correctly more often than two or three syllable utterances. This is probably due to the difficulty in recognizing late stress in two syllable items and early stress in three syllable items. When length of utterance was viewed with respect to each feature separately, no consistent pattern favoring longer utterances was apparent.

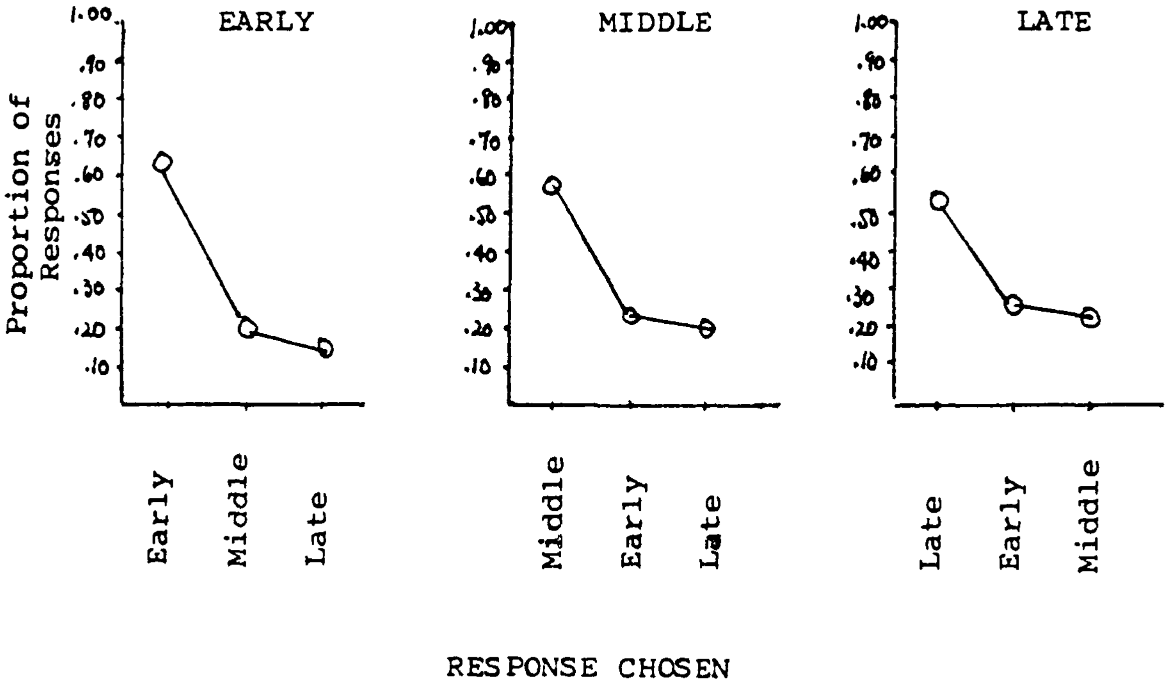
Prosodic feature reception: Test II

Prosodic Feature Reception Test II was designed to determine the effects of place of stress and degree of stress as well as length of utterance and sentence type on prosodic feature reception by hard-of-hearing and deaf children. (See Chapter III for a description and rationale.) Scores on this test ranged from 29.1% to 91.6% with a mean of 59.5%. The hard-of-hearing group covered the full range with a mean of 61.5% while the deaf children's scores ranged from 29.1% to 83.3% with a mean of 57.5%. These means were not significantly different.

When place of stress was averaged across all other features tested, both the hard-of-hearing and deaf groups did best on items testing early stress and worst on stress in late position. The deaf group did significantly better on items testing stress in early position compared with late position ($p<.05$) but no other positional differences were significant for either group of children. In addition, when an error was made on an item testing stress in middle or late position, the children tended to circle an item with stress in early position. This may reflect a trend on the part of the hearing impaired children to choose early location regardless of what is presented and therefore to have a higher percentage correct in early location (Figure 9). This trend would not have shown up on Prosodic Feature Reception Test I because the balance of choices was not

FIGURE 9

Distribution of responses for place of stress in the utterance on Prosodic Feature Reception Test II. Data are pooled across children, syllable length. degree of stress and sentence type. Place of stress in the target item is marked on the top of each box.



based solely on place of stress. Question and pause were added as foils. Thus other factors might have affected the children's selections.

In the present test, the same basic utterances were read once with normal sentence stress on the intended word and once with emphasis. Although the place of stress was not the same in each reading of a word group, a balance of relatively equal representation for each place of stress was achieved over the whole group of twenty-four items. Both the deaf and hard-of-hearing children did better on items testing emphasis (the addition of extra stress on the intended word) than they did on items testing stress. However, these differences did not reach a level of statistical significance.

Due to an error in the recording of the master tape, one test item was read twice, once with stress and once with emphasis on the same target word. This allowed an opportunity for a direct comparison of stress and emphasis without the effects of sentence type, length or location of stress. Performance for hard-of-hearing and deaf groups was much better (stress, 50%, emphasis, 70%) when emphasis was used.

As was true for Prosodic Feature Reception Test I, both groups of children did better on the average on five syllable items than on shorter ones. Here too, the difference did not reach a level of statistical significance.

For both the hard-of-hearing and deaf groups, comparisons were made between performance on Wh questions and on statements. There were no significant differences between the mean scores on the two kinds of test items. In addition, there were no significant differences in mean scores on these items when the hard-of-hearing and deaf groups were compared.

Question intonation was tested in three-syllable items only. Since this sentence type utilized a rising intonational pattern, performance for both hard-of-hearing and deaf groups was compared for question intonations and for statements which used a falling intonational pattern. For the hard-of-hearing group, there were minimal differences in the mean scores for question intonation and statement. The deaf group, however, had considerably lower scores on yes/no questions than on statements ($t=1.47$, $df=8$, $p<.10$).

Inter-Test Relationships

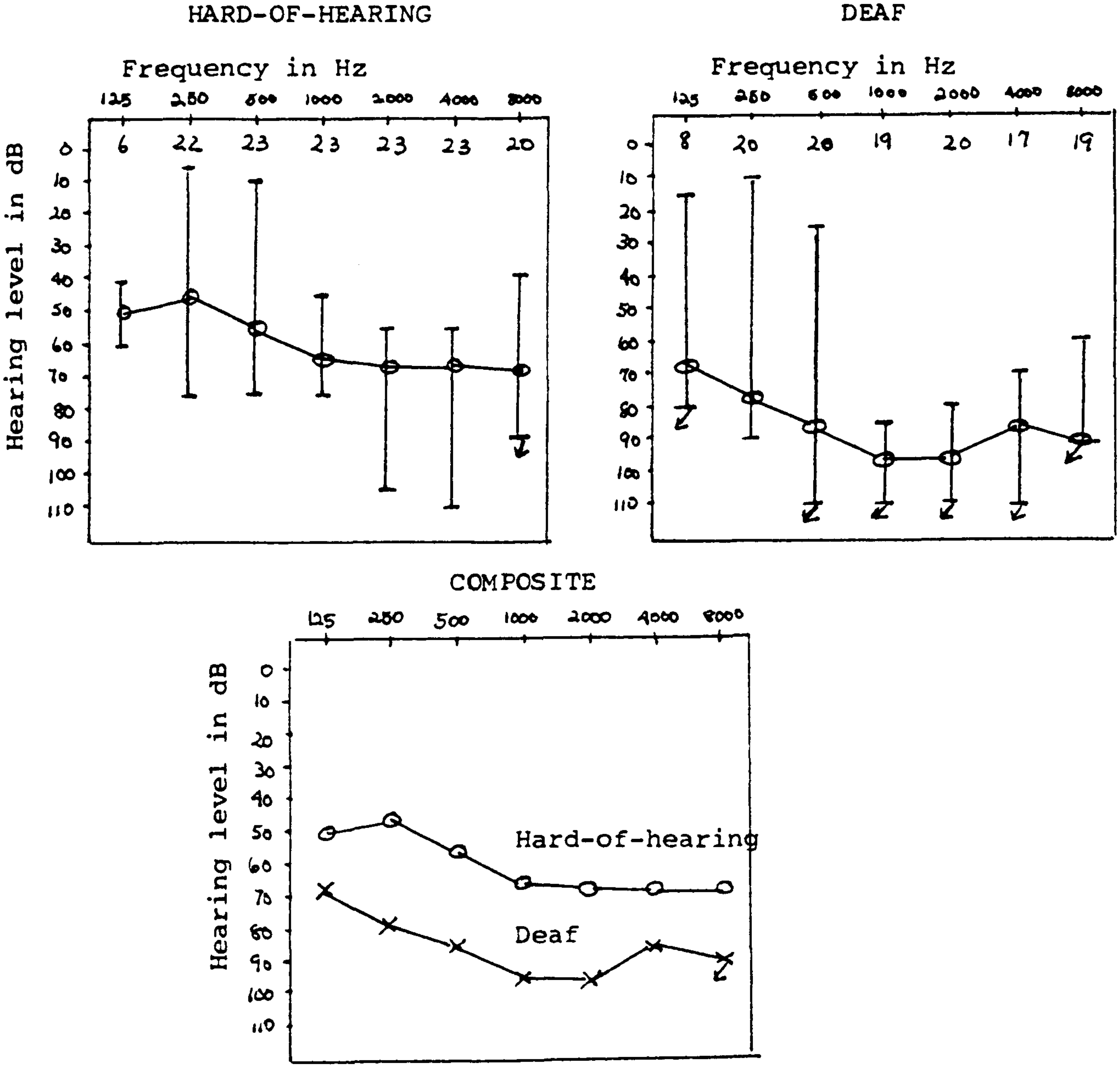
Test Performance as a Function of the PTA

The major concern of this study was to determine the relationship between hearing sensitivity and overall speech intelligibility. A three frequency pure tone average (PTA) was calculated for each child based on hearing thresholds at 500, 1000 and 2000 Hz in the child's better ear. Whenever thresholds at any of these frequencies were beyond the limits of the audiometer, a value of 110 dB + HTL was assigned as the pure tone average.

Figure 10 is a plot of the median audiograms and ranges of thresholds for the hard-of-hearing and deaf groups

FIGURE 10

Median and range of audiograms for the hard-of-hearing and deaf groups separately. Numbers on top of each audiogram indicate the number of children for whom data were available at each frequency. Also included is a composite audiogram showing mean thresholds for each group.



HARD-OF-HEARING

DEAF

COMPOSITE

of children. Also included is a composite audiogram comparing the means of the two groups. The figure shows that the median values were considerably worse for the deaf group for all octave frequencies from 125 to 8000 Hz. Figure 11 contains similar plots for the children grouped according to their intelligibility scores, with the ten most intelligible children in quartile 4 and nine children each in quartiles 3 through 1. A comparison of the audiograms for the four quartiles from most intelligible to least intelligible shows that the largest changes in threshold from one quartile to the next occurred at 125, 250 and 1000 Hz. At 500 and 2000 Hz there was little difference between the mean thresholds for the less intelligible quartiles but there were considerable differences for the more intelligible groups.

The scatterplot in Figure 12 shows that there is not a simple monotonic relationship between the pure tone average in the better ear and overall speech intelligibility, though there was a significant correlation between the two factors ($r=-.54$, $p<.001$). Although those with the best hearing generally had the best intelligibility, as the pure tone average increased above 90 dB, this approximate relationship broke down. In addition, there were four children who had relatively good pure tone averages but poor intelligibility (lower left section of Figure 12). All of these children had reasonably good scores on phonemic production (over 68%). There is no apparent reason for the

FIGURE 11A

Median and range of audiograms for the hearing impaired children divided into four quartiles of intelligibility. Numbers on top of each audiogram indicate the number of children for whom data were available at each frequency.

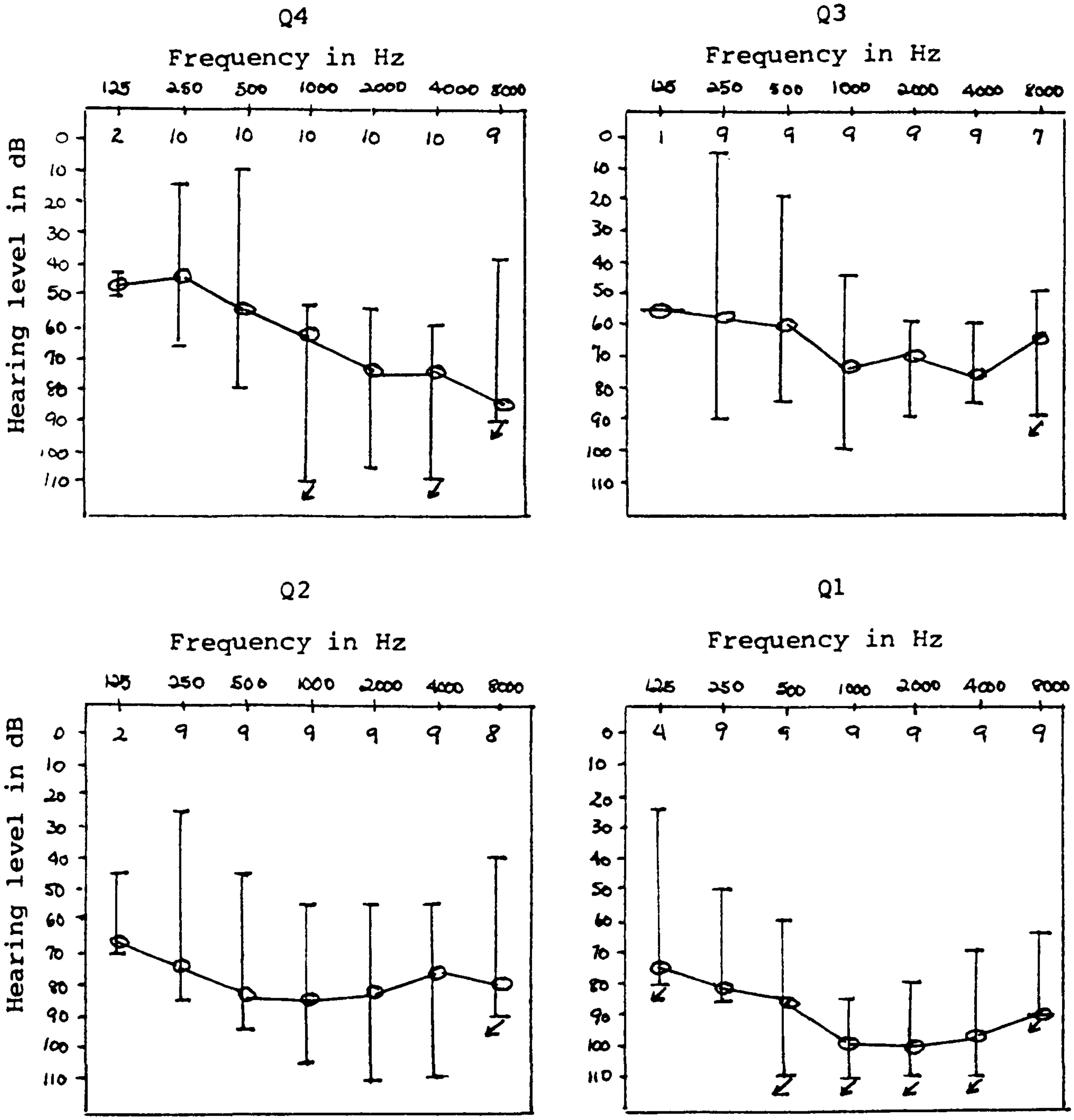


FIGURE 11B

Composite audiogram for the four quartiles of intelligibility

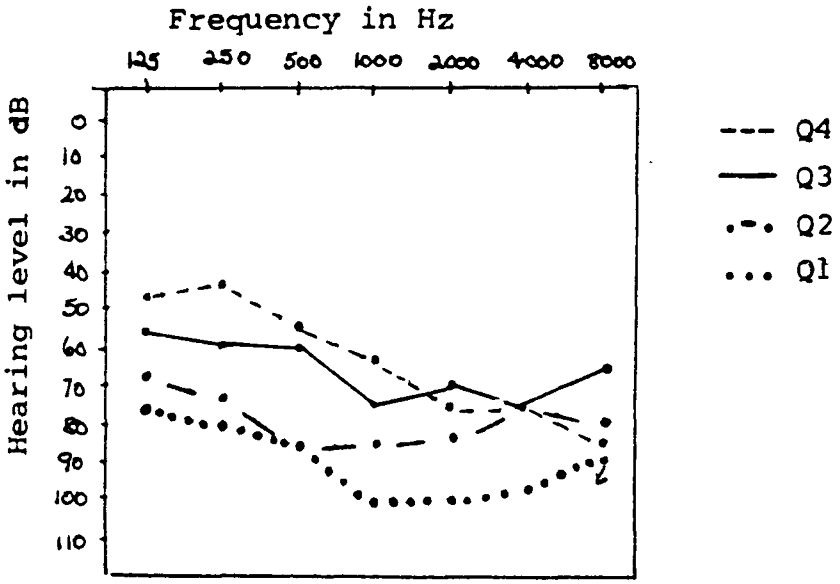
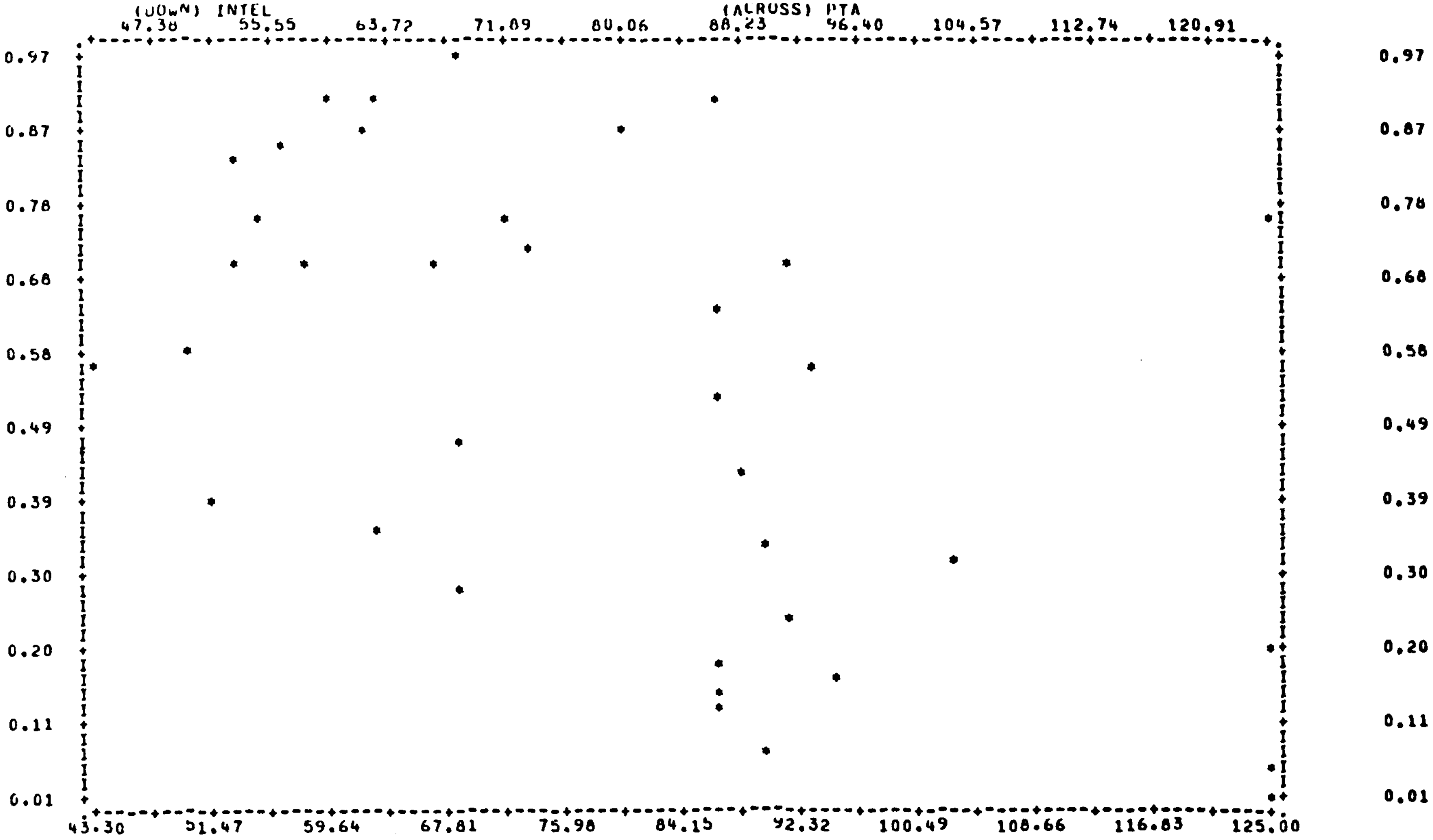


FIGURE 12

Scatterplot of Pure Tone Average in the better ear as a function of intelligibility scores.



low intelligibility scores for these children.

In addition to showing a moderate correlation with intelligibility, the PTA also correlated with those production abilities most closely related to intelligibility. Table 23 contains a list of the correlations of the PTA with all test scores. The table shows that the PTA correlated fairly well with phoneme scores on isolated words, phoneme scores for words in sentences and for spontaneous speech ratings. There were no significant interactions between the PTA and scores on any of the Prosodic Feature Reception Tests.

The highest correlation to PTA was with scores on the Phoneme Reception Test ($r=-.64$, $p<.001$), which showed that as hearing got worse, phoneme reception skills decreased. Performance on this test was a better predictor of speech production ability than was the PTA (Table 23). The stronger correlations of phoneme reception ability to spontaneous speech ($r=.70$) and phoneme scores on isolated words ($r=.73$) and words in context ($r=.82$) seem to show that the way in which the auditory stimulus is processed is more important than hearing level itself, at least for the three frequency pure tone average used. There was also a much better interaction between phoneme reception ability and prosody reception scores ($r=.47$, $r=.47$, for tests I and II, respectively) than between the PTA and prosody reception scores ($r=-.16$, $r=-.19$, for tests I and II, respectively).

TABLE 23

Correlation coefficients for the pure tone average and for scores on the Phoneme Reception Test with scores and ratings on all tests administered. (*=p<.005, **= p<.001)

Tests	Pure Tone Average	Phoneme Reception Test
Phoneme production score - words	-.45*	.73**
Phoneme production score - sentences	-.48**	.82**
Prosodic Feature Production I	-.14	.25
Prosodic Feature Production II	-.21	-.21
Spontaneous speech ratings	-.49	.70**
Intelligibility score	-.54**	.85**
Intelligibility rating		
Inexperienced	-.53**	.85**
Experienced	-.57**	.79**
Prosodic Feature Reception I	-.16**	.47**
Prosodic Feature Reception II	-.19	.47*
Phoneme Reception	-.64**	-

Test Scores as a Function of Intelligibility

The thirty-seven children who were able to read the twenty test sentences were divided into four quartiles of intelligibility based upon their intelligibility scores. These scores were derived from the mean number of words that inexperienced listeners were able to understand from the children's reading of the twenty sentences. There were ten children in Quartile 4 and nine children each in Quartiles 3 through 1. The most intelligible children were in Quartile 4 and the least intelligible in Quartile 1. The range of scores for each quartile of intelligibility is found in Table 24.

A second major concern of this study was to determine those factors which had the greatest effect on overall speech intelligibility. No significant interaction was found between the age, socio-economic level or home language of the child and his speech intelligibility. Table 25 contains a list of the correlations for performance on the various tests of phonemic and prosodic speech reception and production skills and intelligibility.

As anticipated, as the number of phonemes produced correctly increased, intelligibility increased ($r = .90$, $p < .001$, Figure 13). When phonemic errors in the present study were divided into vowel and consonant errors, both decreased as intelligibility increased, and the correlations to intelligibility were similar for both kinds of errors

TABLE 24

Means and ranges of intelligibility scores for the hearing impaired children divided into four quartiles of intelligibility.

Quartile	Mean	Range
4	.874	.769-.966
3	.687	.578-.766
2	.416	.281-.575
1	.142	.013-.259

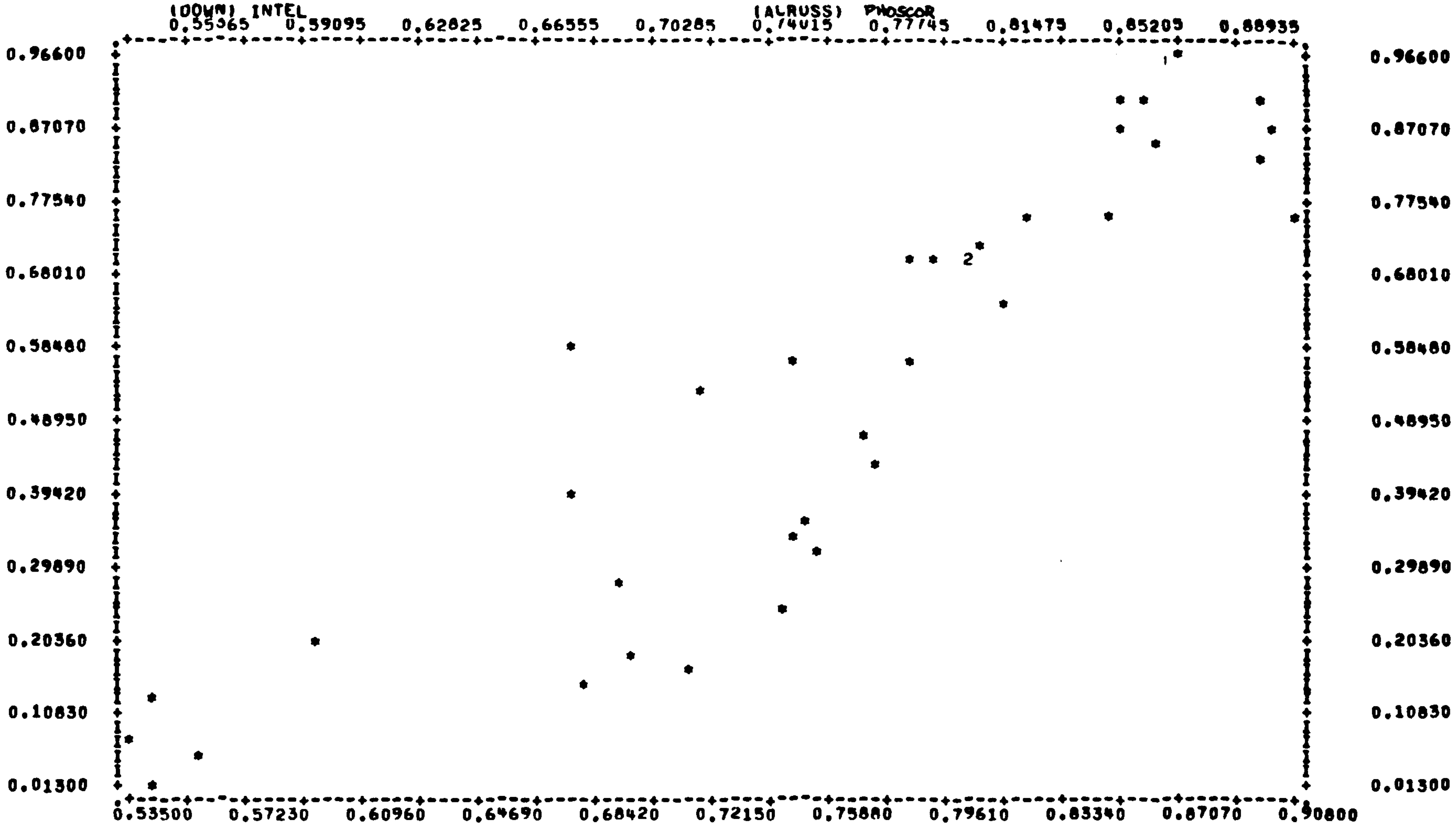
TABLE 25

Correlation coefficients for intelligibility scores with scores on all tests and with the pure tone average.

Tests	Correlation Coefficients	Level of Significance
Phoneme production score - words	.88	.001
Phoneme production score - sentences	.90	.001
Prosodic Feature Production I	.34	.020
Prosodic Feature Production II	.01	.471
Spontaneous speech ratings	.88	.001
Intelligibility ratings		
Inexperienced	.99	.001
Experienced	.92	.001
Phoneme Reception	.85	.001
Prosodic Feature Reception I	.39	.008
Prosodic Feature Reception II	.52	.002
Pure tone average	.54	.001

FIGURE 13

Scatterplot of phoneme production scores for sentences as a function of intelligibility scores.



($r=-.78$ and $-.80$, $p<.001$, respectively). More information can be derived from looking at specific kinds of vowel and consonant errors. Figure 14 shows that omission of the intended phoneme is the error type most highly correlated with intelligibility ($r=-.88$, $p<.001$). There is a dramatic decrease in the proportion of omissions as intelligibility increases. Substitution of a vowel for the intended vowel or a consonant for the intended consonant contributes less to the reduction in intelligibility ($r=-.73$ and $-.78$, $p<.001$, respectively). The use of severe distortions does distract from overall intelligibility ($r=-.63$, $p<.001$) while the use of recognizable distortions does not ($r=-.27$).

Mean spontaneous speech ratings increased rapidly from one intelligibility quartile to the next. As intelligibility increased for read materials, it also increased for spontaneous speech materials ($r=-.88$, $p<.001$, Figure 15).

There was a small interaction between performance on Prosodic Feature Production Test I and overall intelligibility scores ($r=-.34$, $p<.05$). For a good portion of the children, performance on this prosody test correlated well with intelligibility (Figure 16). Those who were intelligible performed well and those with poor intelligibility had poor prosody scores. There were two groups of subjects for whom this correlation was not direct. Several subjects with fairly good scores on the prosodic feature tests were still highly unintelligible (lower right of figure). It should be noted that these children had very poor articula-

FIGURE 14

Distribution of phonemic errors for the four quartiles of intelligibility. Errors are classified as consonant-consonant substitutions, vowel-vowel substitutions, diphthong errors, omissions, recognizable and severe distortions.

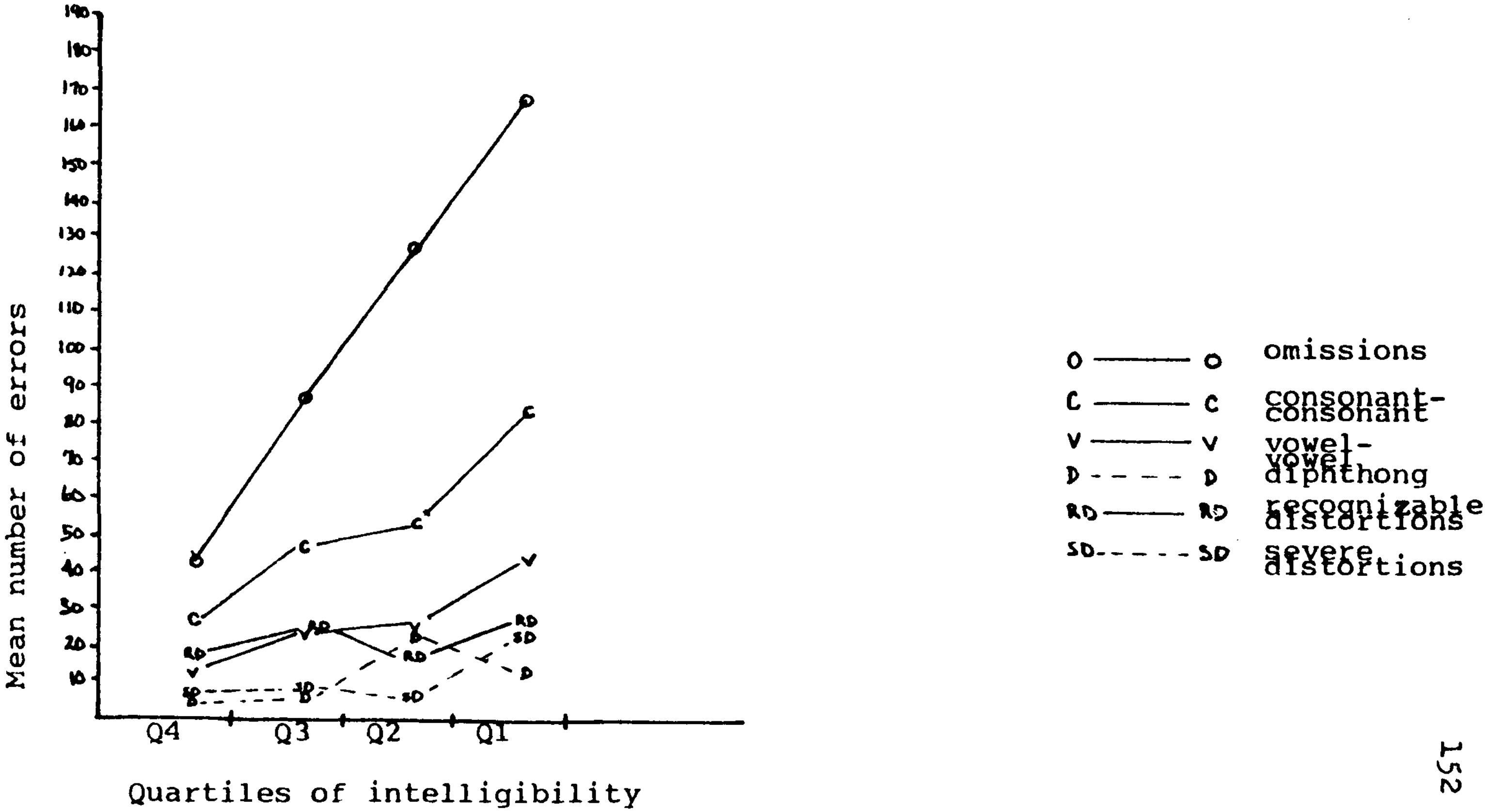


FIGURE 15

Scatterplot of spontaneous speech ratings as a function of intelligibility scores.

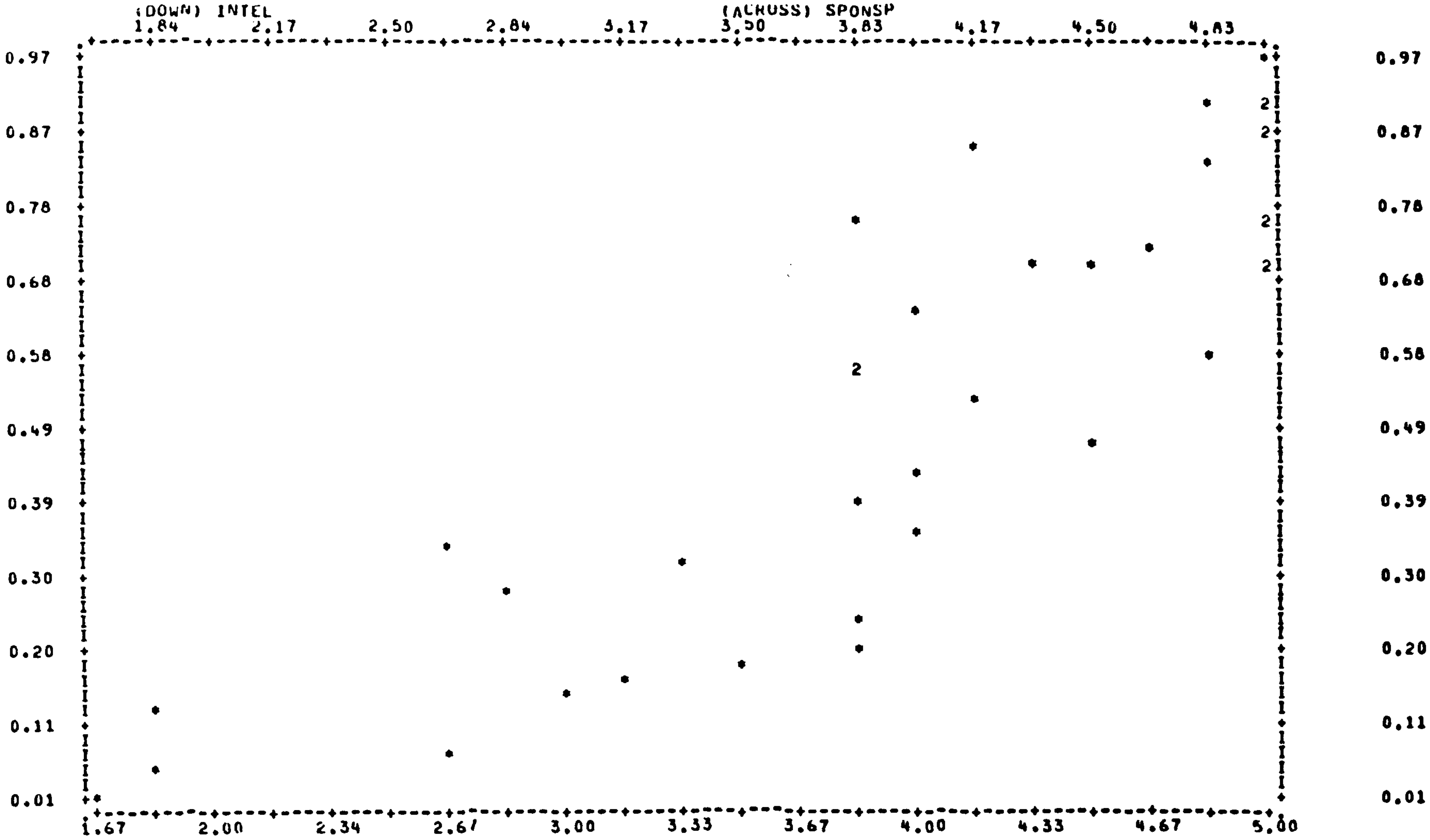
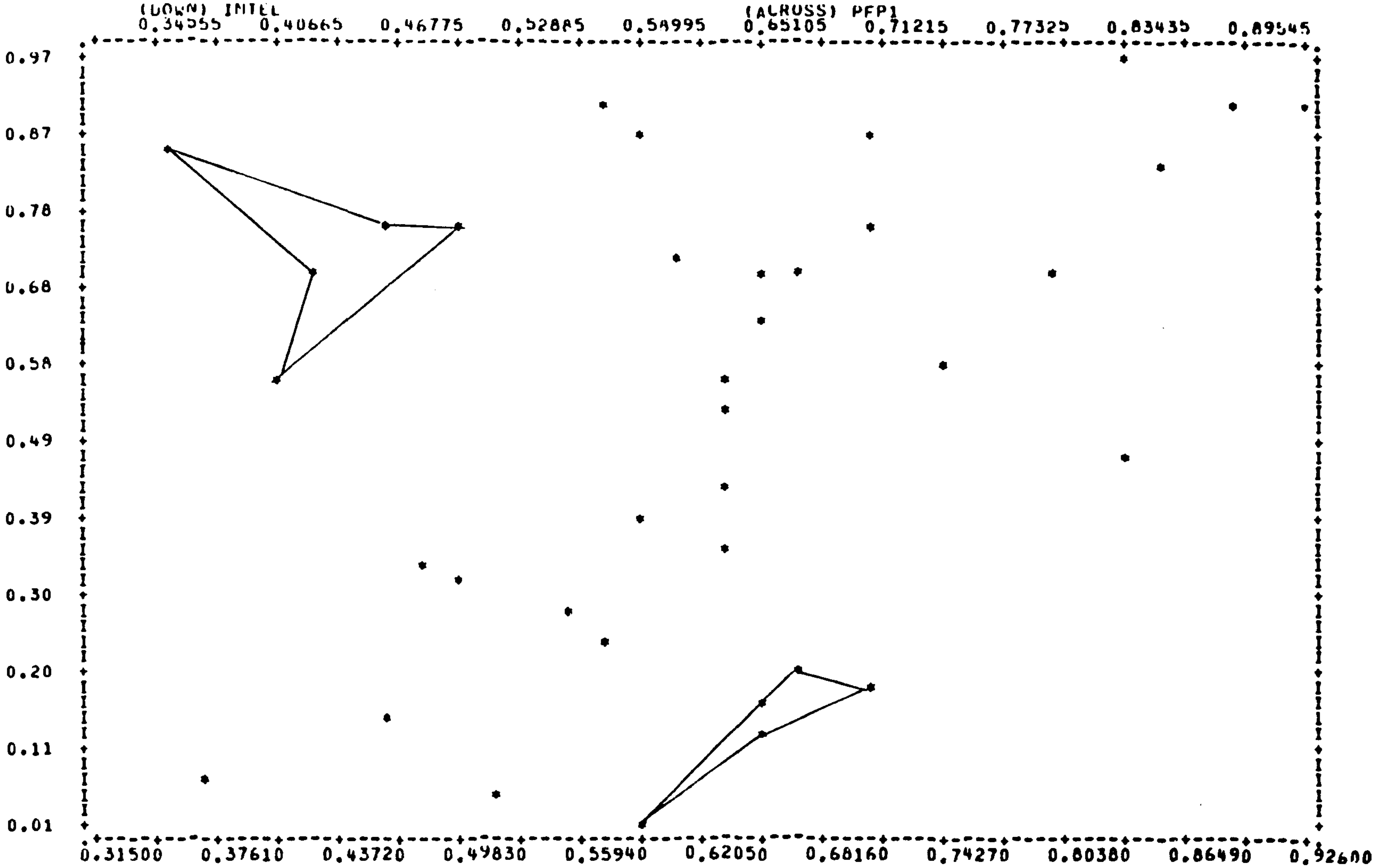


FIGURE 16

Scatterplot of scores on Prosodic Feature Production Test I as a function of intelligibility scores.



tory skills. Whereas good prosodic skills may ordinarily contribute to good overall intelligibility, in the presence of very poor articulatory skills even good prosodic skills may not be able to bring about reasonably good intelligibility. The other group (upper left of figure) consisted of children with good intelligibility and poor prosody scores. A possible explanation for their performance will be offered in Chapter V.

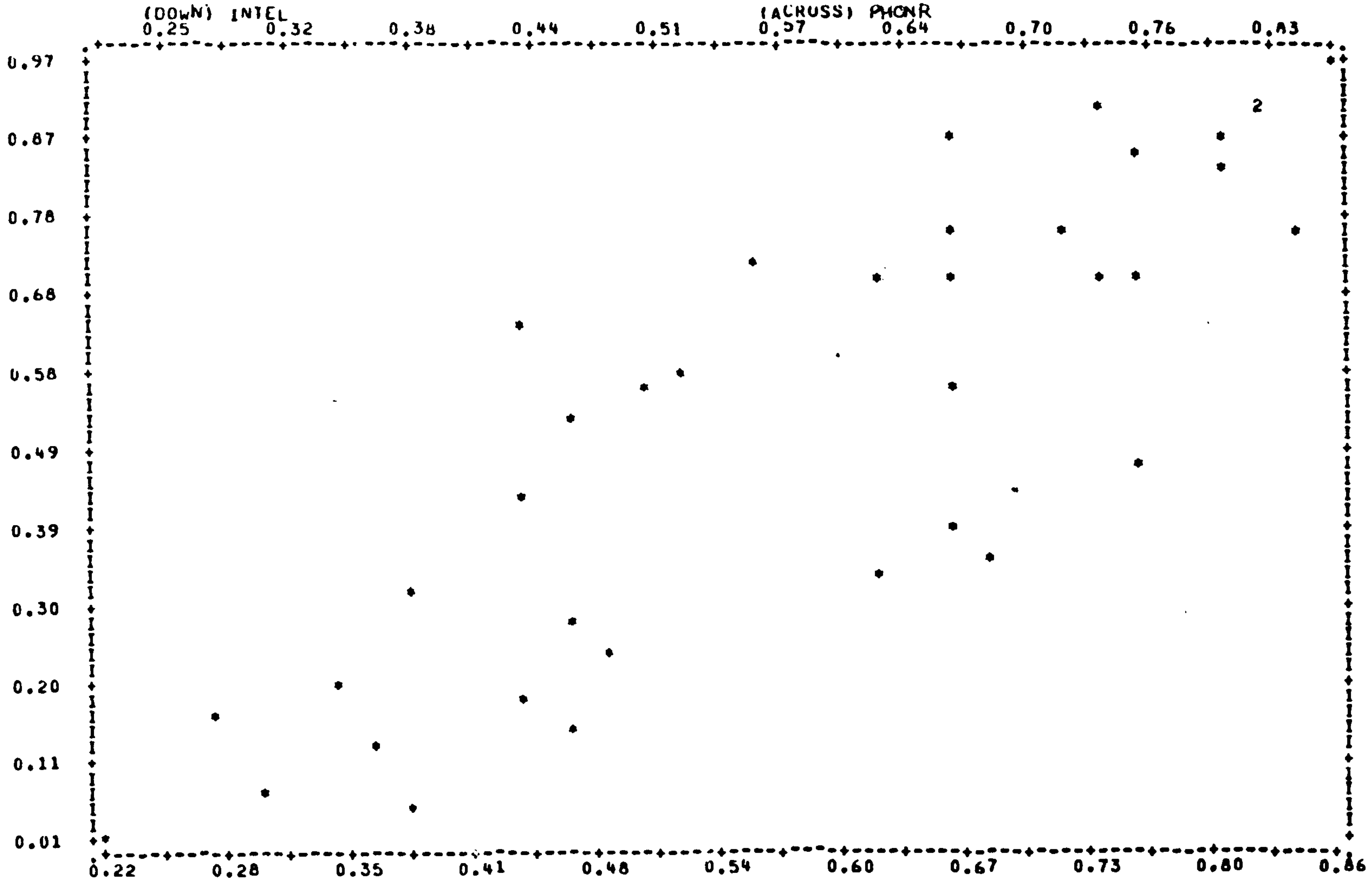
There was not a significant correlation between performance on Prosodic Feature Production Test II and intelligibility.

Performance on the Phoneme Reception Test correlated highly with speech intelligibility. Figure 17 shows that as scores on the Phoneme Reception Test decreased, intelligibility decreased ($r=.85$, $p<.001$). The voicing, vowel and place-manner subportions of the test correlated most highly with intelligibility ($r=.72$, $.71$, $.70$, $p<.001$, respectively). Manner and place items also correlated highly with intelligibility ($r=.67$, $.56$, $p<.001$, respectively). These two lower correlations may be related to the fact that manner items were easiest and place items were hardest. In neither case was there much variation in the scores.

The next concern was whether good reception ability on suprasegmental tests is correlated with good intelligibility. For Prosodic Feature Reception Test I, where the children were asked to identify items testing stress, pause and question intonation, the correlation to intelligibility

FIGURE 17

Scatterplot of scores on Phoneme Reception Test as a function of intelligibility scores.



was low ($r=.39$, $p<.01$). For some of the children, the relationship between prosodic reception and intelligibility was a direct one. However, there were about six children (upper left of Figure 18) who had far better intelligibility scores than prosody performance would predict. Another group of six children (lower right of figure) had much poorer intelligibility than one would expect for these prosody scores.

The correlation between scores on Prosodic Feature Reception Test II and intelligibility was good ($r=.52$, $p<.01$). A handful of children did not fit into the pattern. Three children with rather good prosody scores had poor intelligibility (lower right of Figure 19). Several others had poorer prosodic reception scores than would be expected from their intelligibility scores.

FIGURE 18

Scatterplot of scores on Prosodic Feature Reception Test I as a function of intelligibility scores.

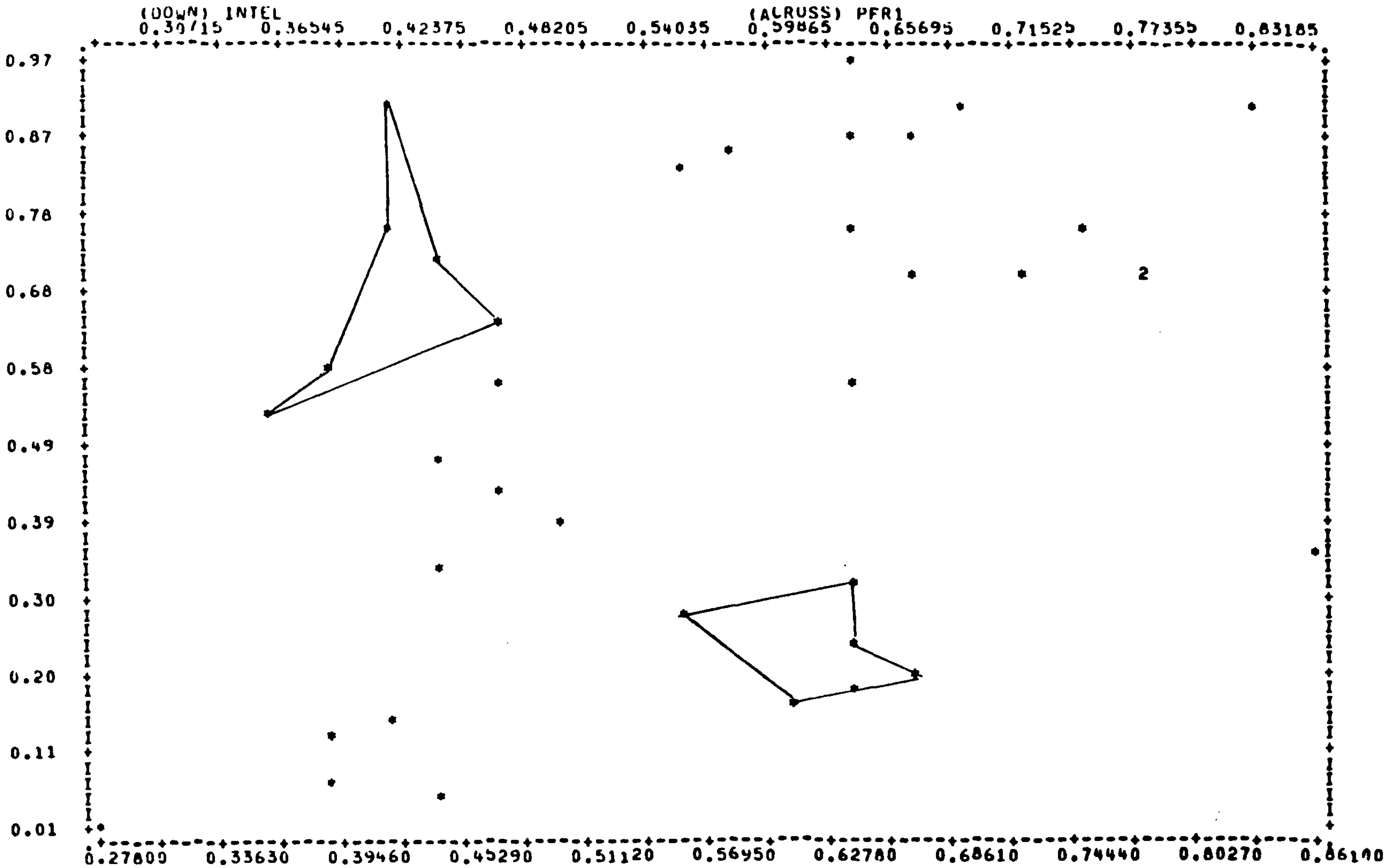
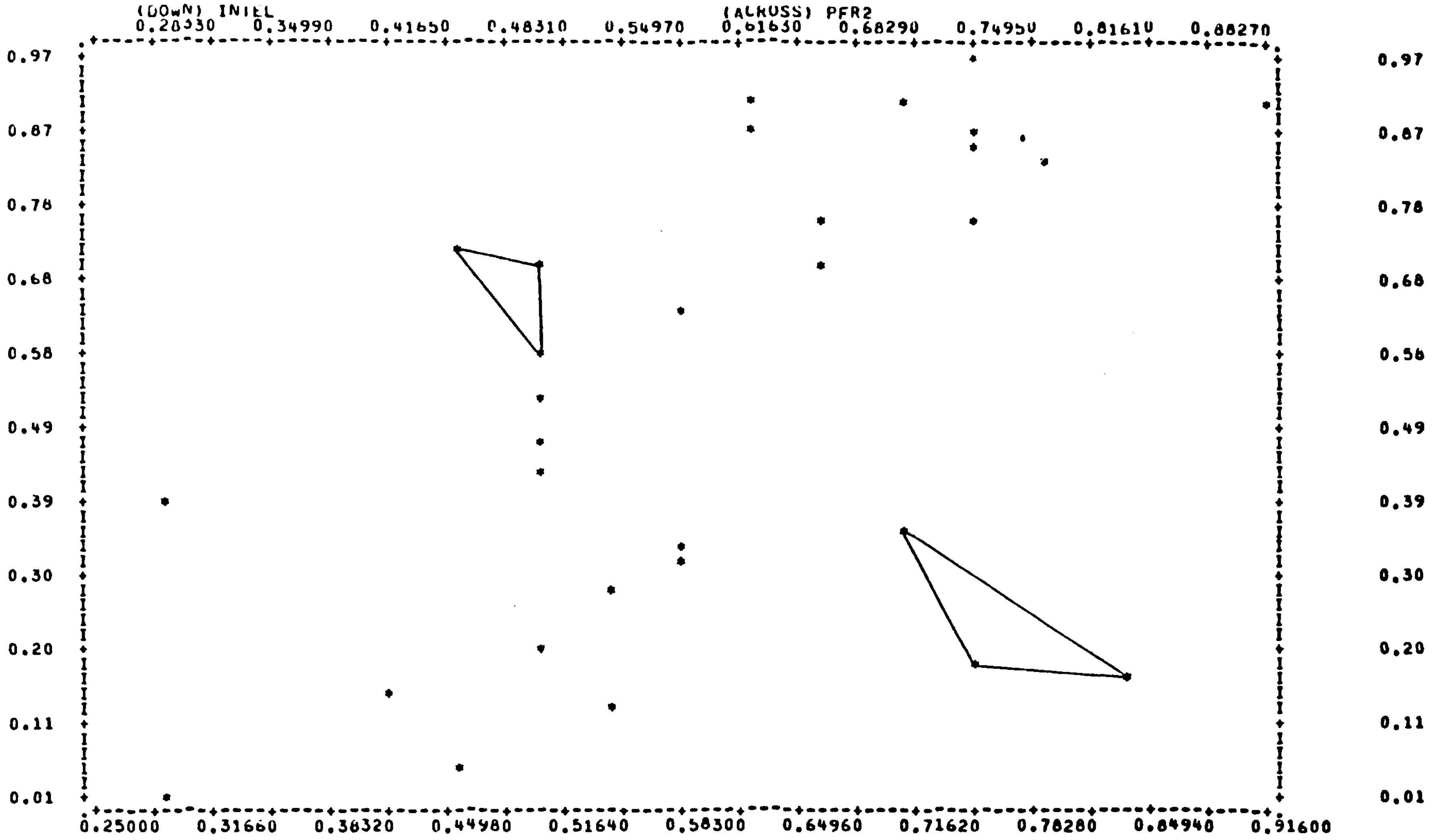


FIGURE 19

Scatterplot of scores on Prosodic Feature Reception Test II as a function of intelligibility scores.



CHAPTER V

DISCUSSION

In this study, an evaluation was made of the phonemic and prosodic speech reception and production skills of a group of hard-of-hearing and deaf children integrated into the New York City Public School System. The two main purposes of the study were to determine (1) whether there were significant differences in the performance of the hard-of-hearing and deaf groups and (2) which skills correlated most highly with overall speech intelligibility. The discussion will focus on these two concerns, attempting to compare the present findings with those of other investigations and to suggest explanations for unexpected findings.

Differences between the Hard-of-Hearing and Deaf Groups

The present findings indicate that hard-of-hearing and deaf groups can be differentiated by their performance on phonemic reception and production tests and by intelligibility scores and ratings of intelligibility but not by performance on the prosodic feature reception and production tests administered in this study. Although the hard-of-hearing group had significantly higher mean scores than the deaf group on most of these tests, a simple monotonic relationship was not obtained between hearing level and test scores. The pure tone average correlated most highly with performance on the Phoneme Reception Test ($r=-.64$, $p<.001$) and with overall speech intelligibility ($r=-.54$, $p<.001$). There were also fairly high correlations between hearing level and intelligibility ratings of their spontaneous speech ($r=-.49$, $p<.001$), and between hearing levels and phoneme production scores ($r=-.48$, $p<.001$). Smith (1972) who used these same tests found similarly high correlations for phonemic reception and production and intelligibility with hearing level.

It is in no way surprising to find that on the average better hearing is accompanied by better test performance. The focus of much of the discussion is on the kinds of errors made by each test group and which factors in addition to hearing level may affect performance.

Phonemic Production

Rater reliability

For the present study, broad phonetic transcriptions were made by two individuals who were experienced in listening to the speech of the deaf. One of the transcribers was a trained phonetician, the other was not. As mentioned above (Chapter III), each transcriber transcribed all of the children's utterances independently and a confusion matrix was drawn up to compare how closely the two transcribers agreed. The overall rate of agreement was 79%. This was higher than an agreement rate of 67% reported by Smith

(1972) for a group of trained phoneticians transcribing the speech of deaf children. The good agreement between transcribers is encouraging. It suggests that where broad phonetic transcriptions are useful, one need not be a trained phonetician in order to obtain reasonably reliable transcriptions at the phonemic level. Thus, with some training, teachers of the deaf should be able to produce fairly good phonetic transcriptions of their students' speech. In cases where narrow phonetic transcriptions are important, it may be necessary to require the services of a trained phonetician.

Phonemic production

Although the deaf group produced significantly more errors when reading the twenty test sentences, the pattern of errors for the deaf and hard-of-hearing groups was very similar. That is, the relative frequency of different error types within each group was very similar. Omissions of the intended phoneme made up about 40% of the total error for each group. There was a small difference between the two groups in the frequency of vowel-vowel substitutions; these constituted 26% of the total error for the hard-of-hearing group and 23% for the deaf group. Similarly, consonant-consonant substitutions accounted for 18% of the total error for the hard-of-hearing group and 21% for the deaf group.

Consonants

The most frequent type of consonant substitution for both groups involved errors in both place and manner of articulation. The unusually high incidence of this type of error is due in part to the substitution of /d/ for /ð/, an error which some phoneticians classify as one of manner alone when the place of articulation of /d/ is accepted as dental. Manner errors and voicing errors were also fairly common. These findings are similar to those reported by Smith (1972). The differences between the hard-of-hearing and deaf groups occurred for errors of place and place-manner-voicing, error types which did not occur very frequently.

A G^2 statistic (see Chapter IV for a description) comparing all entries except the diagonals, for the confusion matrices for consonants for hard-of-hearing and deaf children showed the pattern of confusions differed for the two groups on only two consonants. For the phonemes /ŋ/ and /z/, the deaf children omitted the sounds more often than did the hard-of-hearing children, while the hard-of-hearing group tended to produce sounds similar to the targets, e.g., /n/ for /ŋ/ and /s/ for /z/.

If the consonants are ranked in terms of their relative frequency of correct production, the same ranking is obtained as that reported by Nober (1967), Markides (1970) and Smith (1972); bilabials and glides and the labiodental fricatives, /f/ and /v/, were best and palatal and alveolar fricatives and affricates were worst. Whereas Nober claimed that correct phoneme production decreased as place of articulation moved further back in the mouth (except for glottals) the present findings are slightly different. In the present study, lingua-velars (/k/, /g/, /ŋ/) were more often correct than lingua-palatals (/ʃ/, /tʃ/, /dʒ/) which are made more forward in the mouth. It appears that since bilabials, labio-dentals and glottals are produced correctly most often, sounds involving major tongue movement are less often produced correctly than those not involving major tongue movement. One obvious exception is the group of glides which requires major tongue movement. However, glides are produced like vowels and as such may be treated with vowels which in general have fewer errors than consonants.

Vowels

Vowel substitutions were characterized by production of a near neighbor in the vowel quadrilateral. Often the sound was correct with respect to tongue frontness but wrong with respect to tongue height. There was also a tendency toward a neutralization of the vowel with frequent substitutions of /ə/ or /ʌ/ for the intended vowel. The latter error type did not occur as frequently in this study as for Smith's deaf subjects. These findings are in good agreement with those reported by Mangan (1961) and Smith (1972) for near neighbor errors, and Heider et al. (1941), Markides (1970), Angelocci et al. (1964) and Smith (1972) for neutralization of the intended vowel.

For both the deaf and hard-of-hearing groups, the most frequent vowel substitutions involved errors of tension, rounding and tension, and height. For both groups, back vowels were produced correctly more often than front vowels, as reported by Mangan (1961), Nober (1967) and Boone (1966) but low vowels were not better than mid or high ones as had been found by Boone and Nober. In the present study, differences between vowels based on categories of tongue height were not very large.

Overall error rate

The overall error rate for all phonemes for the deaf children in the present study was considerably lower than rates reported from other studies. Smith (1972) and Markides (1970) found overall error rates of 43% and 64%, respectively. The deaf children in the present study had an overall error rate of 29%. Whereas Smith and Markides reported the incidence of consonant errors for the deaf children to be 53% and 72%, respectively, the mainstreamed deaf children had an error rate of 34%. Vowel errors occurred 39% of the time for Smith's deaf subjects and 56% of the time for Markides'. The mainstreamed deaf children had a vowel error rate of 21%.

The mainstreamed hard-of-hearing children had an overall error rate of 19% for all phonemes. The incidence of consonant errors was 22% and of vowel errors was 16%. When compared with Markides' hard-of-hearing subjects, the overall error rate (18%) and the incidence of consonant errors (26%) were similar but the incidence of vowel errors was less for Markides' subjects (9%).

Direct comparisons between any of these studies must be made with extreme caution because of differences in test materials, methods of evaluation and types of populations that were tested. The most valid comparison would be with Smith's findings since Smith's test materials and procedures were used in the present study. The subjects read the same test sentences which were transcribed using similar techniques. Where Smith's subjects were deaf children in an oral school for the deaf, the present population consisted of hard-of-hearing and deaf mainstreamed children. To eliminate hearing level as a variable a comparison was made of articulatory errors in Smith's deaf group and in the mainstreamed deaf group.

A G^2 statistic comparing the kinds of errors on a phoneme by phoneme basis made by the deaf subjects in the present study and those deaf subjects in Smith's study, shows significant differences in the patterns of confusions made by the two groups. There were considerable differences in the relative proportion of /ə/ and /ʌ/ substitutions for vowels and in the omissions of consonants. Smith's subjects substituted the glottal stop for /t/ and /k/ far more often than the deaf mainstreamed children. Also, her subjects frequently substituted /b/ for most labial sounds.

Thus, whereas the nature of the confusions did not differ significantly between the hard-of-hearing and deaf children in the same educational setting, there were significant differences between the deaf children in schools for the deaf and those in the regular public schools. This difference in performance for the two groups must be interpreted carefully. The mainstreamed children in many cases may be compared with those in the top of the class in the schools for the deaf. These are children who were either "successful products" of schools for the deaf or who have bypassed this special educational system entirely. They are children judged by qualified individuals to be able to cope with the regular public school environment. Although one must not eliminate the possibility that their speech skills improved as a result of being in a completely oral setting, one must not forget that they were probably placed in this environment because their speech skills were already good. To determine the effects of the setting itself, the progress made by these deaf children in overall intelligibility should be compared with that made by some of the better students in schools for the deaf over the same period of time.

Aside from these variables, the type of speech training, the frequency of speech training, the criteria of speech production, and the acceptance of speech intelligibility by the teachers, are all factors which may account for differences between the groups.

Speech intelligibility

The mean intelligibility score obtained for the deaf children in the present study was much higher than those found in previous reports. Brannon (1964), John and Howarth (1965), Markides (1970) and Smith (1972) found mean intelligibility scores of 20.7%, 19.0%, 19.1% and 18.7%, respectively. The deaf children in the present study had a mean score of 38.5%. This higher mean score may be a result of the population tested, test materials used or any of the other variables mentioned above (p.167).

The mean intelligibility score of 68% for the hard-of-hearing group in the present study was significantly higher than the mean score for the deaf group. Hudgins and Numbers (1942) reported mean scores of 73% and 44% for their two groups of hard-of-hearing children. An accurate comparison to these data is somewhat difficult since audiometric data are not available for these hearing loss groups classified as A and B (p. 302). If groups A and B can be considered moderate and severe impairments and we account for there being two to three times as many children in group B as A, then the mean score of 58% would be reduced still further to yield the average performance of these "partially hearing" children of about 52% to 54%. This performance would be considerably worse than that of the children of the present study.

The present finding of a mean intelligibility score of 68% is in rather good agreement with findings reported by Markides (1970). He found a mean intelligibility score of 76% for children with losses up to 80 dB. His slightly higher scores may be attributed to the fact that the children in his study did not read unrelated sentences, but described several pictures. This would allow the speakers to use words with which they felt most comfortable and would afford raters the advantage of contextual cues in comprehending sequential utterances.

Whereas the deaf children in the present study seemed to be more intelligible than most deaf subjects tested elsewhere, the hard-of-hearing group was not consistently more intelligible than those hard-of-hearing children tested in other studies. Hudgins and Numbers' subjects were far less intelligible than the present group. They read similar kinds of test materials but came from residential schools. Markides' subjects were somewhat more intelligible than Hudgins and Numbers', came from day schools and residential schools with high academic standards, but used different test materials. Because of these differences, direct comparisons between studies should be interpreted with caution. However, in view of the consistency of this result across different studies and, in particular since both this study and that of Smith used the same test materials (for speech intelligibility), it seems reasonable to conclude that the more integrated the educational setting, the more intelligible the child's speech for a given level of hearing impairment. An important caveat, however, is that the relationship is not necessarily a causal one. The mainstreamed children may have better speech not because of the effects of mainstreaming but rather as a result of the selection procedure whereby the more successful hearing impaired children are mainstreamed. It may also be that both factors combine in helping the more successful hearing-impaired child.

Imitation

A number of children who participated in this study needed assistance in reading some of the words in the twenty sentences. When they hesitated before reading a word, apparently because they were not familiar with it, the tester said the word and the child imitated it. A notation was made whenever this happened. Most of the time the children remembered the word for the second reading of the sentence and that was the version that was presented to the inexperienced listeners for the purpose of writing down as many words as they could recognize. The words spoken by the examiner were spliced out of the recordings heard by the inexperienced listeners. A comparison was made of the mean intelligibility score for these children for imitated sentences compared with the mean intelligibility score for non-imitated sentences. There was no significant difference between the two, suggesting that imitation did not contribute greatly to the overall intelligibility score.

Thus, whereas imitation of a model may have made a child appear more intelligible because of the elimination of a reading problem, it does not appear to have significantly altered the child's speech intelligibility per se. Furthermore, intelligibility ratings of spontaneous speech samples were also considered for those who imitated most often. Ten of the thirteen most frequent imitators had ratings of over 3.5, meaning that even without models to imitate they made themselves fairly intelligible. The above results suggest that the need to imitate was due to reading problems and not an inability to produce speech correctly.

Phonemic Reception

Mean overall scores and scores on subportions of the Phoneme Reception Test were significantly better for the hard-of-hearing than the deaf group. Both groups did best on that subsection of the test involving manner contrasts, and scores on the section involving voicing contrasts were almost as high. A much greater proportion of errors was obtained on items testing place and place-manner contrasts. This result is consistent with the published literature in which relatively good discrimination of voicing and poor performance on recognition of place of articulation has been reported (Siegenthaler, 1949; Oyer and Doudna, 1959; Owens and Schubert, 1968; Schultz and Kraat, 1971; Pickett et al., 1972; Smith, 1972; Bilger and Wang, 1976).

Smith's subjects and the hard-of-hearing children in the present study had lower mean scores for items testing place-manner than for place contrasts. This seems unusual since one would expect the presence of manner cues which are perceived fairly well to make the perception of place-manner contrasts better than the perception of place contrasts. A possible explanation for this behavior is that the low frequency manner cues are causing a spread of masking to the higher frequency place cues. This kind of behavior was demonstrated by Pickett et al. (1972) for synthetic speech samples. If this is the case, then when place cues occur alone, they are more readily perceived by the hearing impaired subjects than when they occur in conjunction with manner cues.

Smith created the Phoneme Reception Test used in this study for a group of forty deaf subjects from a school for the deaf. A comparison of the present findings to those reported by Smith (1972) shows that scores on subportions of the test were similar for the two deaf populations. For all but one subtest, the children in schools for the deaf had lower mean scores than those mainstreamed into regular schools. However, for items testing place contrasts, Smith's deaf children had a higher mean score than the deaf children in the present study. The mean score for Smith's subjects was 42.5% and for the mainstreamed deaf subjects was 31.3%. Even these large differences did not reach a level of significance.

As in Smith's study, performance on target phonemes in word-final position was not significantly worse than performance on target items in initial position in the word. This is contrary to many previous findings which report significantly better scores when the target phoneme is in initial position in the word (Oyer and Doudna, 1959; Rosen, 1962; Owens and Schubert, 1968; Pickett et al., 1972; Jones and Studebaker, 1974; Sher and Owens, 1974; McGarr et al., 1977). Recently, Bilger and Wang (1976) noted better performance on consonants in final position than in initial position of nonsense syllables. They suggested that their results may differ from findings for CVC's because of the generally poorly articulated final consonant in CVC's which contributes to the sound being less often identified correctly. When the talker is more careful at producing the targets, as in nonsense syllables, there is less difference between initial and final position, and final position may even be better if the initial vowel serves to alert the listener to the coming consonant.

Prosodic Production

In neither Prosodic Feature Production Test I nor II was there a significant difference in the mean scores of the hard-of-hearing and deaf groups. In fact, on both tests, the deaf children as a group, scored higher than the hard-of-hearing group on items testing stress. This was an entirely unexpected finding. A more detailed analysis of the utterances produced by the children on Prosodic Feature Production Test I showed that the problem seemed to be twofold. Some hard-of-hearing subjects were producing utterances with stress placed on syllables other than the target syllable. The utterances they produced were acceptable in normal conversational speech but were not appropriate for the test. The children seemed to be following their own internalized rules for where stress should occur in a given group of words. This accounted for low scores on production of stress items by the hard-of-hearing group.

At the same time, the deaf group was obtaining fairly good scores on the production of items testing stress. Analysis of their production showed that they were often placing stress on the appropriate syllable but were frequently exaggerating its production. Excessive intensity, pauses before the target syllable or excessive duration were cues used by the deaf group to produce stress. The result was that the feature of stress was conveyed, but at the detriment of other features.

In an attempt to verify this interpretation of the data, prosodic production skills were analyzed again, this time with particular concern for the naturalness of production. On Prosodic Feature Production Test I, the six stress items were listened to again by two listeners. One had not previously served as a listener, the other was one of the original three who evaluated the test performance. The two listeners indicated whether they felt the utterance produced sounded natural. If the stress pattern of the utterance sounded as if it might have been produced in ordinary conversation, it was rated "natural" regardless of where the stress occurred in the sentence. If the utterance was produced with excessive stress on a word or in a way in which it would seem abnormal in normal conversational speech, it was rated "unnatural". For each child a score was derived from the "natural" ratings given by the two raters relative to the total number of possible ratings.

Comparisons showed that the mean naturalness score was higher for the hard-of-hearing (50%) than the deaf group (38%), whereas the correctness scores were higher for the deaf group. Thus, although the deaf children were producing something at the target location they were not succeeding in producing something that would be acceptable in normal conversational speech. This is consistent with the general observation that training on a specific problem may result in marked improvement in that area at the expense of overall improvement. Stratton (1974) observed that while a tactile feedback display helped to develop intonation control that was clearly evident, improvement in intonation quality was only slight and, occasionally, "the newly-acquired intonation was heard as being exaggerated, abrupt, or ill-timed (p. 31).

Although test scores fail to show significant differences between the hard-of-hearing and deaf groups, the rank order of correct production of prosodic features reported in the present study is in good agreement with findings of Levitt et al. (1975). In both cases, the children produced pause correctly most often, were better at producing stress later rather than earlier in a sentence and were worst at producing the rising intonation characteristic of yes/no questions. The tendency of normal and deaf individuals to prolong the duration of the sentence- or phrase-final syllable (Nickerson et al., 1974) may account for better scores on items testing stress late in the utterance compared with early in the utterance. Poor production of rising intonation for questions has been noted by Phillips et al. (1968), Stratton (1974) and McGarr (1976). Phillips et al. also reported the tendency for the deaf to use increased intensity rather than pitch change to mark rising intonation. This is in agreement with the kinds of errors reported for the present test group since they frequently produced late stress for question intonation.

For Prosodic Feature Production Test II, all nine test items were evaluated by the two listeners for correctness of production of the target feature and for naturalness of production of the utterance. Although there was no significant difference between the deaf and hard-of-hearing groups on correctness of production, the hard-of-hearing children were signficantly more natural in their reading than were the deaf children ($F=149.5$, $df=1$, $p<.05$).

Scores for correctness improved significantly with training ($F=768.0$, $df=1$, $p<.05$) for both the hard-of-hearing and deaf groups. There were, however, no apparent changes in naturalness as a result of training. This implies that training can be effective in improving performance on a specific feature, but not necessarily on more global characteristics. It would seem, however, that more extensive training or training geared specifically towards improving naturalness may be necessary to incorporate naturalness into the way the feature is produced. When Stratton (1974) used a tactile device for training intonation, he too found no noticeable difference in the quality of his subjects' speech, even though he found improvement in production of pitch contours after training.

The items testing rising intonation in question forms were seldom produced correctly. The very low scores on production do not agree with the fairly good scores on reception of this feature (see Chapter IV, page 130). Although the reception test was a closed set paradigm which made the chances of a correct response better than in an open-ended test, it should be noted that the acoustic cues for one response foil, that of late stress, are very similar to those for another response foil, rising intonation as in questions, and yet many children were able to make the differentiation between the two features. This means that in many cases the child is able to distinguish between rising and falling intonation in reception and yet cannot produce such a distinction. In addition, during the course of testing and talking with the children, it became apparent that some of them were using rising intonation questions in their every day speech. Utterances such as "Now?" to indicate "Shall I read it now?" and "Come home?" meaning "Are you going to come home with me?" were produced by two of the children. These very same children were not able to produce the feature when it appeared on the test, even after training. This informal observation suggests that our training and test materials may not be meaningful enough for this population.

Another problem with the test materials pertains to the two-syllable items on the Prosodic Feature Production Test I. Whereas longer utterances usually create more difficulty for the deaf child in production (Hood, 1966), the present findings showed poor production on the shorter items. This latter observation may be related to the artificiality of differentiation of place of stress in two-syllable phrases since there is a greater chance of confusing location of stress in a two-syllable item where it is difficult to differentiate early stress on the first syllable from the normally increased duration of the final syllables. In longer utterances there is more opportunity to differentiate these features because of the intervening syllables.

The sequential question and answer series used in Prosodic Feature Production Test II represents an attempt at devising a more natural test of prosodic feature production. In this test, each of three groups of questions and answers began with a question which was answered by the second utterance in the group. If the sentence was read properly as an answer to the question, stress had to fall on a specific syllable. In this way specific features were tested as they might be called for in normal conversational speech. In the future, children must be given contextual materials with which they can familiarize themselves before being asked to read test utterances. If the materials are properly designed, special features would be required for appropriate reading.

Prior knowledge of raters

In choosing listeners to evaluate the children's performance on tests of prosodic feature production it is necessary to decide whether these listeners should have prior knowledge of which feature is intended for each test item. The disadvantage of prior knowledge is that the listener may be unduly influenced by what is expected. The advantage is that the listener can attend to the target feature without being confused by other features which may be produced simultaneously. In addition, if the listener is told in advance which prosodic feature is intended, there is no need to randomize tape recordings. It would seem that for practical reasons it would be better to use listeners with a priori knowledge of the test materials. Yet, in order to check against results obtained with listeners having no a priori knowledge two sets of listeners were used for Prosodic Feature Production Test I (see Chapter III).

The results of the comparison showed that there were large differences in scores given by the two groups of listeners for some of the features produced by the deaf children. The listeners with a priori knowledge of the intended features, gave scores for these features as much as eighteen percentage points higher than the uninformed listeners. However, the pattern of confusions revealed that the group with no prior knowledge had a greater tendency to rate the badly produced utterances as unintelligible, thereby reducing the total number of correct items in the group. As a result, it appears that information as to what confusions are being made is lost due to the large number of unintelligible ratings. Thus, apart from the practical advantages of using a group of practiced listeners, there is additional information to be gained from using listeners who know in advance the feature the child is attempting to produce.

Prosodic Reception

There were no significant differences in performance for the hard-of-hearing and deaf groups on the Prosodic Feature Reception Test I. Both groups of children did best on recognition of pause and worst on items testing stress. Scores on rising intonation for question and on early stress were very similar within each test group. The pattern of confusions for errors made was essentially the same for the hard-of-hearing and deaf groups.

Late stress in two-syllable utterances was the most difficult item for the deaf group. The hard-of-hearing children did much better on this item. Levitt et al. (1975) and McGarr (1976), who reported great difficulty on the part of their deaf subjects on this test item, noted that a common confusion was that of question intonation. They explained that similarities in durational and pitch changes might account for this kind of confusion. The mainstreamed deaf children reported question intonation nearly as often as they reported the intended late stress. However, early stress was reported most often. It was also the most common confusion whenever late stress was produced. The subjects seemed to have recognized the presence of stress in the two-syllable items but could not locate it correctly. If the children confused question with late stress because of similar acoustic cues, why were they so much more successful at identifying question? Were they able to detect the additional cue of <u>changing</u> pitch and, if so, why did they have so much trouble producing question intonation? These questions need to be answered in order to gain further understanding of how the hearing impaired child is handling prosodic cues.

Another unexplained result was that when early stress was the target feature in two- and three-syllable items, the children frequently reported hearing early pause. Since it is not unnatural for a speaker to pause after a stressed word, this may have been the cue that the subjects responded to. Scores obtained for the present population for early stress are considerably lower than those reported by McGarr (1976) for children at schools for the deaf. One interpretation of the differences is that the subjects in the present study were more aware of the acoustic cues available to them than were the subjects reported on by McGarr, and that although the former group of children possessed more of the available acoustic cues, their scores were actually lower because of a high rate of confusion between the target and a foil with very similar acoustic properties.

One of the purposes of Prosodic Feature Reception Test II was to determine the effects of the location of the target feature on the child's reception of stress. The test results showed that performance was best when stress was early, rather than middle or late in the utterance, although the differences did not reach a level of statistical significance. This finding is somewhat contrary to those of Prosodic Feature Reception Test I, where reception of late stress was better on the average than reception of early stress. The difference lies in performance on items testing early stress, since the proportion correct for items testing late stress was similar for both tests. A possible explanation for the differences in findings may pertain to the kinds of foils used in the two tests. For Prosodic Feature Reception Test II the choice was based solely on location of stress, whereas in Prosodic Feature Reception Test I there were also choices featuring pause as the target.

Since early pause was frequently confused with early stress, as explained above, the number of times early stress was correctly identified was significantly reduced. Thus, at this point it is not clear whether there is any advantage to recognition of one place of stress over another.

A second objective of Prosodic Feature Reception Test II was to determine whether the addition of extra stress (emphasis) on the intended syllable would improve the child's reception of place of stress. When averaged across all test items, there were no statistically significant differences between performance on stress and emphasis. For one test item which was read once with stress and once with emphasis because of an error in the original test recording, scores were significantly better when emphasis was used. If this utterance is to be considered typical of test items, this finding suggests that any of the other variables tested may have interfered with the child's ability to demonstrate the benefit of emphasis over stress. Another possible explanation lies in the variability in factors used to produce stress or emphasis. Whereas it may be possible to recognize that "more" stress was used for one utterance than another, it is not certain that the same cues were being used in each case. Also, because some cues may be more perceptible to the normal listener than are other cues, the same benefit may not exist for the hearing-impaired listener. It would be best to test perception of degree of stress with well-controlled synthesized speech for the hearing-impaired population.

A comparison of scores on place of stress for statements and yes/no questions was available for three-syllable items. Whereas the deaf did significantly worse overall on question intonation than on statements, there was no significant difference for the hard-of-hearing group. For question intonation,scores were much higher for items in early position than in either middle or late position. This is consistent with the overall findings for recognition of place of stress.

Test Scores as a Function of Intelligibility

The second major objective of this study was to determine which of the skills tested correlated most highly with overall speech intelligibility. Since a primary concern in dealing with the deaf is to increase their speech intelligibility, knowing which factors are most closely related to intelligibility is of considerable importance for developing effective speech improvement programs. The variables correlating most highly with intelligibility in this study were found to be intelligibility ratings for read speech ($r=.99$, $p<.001$), phonemic production ability ($r=.90$, $p<.001$), spontaneous speech ($r=.88$, $p<.001$), phoneme reception ability ($r=.85$, $p<.001$) and naturalness of suprasegmental production ($r=.72$, $p<.001$). As expected, the test scores correlating highly with speech intelligibility deal primarily with speech production skills. It is significant to note that the Phoneme Reception Test is also highly correlated with speech intelligibility and that this is the only test in the above-mentioned group that did not measure some aspect of speech production.

Phonemic Reception

In her study of a group of forty deaf subjects in a school for the deaf, Smith (1972) showed that performance on her Phoneme Reception Test correlated highly with overall speech intelligibility. In the present study, where the test was used for both hard-of-hearing and deaf subjects educated in the public schools, a similarly high correlation ($r=.85$, $p<.001$) was found. Of particular interest is the fact that in both studies performance on this Phoneme Reception Test was a better predictor of speech intelligibility than audiogram-based measures. The correlation between the pure tone average and intelligibility was -.54. Fourteen children with pure tone averages between 80 and 93 dB HTL had intelligibility scores between 8 and 92%. This shows how poor the three-frequency pure tone average is in predicting speech intelligibility. The high correlation between phoneme reception scores and speech intelligibility implies that ability to process speech cues auditorially is closely related to speech production ability.

For the subjects of the present study there were high correlations between all subportions of the test and overall speech intelligibility. As with Smith's subjects, recognition of voicing and vowel contrasts were most highly correlated with intelligibility. In addition, for the children at regular schools, there was a high correlation for performance on place contrasts and intelligibility, a fact not found by Smith. This may be because of the comparatively high scores obtained by her subjects on place contrasts.

Performance on the Phoneme Reception Test also showed a fairly high correlation with performance on the Prosodic Feature Reception Tests ($r=.47$, $p<.005$) and with naturalness of production of suprasegmentals on the Prosodic Feature Production Test II ($r=.58$, $p<.001$). Performance on the prosodic reception tests correlated fairly highly with naturalness ($r=.42$, $p<.001$; $r=.50$, $p<.005$; for Prosodic Feature Reception Tests I and II, respectively). Thus, it seems that those children who are able to process phonemic information auditorially are also reasonably good at processing prosodic information and both of these skills are reflected in improved speech production.

Phonemic Production

A correlation of .90 ($p<.001$) was found for the number of phonemes produced correctly and overall speech intelligibility. This is in agreement with the findings of Brannon (1964), Montgomery (1967), Markides (1970) and Smith (1972), who reported correlations of .79, .80, .87 and .80, respectively. Hudgins and Numbers (1942) and Smith found vowel errors to correlate with intelligibility at a rate of -.61 and -.75, respectively and consonant errors to correlate at a rate of -.70 (Hudgins and Numbers). The present findings lean toward slightly higher correlations, .78 for vowels and .80 for consonants.

The error type which correlated most highly with intelligibility was omission of the intended phoneme ($r=-.88$, $p<.001$). Vowel-vowel substitutions and consonant-consonant substitutions decreased significantly as intelligibility increased ($r=-.73$, $-.78$, respectively).

A word of caution is important when interpreting the frequency of occurrence of errors and correlations to intelligibility. For example, the high correlation between the number of omissions and the decrease in speech intelligibility is not sufficient evidence that correction of the omission errors would significantly improve understandibility. There may be interrelationships between different error types which are not apparent on the surface but which help to explain why certain errors detract more than others from intelligibility. Certain omission errors are common in normal speech. It is not necessarily true that insertion of these omitted phonemes would contribute much to improving intelligibility. Treatment of all error types with multiple-linear regression would serve to identify those factors which, when truly isolated, contribute most to intelligibility.

Prosodic Production

Performance on specially designed tests of prosodic feature production showed rather low correlations between overall speech intelligibility and the ability to produce stress, pause and question intonation. For Prosodic Feature Production Test I, where the correlation to intelligibility was -.34 ($p < .05$), those children with the best prosodic production scores also had good intelligibility, while not all those with good intelligibility scored high on the test. This may be related to previous findings that rhythmic speech generally has better than average intelligibility if articulatory skills are not exceptionally poor (Voelker, 1938; Hudgins and Numbers, 1942; John and Howarth, 1965). Proper use of stress and pause in an utterance should create better rhythm in a sentence. Thus, the children who performed well on the test should also be more intelligible. Those children who had fairly good prosody scores but very poor intelligibility also had poor articulatory skills. The data suggests that if articulatory skills are very low, even good prosodic skills cannot produce good intelligibility.

The presence of a group of children with very good intelligibility and rather poor prosody scores raises a question about the validity of the test. A closer look at the performance of these subjects shows that they had very low scores on the production of stress items. Most of these children were hard-of-hearing and like the hard-of-hearing group as a whole they had lower mean scores than the deaf group for stress items. Analysis of their production as described above, showed that the deaf group was often exaggerating the intended feature and were scored correct. The hard-of-hearing children read the utterance more naturally but placed stress where they felt it should fall and were judged incorrect. A second score on naturalness of production was derived. When this score was compared with overall speech intelligibility it still showed a rather low correlation. This may be because not all test items were rated for naturalness and because different raters determined correctness and naturalness.

For Prosodic Feature Production Test II, the same two listeners rated the nine test items on correctness and naturalness. Although the correlation between items correct and intelligibility was extremely low, naturalness ratings correlated highly with intelligibility ($r=.72$, $p<.001$). This is rather encouraging since there is a need for a measure which can bring suprsegmental performance in line with intelligibility. The use of a two alternative natural/unnatural decision had its drawbacks. A five point system would be far more accurate in assessing actual production. Such a system should be devised and applied to spontaneous speech as well as read materials. This coupled with articulatory scores might yield a better predictor of overall speech intelligibility.

Prosodic Reception

Whereas performance on the Phoneme Reception Test was a very good predictor of overall speech intelligibility, the same was not true for reception of prosodic features as tested. The correlation between scores on Prosodic Feature Reception Test I and intelligibility was .39 ($p < .01$). There were a number of children whose intelligibility was above average but who had unusually poor scores on this prosody reception test. These children also had disproportionately poor scores on both the Phoneme Reception Test and the Prosodic Feature Reception Test II. Because performance on the Phoneme Reception Test was found, on the average, to be closely related to intelligibility in both this and Smith's study, it would seem that there is something unusual about a small group of subjects who showed the opposite effect. One possible explanation for good intelligibility in spite of poor performance on reception tests is that these children may have had poor auditory-visual-integration skills. In other words, they may have actually perceived the features correctly but have had difficulty associating the auditory stimulus with the visual counterpart on the page.

A second problem group consisted of those children who, in spite of reasonably good prosodic feature reception scores, had poor intelligibility. All of these children had very poor phoneme reception skills and phoneme production scores below the median score. Thus, they may actually have been perceiving the prosodic features but without mastery of phonemic skills could not make themselves intelligible.

The correlation between scores on Prosodic Feature Reception Test II and intelligibility was somewhat higher than for Prosodic Feature Reception Test I ($r=.52$, $p<.01$). However, the range of scores for most subjects on this former test was not very large and a number of subjects with similar scores had intelligibility scores covering a wide range.

Implications

The major purpose of this study was to determine whether there were differences in performance on various tests of speech production and reception ability between hard-of-hearing and deaf subjects. The results of the study showed that for tests of phonemic reception and production ability and for intelligibility scores and ratings, there were significant differences between the mean scores of the hard-of-hearing and deaf groups. For a number of the tests, the differences between the mean scores for the two groups were rather large. The mean intelligibility score for the hard-of-hearing group was 30 percentage points higher than for the deaf group and the mean score for the hard-of-hearing group on the Phoneme Reception Test was 23 percentage points higher than for the deaf group. However, in spite of these large differences in mean performance of the two groups, there was considerable overlap in the performance of the hard-of-hearing and deaf subjects. The distribution of intelligibility scores, for example, showed that whereas most hard-of-hearing children had scores over

70%, the deaf children covered a wide range of scores, some having scores over 70% and one even having a score of 92%.

This points out the weakness of the pure tone average as a predictor of speech intelligibility. In the early years of diagnosis and training of the hearing-impaired child it is most important that there be some basis on which to predict which children will be most successful at producing intelligible speech. For the other children, greater concentration on manual communication might be in order. For lack of a better tool, much emphasis has been placed on the pure tone average as a predictor of intelligibility. Since there is only a moderate correlation between the pure tone average and intelligibility, there are some children who may be shortchanged in education due to their profound losses if the pure tone average is used as the sole determiner of their potential at speech production. It is rather encouraging to note that some subjects in this study with pure tone averages worse than 90 dB HTL had intelligibility scores of 58-78%. This emphasizes the fact that we can not depend on the pure tone average as a means of predicting the child's speech intelligibility.
As was demonstrated by Smith (1972), performance on the Phoneme Reception Test showed a higher correlation to intelligibility than did the pure tone average. This suggests that the more speech-like the auditory test materials, the better they are at predicting eventual speech production skills. What is unknown is to what extent

performance on this test is an acquired skill and if so how these skills are acquired.

For the most part, the differences between the performance of the deaf and hard-of-hearing groups were of degree rather than nature. The relative frequency of articulatory error type was the same for both groups, although the deaf children made significantly more errors overall. It seems then that for children in the same educational settings, degree of hearing loss would not play a major part in the planning of which articulatory errors should receive attention first. The generalization of these findings to other educational settings can not be made. Present findings show that there were significant differences between the nature of articulatory errors made by mainstreamed deaf children and those in schools for the deaf. As mentioned above, the mainstreamed deaf children may have had an advantage over the other deaf children even before they were placed in regular schools. This is because generally the best deaf pupils and/or those showing the potential to cope are selected for mainstreaming. In order to evaluate this effect on speech skills of the deaf, a comparison must be made to the top children in schools for the deaf. Finally, when planning therapy for the hearing-impaired, articulatory errors should be treated with multiple linear regression analysis so as to isolate those factors which truly influence intelligibility and which would yield the greatest improvement in intelligibility when corrected. This is extremely important in light of the problems of interpreting correlations of specific errors to intelligibility due to problems of frequency of occurrence of the error type and interdependence of factors.

An interesting observation of this study pertains to the effectiveness of using other than well trained phoneticians to make broad phonetic transcriptions. In the present study, the agreement rate was good between a well trained phonetician and a second transcriber with less experience at broad phonetic transcription. This suggests that teachers of the deaf who have some training in making broad phonetic transcriptions may be relied upon to give valid reports of the articulatory production of their students. If the teachers are trained as a group and use the same criteria for description of sounds, consistency between teachers should be high.

It would appear that a rather critical link in the understanding of what determines a child's speech intelligibility lies in the prosodic feature skills of the child. To date, we are still limited in our ability to measure these skills and to correlate them to intelligibility. One of the problems with Prosodic Feature Production Test I was that each utterance was read in isolation without the benefits of context which should make them more meaningful to the reader. With this problem in mind, Prosodic Feature Production Test II was designed as a question and answer sequence in which the test items were responses to specific questions and all items in each test unit were bound by context. It was hoped that this might in some way make read materials more like realistic situations.

An unexpected finding in both the Prosodic Feature Production tests was that the deaf produced stress correctly more often than did the hard-of-hearing group. The deaf exaggerated stress to the point of it being unnatural but were nevertheless graded correct for stressing the target item. The hard-of-hearing group seemed to follow their own rules for where stress should naturally occur in the utterance. This led to a second way of analyzing prosodic feature production data. The tapes were evaluated again and additional scores were given for naturalness of production. When this was done, the hard-of-hearing children were considerably better than the deaf. A correlation of naturalness scores for production of stress on Prosodic Feature Production Test I with intelligibility was .38 ($p < .01$), whereas the correlation of naturalness on all test items on Prosodic Feature Production Test II with intelligibility was .72 ($p < .001$). These correlations were higher than those for correctness of production and intelligibility. The significantly higher correlation for performance on Prosodic Feature Production Test II than I with intelligibility suggests the possibility that the format of the second test, with emphasis on context, may have contributed somewhat to more natural production.

There is a definite need for more realistic materials with which to test the hearing-impaired child's use of prosodic feature production. Whereas measurements for spontaneous speech samples would appear best, it is hard to elicit specific prosodic features in spontaneous speech. For this reason more and more context must be used to make the test materials more realistic.

For prosodic feature reception testing, the child might be asked to match the auditory stimulus with a question that would elicit the target statement as a response. For example, "JOHN drank milk." is a response to the question "Who drank milk? not "What did John do?". Appropriate selection of the question would indicate that the child heard and understood the stress marked in the utterance.

For production testing, a question should precede the test utterance. The answers should be restricted to brief unambiguous responses in which only one word can be appropriately stressed and other words must be unstressed. In this way we can test whether the child uses stress meaningfully and how he produces stressed syllables in comparison to unstressed ones. For example, the question might be "What is blue?". The response is "My HAT is blue." In this utterance there should be no doubt as to which word receives primary stress. Also, in rating these responses, the listener should be given a system whereby he rates both correctness and naturalness of production.

With these modifications it may be possible to devise new tests of prosodic abilities. Together with a weighting scale of the significance of different types of phonemic errors and a rating scale of naturalness of production, these new prosodic tests may lead to a better understanding of what makes the hearing-impaired child more intelligible.

CHAPTER VI

SUMMARY

This study was undertaken to evaluate phonemic and prosodic speech reception and production skills of hard-of-hearing and deaf children. The specific purposes were to determine (1) whether there were significant differences in the performance of the hard-of-hearing and deaf groups and (2) which skills correlated most highly with overall speech intelligibility. This study was designed to compare hard-of-hearing and deaf children in a similar school setting and for this reason children mainstreamed into the regular school system were considered. Data on deaf children at schools for the deaf have already been obtained in a companion study by Smith (1972). For purposes of comparison several of the same tests were used as in the Smith study.

Forty-three children between the ages of nine and twelve served as subjects. The children were all integrated into the New York City Public Schools and all received special assistance in all subject matter and in speech and language skills from their resource room teachers. Twenty of the children had pure tone averages in the better ear of 80 dB HTL or worse and twenty-three had pure tone averages better than 80 dB HTL.

The following tests of phonemic and prosodic reception and production ability were administered to the children:

1. Phoneme production: sentences. The children read twenty test sentences. Broad phonetic transcriptions were made and phoneme scores were generated for each child. Inexperienced and experienced listeners rated the intelligibility of each child's utterances. Intelligibility scores were generated.

2. Phoneme production: words. The children read fifty-six words which also appeared in the twenty test sentences. Phoneme production scores were compared for words in isolation and words in context.

3. Spontaneous speech samples. The children described one picture and one picture sequence and experienced listeners rated them on their intelligibility.

4. Prosodic feature production. One test evaluated production of the prosodic features of stress, pause and question intonation in three and five syllable utterances. The second tested these same features singly and in combination in sequential utterances bound by context.

5. Phoneme reception test. This test measured the child's ability to discriminate different phonemic features in a closed-response set test designed to test reception of the major articulatory features.

6. Prosodic feature reception. The first test evalu-

ated the child's ability to discriminate the features of stress, pause and question intonation in two, three and five syllable utterances. The second test evaluated their ability to recognize the place of stress in statements and questions.

The test results show that the hard-of-hearing and deaf groups can be differentiated by their performance on phonemic production and phonemic reception tests and by intelligibility scores and intelligibility ratings. Performance on prosodic feature reception and production tests did not yield significant differences between the two test groups except when naturalness of production of test features was considered.

The following are more specific findings for the various tests:

Although the deaf group produced significantly more phonemic errors (29%) than did the hard-of-hearing group (19%), the pattern of errors was very similar for both groups of children. That is, the relative frequency of different error types within each group was similar. Omission of the intended phoneme constituted the largest portion of all error types. Errors of place-manner, manner and voicing also occurred frequently. Vowel substitutions were characterized by production of a near neighbor in the vowel quadrilateral. There was also a tendency to substitute a neutral /ə/ or /ʌ/ for the intended vowel.

Mean intelligibility scores for the mainstreamed deaf children were 39% and for the hard-of-hearing children were 68%.

When phonemic production was compared for a list of test words read in isolation and those identical words read in context, no significant differences in performance based on context were found.

Results of a phoneme reception test showed that discrimination of voicing contrasts and manner contrasts was good and discrimination of place contrasts was poor.

The rank order of correct production of prosodic features was pause, late stress, early stress and yes/no questions. Portions of the prosodic feature production tests were scored for both correctness and naturalness of production of test features. Whereas no significant differences were reported between hard-of-hearing and deaf groups of children for correctness of production of test features, for test materials bound by context (Prosodic Feature Production Test II), the hard-of-hearing children were significantly more natural sounding in their test performance than were the deaf children.

The pattern of confusions and overall scores for the hard-of-hearing and deaf groups were similar for Prosodic Feature Reception Test I. Both groups of children did best on recognition of pause and worst on items testing early stress.

The variables correlating most highly with intelligibility in this study were intelligiblity ratings for read speech ($r=.99$, $p<.001$), phonemic production ability ($r=.90$, $p<.001$), spontaneous speech ratings ($r=.88$, $p<.001$), phonemic reception ability ($r=.85$, $p<.001$) and naturalness of suprasegmental production ($r=.72$, $p<.001$).

Consonant errors in speech production correlated more highly with intelligibility than vowel errors. Omission of the intended phoneme was the phonemic error which correlated most highly with intelligibility. The correlation between phoneme reception ability and intelligibility was far higher than between the pure tone average and intelligibility. Whereas there was no significant interaction between intelligibility and correctness of production of prosodic features (Prosodic Feature Production Tests I and II), there was a good correlation between naturalness of production of prosodic features and intelligibility (Prosodic Feature Production Test II).

Recommendations were made for the creation of new tests of prosodic feature reception and production ability and of new ways to analyze the interrelatedness of phonemic and prosodic skills so as to gain a better understanding of those factors which make the hearing-impaired child more intelligible.

APPENDIX A

SCHOOL DATA

School	Borough	Socio-economic Area	Number of Subjects	Subject Numbers
#1	Queens	Middle	8	(201-208)
#2	Queens	Low-Middle	8	(209-216)
#3	Staten Island	Middle	7	(217-223)
#4	Brooklyn	Low	9	(224-230, 232-233)
#5	Brooklyn	Low-Middle	4	(231,234-236)
#6	Queens	Middle	5	(237-241)
#7	Brooklyn	Middle	2	(242-243)

APPENDIX B-1

PURE TONE AIR CONDUCTION RESPONSES FOR ALL SUBJECTS, IN dB RE: AUDIOMETRIC ZERO (ISO)

Frequency in Hz

CHILD		125	250	500	1000	2000	4000	8000
1	r	70	75	90	100	90	85	NR
	l	70	70	95	100	105	105	NR
2	r	80	80	100	105	105	NR	NR
	l	55	75	85	100	90	85	DNT
3	r	NR	85	85	95	95	100	90
	l	NR	85	90	100	105	105	NR
4	r	DNT	60	60	55	60	60	75
	l	DNT	70	65	65	70	60	75
5	r	75	80	85	100	85	80	65
	l	65	70	100	95	100	85	60
6	r	DNT	50	60	85	80	90	NR
	l	DNT	65	75	75	65	65	60
7	r	75	85	95	85	80	75	90
	l	55	60	65	70	60	60	70
8	r	DNT	15	50	65	70	65	55
	l	DNT	15	25	45	60	60	50
9	r	DNT	75	85	85	95	85	80
	l	DNT	75	95	95	90	90	85
10	r	DNT	85	100	105	90	80	NR
	l	DNT	85	85	95	80	70	70
11	r	DNT	75	55	NR	NR	NR	NR
	l	DNT	80	60	NR	NR	NR	NR
12	r	DNT	85	100	105	110	110	NR
	l	DNT	80	95	105	110	110	NR
13	r	DNT	65	90	100	105	NR	NR
	l	DNT	80	100	105	NR	NR	NR
14	r	DNT	70	80	100	105	NR	NR
	l	DNT	80	100	NR	NR	NR	NR
15	r	55	75	90	90	80	65	60
	l	60	75	75	75	70	60	50

APPENDIX B-1 (CONT'D)

CHILD		125	250	500	1000	2000	4000	8000
16	r	DNT	25	35	60	70	75	85
	l	DNT	20	70	80	80	75	85
17	r	DNT	15	20	70	75	80	DNT
	l	DNT	5	20	65	75	75	DNT
18	r	DNT	40	60	70	70	70	65
	l	DNT	35	55	75	70	65	65
19	r	50	55	70	70	65	60	55
	l	50	70	80	75	60	65	60
20	r	70	85	NR	NR	NR	NR	NR
	l	75	85	NR	NR	NR	NR	NR
21	r	DNT	90	85	85	90	85	60
	l	DNT	90	110	105	NR	NR	NR
22	r	DNT	50	60	80	95	90	75
	l	DNT	30	50	75	80	75	80
23	r	DNT	60	70	75	75	75	NR
	l	DNT	75	90	60	75	100	NR
24	r	DNT	85	90	90	80	75	70
	l	DNT	80	85	95	90	75	75
25	r	DNT	30	60	65	65	70	DNT
	l	DNT	25	45	55	55	55	DNT
26	r	DNT	20	40	45	65	85	70
	l	DNT	85	95	105	NR	NR	NR
27	r	DNT	85	85	90	95	70	85
	l	DNT	NR	NR	NR	95	85	75
28	r	55	60	75	70	70	65	50
	l	45	60	60	65	65	75	65
29	r	DNT	85	90	105	105	NR	NR
	l	DNT	70	65	70	70	70	40
30	r	DNT	80	90	90	80	70	75
	l	DNT	75	95	95	90	75	70
31	r	DNT	45	50	60	60	60	NR
	l	DNT	45	55	60	55	65	80
32	r	40	40	50	60	75	70	65
	l	60	60	75	95	85	75	NR

APPENDIX B-1 (CONT'D)

CHILD		125	250	500	1000	2000	4000	8000
33	r	DNT	35	55	60	70	70	70
	l	DNT	30	50	55	55	75	75
34	r	DNT	50	60	75	75	75	55
	l	DNT	45	55	70	80	65	65
35	r	DNT	25	25	70	95	NR	90
	l	DNT	20	20	55	105	110	NR
36	r	DNT	20	65	60	75	85	NR
	l	DNT	60	65	65	60	60	NR
37	r	55	75	100	100	95	75	70
	l	45	65	80	90	90	100	NR
38	r	20	15	75	100	110	110	NR
	l	15	10	65	100	105	110	NR
39	r	25	55	70	85	105	NR	NR
	l	25	50	75	85	100	NR	NR
40	r	DNT	NR	NR	NR	NR	NR	NR
	l	DNT	15	25	NR	105	NR	NR
41	r	DNT	55	70	85	85	80	80
	l	DNT	80	90	90	110	105	NR
42	r	50	60	65	65	55	65	40
	l	55	65	80	80	70	70	60
43	r	DNT	0	10	60	75	90	DNT
	l	DNT	50	70	90	95	100	DNT

NR= no response at maximum output of audiometer

DNT= did not test

APPENDIX B-2

BACKGROUND DATA

CHILD	SEX	BIRTH DATE	SOCEC LEVEL	HOME LANG	PTA	AMPLIF	EARCH
1	F	11/64	1	9	93.3	B	R
2	F	12/64	1	2	91.7	M	L
3	F	1/62	2	9	91.7	M	R
4	F	11/64	2	1	58.0	B	L
5	F	8/64	1	2	90.0	B	L
6	M	10/64	2	2	71.7	B	R
7	F	10/64	2	1	65.0	B	L
8	M	5/64	1	1	43.3	M	L
9	F	10/64	1	2	88.3	B	R
10	M	12/64	1	1	86.7	B	L
11	F	11/64	1	1	110.0+	B	R
12	M	8/64	1	2	103.3	B	L
13	M	1/64	1	1	110.0+	B	L
14	F	3/62	1	1	95.0	B	R
15	M	3/63	3	1	73.3	B	L
16	F	1/62	1	1	55.0	M	R
17	M	10/64	1	1	53.3	M	R
18	M	1/63	2	1	66.7	B	L
19	M	12/63	1	1	68.3	M	R
20	M	11/64	1	1	110.0+	B	L
21	F	3/63	1	1	86.7	M	R
22	M	2/64	1	1	68.3	M	L

APPENDIX B-2

(CONT'D)

CHILD	SEX	BIRTH DATE	SOCEC LEVEL	HOME LANG	PTA	AMPLIF	EARCH
23	F	12/63	2	1	73.3	M	R
24	F	10/64	3	2	86.7	B	R
25	M	10/64	2	1	51.7	M	R
26	F	11/64	3	1	50.0	M	R
27	F	8/64	3	1	90.0	M	R
28	F	3/64	3	1	63.3	B	L
29	F	1/62	3	2	68.3	M	L
30	F	9/64	3	2	86.7	B	L
31	F	5/64	2	1	56.7	M	R
32	M	10/64	2	1	61.7	M	R
33	M	9/63	3	2	53.3	M	R
34	M	3/63	2	1	68.3	B	R
35	F	1/64	2	1	60.0	M	R
36	M	7/64	3	1	63.3	M	R
37	F	10/64	9	1	86.7	B	L
38	M	10/62	3	1	90.0	B	L
39	F	2/63	3	1	86.7	B	R
40	F	4/64	9	1	110.0+	M	L
41	F	10/64	9	1	80.0	M	R
42	M	11/64	2	1	61.7	M	R
43	M	9/64	2	1	48.3	M	R

SOCIO-ECONOMIC LEVEL: 1- upper middle 2- lower middle 3- state aid
LANGUAGE SPOKEN IN HOME: 1- English 2- Spanish 9- no data
AMPLIFICATION: M- monaural B- binaural
EARCH= ear chosen for listening tasks

APPENDIX C-1

INSTRUCTIONS TO LISTENERS

You are going to hear 24 or 25 utterances recorded by hearing-impaired children. Most of the utterances are single sentences. A few consist of two consecutive sentences. No utterance is repeated; each child says something different.

The sppech of these children covers a wide range of intelligibility. You are going to hear each utterance twice. Write down whatever you think the child is saying. If some of the words are unclear, put in your best guess. If you can only catch an isolated word or two, write them in, indicating their approximate position in the sentence, e.g., ________ ________ boy ______ not ________ _________.

Next to each utterance (to the left of the sentence number) write a number from 1-5 following this code:

1. Listener cannot understand the message
2. Listener understands little of the content of the message, but does understand a few isolated words or phrases
3. Listener understands with difficulty about half of the message. (Intelligibility may improve after a listening period.)
5. Listener understands the complete message

ANY QUESTIONS?

APPENDIX C-2

PHONEMIC TRANSCRIPTION CODE

VOWELS

11 /i/
12 /ɪ/
13 /ɛ/
14 /æ/
15 /ɑ/
16 /ɔ/
17 /ʊ/
18 /u/
19 /ʌ/
20 /ə/
21 /ɝ/
22 /ɚ/
23 /eɪ/
24 /aɪ/
25 /aʊ/
26 /oʊ/
27 /ɔɪ/
28 /ju/

PLOSIVES

29 /p/
30 /b/
31 /t/
32 /d/
33 /k/
34 /g/

FRICATIVES

35 /f/
36 /v/
37 /θ/
38 /ð/
39 /s/
40 /z/
41 /ʃ/
42 /ʒ/
43 /h/
44 /hw/

AFFRICATES

45 /tʃ/
46 /dʒ/

NASALS

47 /m/
48 /n/
49 /ŋ

GLIDES

50 /w/
51 /r/
52 /j/

LATERAL

53 /l/

NON-ENGLISH PHONEMES

54 χ vl. velar fricative
55 ɣ vd. velar fricative
56 ʔ glottal stop
57 ç palatal fricative
58 ɸ vl. bilabial fricative
59 β vd. bilabial fricative

OTHER CLASSIFICATIONS

61 unidentified substitution
62 intended vowel diphthongized
63 word misread
64 omission
65 word left out
66 intended diphthong without off-glic

RECOGNIZABLE DISTORTIONS

70 unsure if sound is present
71 extra phoneme added
72 voicing confusion /x̥//x̬/
73 nasality added
74 sibilant distortion
75 miscellaneous

APPENDIX C-3

Confusion matrix comparing transcriptions made by the two transcribers for phonemic production for all children for the twenty test sentences.

Transcriber B

Transcriber A

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
11	1233	64	0	3	0	0	0	0	1	7	0	0	4	0	0	0	0	0
12	100	873	15	2	2	1	0	0	2	29	0	0	1	1	0	0	0	0
13	0	13	374	45	0	0	0	0	4	4	1	0	8	1	0	0	0	0
14	2	2	12	777	9	0	0	0	7	4	0	0	1	1	1	0	0	0
15	1	1	3	22	485	15	0	0	12	23	0	0	4	19	0	0	0	0
16	0	1	0	0	17	399	2	0	1	3	0	0	0	0	0	0	1	0
17	0	1	0	0	0	1	98	15	1	0	0	0	0	0	0	1	0	0
18	2	2	3	0	0	1	2	559	1	7	0	0	0	0	0	11	0	3
19	0	2	2	3	13	21	3	0	84	85	0	0	0	1	0	5	0	0
20	32	45	5	18	1	1	2	10	4	902	0	1	6	1	0	1	0	0
21	0	0	0	0	0	2	0	0	0	1	35	0	0	0	0	0	0	0
22	0	0	1	0	0	0	0	0	0	227	2	41	0	0	0	0	0	0
23	2	2	6	4	1	0	0	0	0	8	0	0	348	1	0	5	0	0
24	0	1	0	4	11	0	0	0	0	0	0	0	0	366	0	0	1	0
25	0	0	0	0	0	0	0	0	0	1	0	0	0	1	29	0	0	0
26	0	0	2	0	1	4	1	2	2	6	1	0	0	0	0	235	1	0
27	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
28	2	1	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	15

	Transcriber B																	
Transcriber A	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0
13	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	1	3	0	0	0	0	0	1	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0

Transcriber B

Transcriber A	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0	2	11
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	7
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1
14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3
19	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
20	0	0	0	0	0	0	12	0	0	0	0	0	0	0	3	0	0	22
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Transcriber B

Transcriber A	65	66	67	68	69	70	71	72	73	74	75
11	0	0	0	0	0	0	1	0	0	0	0
12	0	0	0	0	0	0	4	0	8	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	6	1	0
15	0	0	0	0	0	0	0	0	1	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	1	0	0
20	0	0	0	0	0	0	2	0	1	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	1	0	0
24	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0

Transcriber B

Transcriber A

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
29	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
33	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	3	2	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0
62	2	14	9	27	8	5	5	1	0	2	0	0	6	2	2	5	0	0
63	0	5	3	2	0	2	1	1	0	2	0	0	3	2	2	2	0	0
64	7	11	0	1	1	0	0	0	1	47	0	1	1	0	0	1	0	0
65	0	0	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
66	0	0	0	0	11	0	0	0	0	0	0	0	0	40	3	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
71	9	13	4	6	3	6	1	2	3	9	1	0	0	6	0	4	0	0
72	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	2	0	0	19	2	2	0	0	2	0	0	0	1	0	1	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0

Transcriber A

Transcriber B

	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
29	302	4	0	0	0	0	0	2	1	0	1	0	0	0	1	0	0	0
30	6	547	0	12	0	0	0	12	0	0	0	0	0	0	0	0	0	0
31	1	0	622	16	7	0	1	0	18	2	7	1	1	0	1	0	8	0
32	0	5	46	502	0	0	0	0	2	86	0	5	0	0	1	0	3	4
33	1	0	5	1	488	4	0	0	0	0	0	0	0	0	1	0	1	3
34	0	2	0	2	18	131	0	0	0	0	0	0	0	0	0	0	0	1
35	0	1	1	0	0	0	399	7	1	0	0	1	0	0	0	0	0	0
36	1	2	1	0	0	0	10	245	0	1	0	3	0	0	0	1	0	0
37	0	0	1	0	0	0	1	0	112	9	4	0	0	0	0	0	0	0
38	0	0	1	70	0	0	0	1	3	366	0	0	0	0	0	0	0	0
39	0	0	2	0	0	0	0	0	0	0	156	3	3	0	0	0	0	0
40	0	0	1	4	0	0	0	0	1	5	9	112	0	0	0	0	0	0
41	0	0	2	1	1	0	0	0	0	0	8	1	62	1	1	0	15	1
42	0	0	0	0	0	0	0	0	0	0	1	2	2	1	0	0	0	7
43	1	0	2	0	6	3	0	0	0	1	0	0	0	0	522	0	0	2
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
45	0	0	6	0	0	0	0	0	0	0	1	0	3	0	0	0	90	4
46	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	2	37
47	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	1	7	0	0	2	0	3	3	1	2	0	0	0	0	0	0
49	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
50	0	1	0	0	0	0	0	2	0	0	0	4	0	0	0	5	0	0
51	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
52	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	3
53	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	1	0	16	3	2	0	0	1	0	2	0	0	0	0	1	0	1	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	1	3	12	3	4	4	1	3	1	6	2	4	2	0	1	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	2	3	0	4	0	1	0	0	0	0	0	0	0	0	0	0	1	1
64	6	5	174	125	84	7	31	21	6	9	14	18	3	0	12	0	1	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	1	2	39	17	21	0	10	10	8	6	4	13	2	0	0	0	2	1
71	0	1	15	12	4	0	5	0	11	13	14	3	1	0	0	0	2	1
72	1	1	4	2	4	3	2	3	0	2	3	0	0	0	0	0	1	3
73	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	7	3	0	0	2	3	8	6	29	11	3	0	1	0	1	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0

Transcriber B

Transcriber A

	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
29	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2
30	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
31	0	1	0	0	0	0	0	0	0	2	0	0	0	0	21	0	0	30
32	0	6	1	0	0	0	0	0	0	0	0	0	0	0	8	0	0	24
33	0	1	0	0	0	1	0	0	0	1	0	0	0	1	6	0	0	7
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	2
36	1	0	0	7	0	0	1	0	0	0	0	0	0	0	3	0	1	4
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	2
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3
39	0	0	0	0	0	0	0	0	0	1	1	0	0	0	6	0	0	12
40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	20	0	0	16
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	6
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	7
43	0	3	0	3	1	0	0	0	0	2	0	0	0	0	8	0	0	21
44	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	2	0	0	0	1	0	0	0	0	7	0	0	1
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1
47	563	15	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	9
48	16	924	16	0	0	0	2	0	0	1	0	0	0	0	8	0	2	43
49	0	7	94	0	0	0	1	0	0	0	0	0	0	0	2	0	0	5
50	0	0	0	452	9	0	0	0	0	0	0	0	0	0	3	0	2	1
51	1	1	0	0	220	0	1	0	0	0	0	0	0	0	13	0	0	6
52	0	1	0	0	0	92	0	0	0	0	0	0	0	1	1	0	0	2
53	0	0	0	0	0	0	609	0	0	1	0	0	0	0	4	0	1	9
54	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	1	0	0	0	0	1	0	0	0	7	0	0	0	0	2	0	0	3
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	4	0	3	0	0	2	0	0	1	0	0	0	0	23	0	1	4
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
63	2	2	0	0	0	0	3	0	0	0	0	0	0	0	1	0	14	13
64	12	75	18	0	35	1	81	0	0	30	0	0	0	0	50	0	3	1306
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	5	3	1	0	6	0	19	0	0	4	1	0	0	0	14	0	0	45
71	2	2	0	3	2	1	3	0	0	0	0	0	0	0	20	0	0	4
72	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2	0	0	3
73	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	11
75	0	0	0	19	42	4	11	0	0	1	0	0	0	0	3	0	0	0

Transcriber B

Transcriber A

	65	66	67	68	69	70	71	72	73	74	75
29	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	4	0	0	0	0
31	0	0	0	0	0	0	1	0	0	5	0
32	0	0	0	0	0	0	3	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	2	0	0	0	0
35	0	0	0	0	0	0	1	0	0	1	0
36	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	2	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	1	0
40	0	0	0	0	0	0	0	0	0	1	0
41	0	0	0	0	0	0	0	0	0	4	0
42	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	1	0	0	1	0
46	0	0	0	0	0	0	0	0	0	3	0
47	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	1	0	0	0	0
49	0	0	0	0	0	0	0	0	0	1	0
50	0	0	0	0	0	0	0	0	0	0	1
51	0	0	0	0	0	0	0	0	0	0	4
52	0	0	0	0	0	0	1	0	0	0	0
53	0	0	0	0	0	0	1	0	0	1	0
54	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	2	0
62	0	0	0	0	0	0	0	0	1	0	0
63	0	0	0	0	0	0	3	0	0	1	0
64	0	0	0	0	0	0	6	0	1	3	2
65	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	2	0
71	0	0	0	0	0	0	29	0	0	4	0
72	0	0	0	0	0	0	1	0	0	0	0
73	0	0	0	0	0	0	0	0	2	0	0
74	0	0	0	0	0	0	0	0	0	3	0
75	0	0	0	0	0	0	1	0	0	0	3

EXIT

APPENDIX D-1

SPEECH PRODUCTION TEST - SENTENCES

1. I like happy movies better.
2. My mommy takes me shopping after school.
3. The leaves will be red and yellow in the fall.
4. I saw a fat man on the roof this morning.
5. The tooth paste was all over the bathroom floor.
6. I want chocolate ice cream, thank you. And a piece of cake with it.
7. I think he'd better keep away from here. He can't behave himself.
8. Did Jack find the orange ball? I need it.
9. I wish I could read that book.
10. Uncle Bob has a new dog an Duke is his name. He is huge and lazy.
11. Go and see the rabbit in the box. He's a week old.
12. It's cool on the beach now. We have matches for the fire.
13. The wagon has food and dishes on it.
14. Everybody watches Lassie on T.V. Do you?
15. The zipper on my coat is no good any more.
16. It's very mean to laugh at other people.
17. Will anybody tell me who these girls are?
18. It's easy to swim in deep water.
19. A baby has no teeth or hair.
20. Who will feed the cat today?

APPENDIX D-2

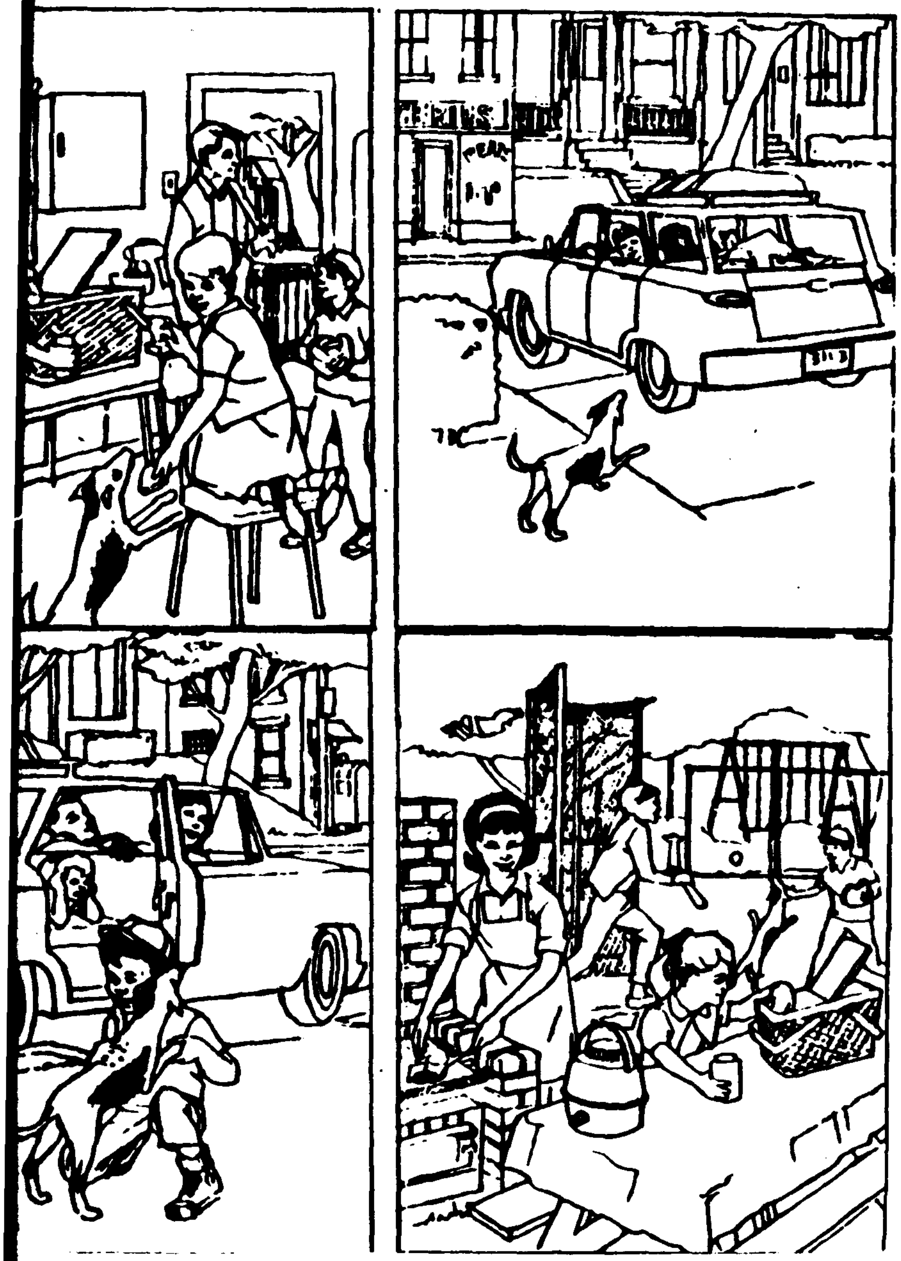
SPEECH PRODUCTION TEST - WORDS

1. piece
2. zipper
3. happy
4. shopping
5. keep
6. deep
7. bathroom
8. Bob
9. rabbit
10. man
11. movies
12. mommy
13. matches
14. swim
15. week
16. away
17. wish
18. feed
19. wagon
20. fat
21. roof
22. food
23. laugh
24. very
25. over
26. leaves
27. think
28. tooth
29. other
30. teeth
31. that
32. these
33. takes
34. after
35. chocolate
36. dog
37. dishes
38. Duke
39. anybody
40. see
41. Lassie
42. easy
43. yellow
44. name
45. beach
46. watches
47. Jack
48. orange
49. huge
50. who
51. read
52. he
53. cat
54. school
55. cake
56. floor

APPENDIX D-3

Picture
Sequence
by
Stuckless

APPENDIX D-3



APPENDIX D-4

PROSODIC FEATURE PRODUCTION TEST I

SEQUENCE			SCRAMBLING A	SCRAMBLING B
I	II	III		
Item Number			STRESS	
1	13	7	COME here.	THANK you.
2	14	8	I want to SEE it.	Oh BOY.
3	15	9	My NEW hat is blue.	He has one BIG dog.
4	16	10	He has one BIG dog.	I want to SEE it.
5	17	11	Oh BOY.	COME here.
6	18	12	THANK you.	My NEW hat is blue.
			PAUSE	
7	1	13	I want...to see it.	He has...one big dog.
8	2	14	Thank...you.	Thank...you.
9	3	15	Oh...boy.	My new hat...is blue.
10	4	16	He has...one big dog.	I want...to see it.
11	5	17	Come...here.	Oh...boy.
12	6	18	My new hat...is blue.	Come...here.
			QUESTION	
13	7	1	Oh boy?	I want to see it?
14	8	2	My new hat is blue?	Thank you?
15	9	3	Come here?	My new hat is blue?
16	10	4	I want to see it?	Come here?
17	11	5	He has one big dog?	Oh boy?
18	12	6	Thank you?	He has one big dog?

APPENDIX D-5

PROSODIC FEATURE PRODUCTION TEST II

PRE-TRAINING

Prompt Questions	Test Items
What color is the apple?	The apple is green.
What is green?	The apple is green.
	This apple is green, the other one is red.
Who ran home?	The boys ran home.
Where did the boys run?	The boys ran home.
Where is John?	John is home.
Who is at home?	John is at home.
	John is at home, Mary is in schoo
	John is at home, Mary is in schoo

POST-TRAINING

Prompt Questions	Test Items
What COLOR is the apple?	The apple is GREEN.
WHAT is green?	The APPLE is green.
	This apple is green...the other one is red.
Who ran home?	The BOYS ran home.
WHERE did the boys run?	The boys ran HOME.
WHERE is John?	John is HOME.
WHO is at home?	JOHN is at home.
	John is at home... Mary is in school.
	John is at home... Mary is in school?

APPENDIX D-6

PHONEME RECEPTION TEST

BOY DOG TOP
HOP RUN SIT
TREE CAT BOOK

ME BE WE
ME BE WE
BUMB GUM DUMB
BUT BUN SUD
TIP DIP NIP
PET POT PUT

FEET FOOT FIT
BET MET WET
POOL PILL PULL
WHEN TEN HEN
BILL MILL WILL

WE D GEE
PEA TEA KEY
WET LET YET
BUM BUZZ BUG
MASS MAP MATCH

ZIP DIP LIP
BIT BOOT BEET
LEAD LID LED
CHAIR FAIR PAIR
MARK PARK BARK

PETE PIT POT
TWO DO NEW
SUP SUB SOME
NOT NEAT NUT
MILL BILL PILL

LOCK LUCK LOOK
FALL FULL FOOL
CUP CUB COME
THEN DEN MEN
LOT DOT NOT

HOT HUT HOOT
SIP SIT SICK
BUD BUZZ BUN
ZOO NEW DO
KNEE D TEA

PEEL PAL POOL
MUMPS BUMPS JUMPS
PAD PAN PAL
FAT SAT HAT
HEAT HIT HUT

WEED LEAD READ
SEAT SEED SEEN
PAT PAN PAD
MAT PAT BAT
HE SEE SHE

RIM RIP RIB
SICK SUCK SOCK
MOO DO YOU
BID BIB BIG
FEEL FULL FOOL

APPENDIX D-7

PROSODIC FEATURE RECEPTION TEST I

1. I CAN go with you.
I can go with YOU.
I...can go with you.
I can go...with you.

2. Go...home.
Go HOME.
GO home.
Go home?

3. I can go...with you.
I can go with YOU.
I...can go with you.
I CAN go with you.

4. Go...home.
Go home?
GO home.
Go HOME.

5. He is...bad.
HE is bad.
He...is bad.
He is BAD.

6. Birds fly?
Birds...fly.
Birds FLY.
BIRDS fly.

7. I CAN go with you.
I can go with YOU.
I can go...with you.
I...can go with you.

8. BIRDS fly.
Birds...fly.
Birds FLY.
Birds fly?

9. He...is bad.
He is BAD.
He is...bad.
HE is bad.

10. He is BAD.
HE is bad.
He...is bad.
He is...bad.

11. Come here?
COME here.
Come...here.
Come HERE.

12. I want to SEE it.
I WANT to see it.
I...want to see it.
I want...to see it.

13. I want...to see it.
I want to SEE it.
I WANT to see it.
I...want to see it.

14. Come HERE.
Come here?
Come...here.
COME here.

15. OH boy.
Oh...boy.
Oh BOY.
Oh boy?

16. I can run.
I...can run.
I can RUN.
I can...run.

17. Bob eats...cake.
BOB eats cake.
Bob...eats cake.
Bob eats CAKE.

18. He has one BIG dog.
He has...one big dog.
He HAS one big dog.
He has one...big dog.

19. I can...run.
I can run.
I can RUN.
I...can run.

20. Bob eats CAKE.
BOB eats cake.
Bob eats...cake.
Bob...eats cake.

21. COME here.
Come...here.
Come HERE.
Come here?

22. He HAS one big dog.
He has one...big dog.
He has...one big dog.
He has one BIG dog.

23. My new hat...is blue.
My NEW hat is blue.
My new hat is BLUE.
My...new hat is blue.

24. I can...run.
I can RUN.
I can run.
I...can run.

25. John drinks MILK.
JOHN drinks milk.
John... drinks milk.
John drinks...milk.

26. Oh...boy.
OH boy.
Oh BOY.
Oh boy?

27. Bob eats CAKE.
Bob...eats cake.
Bob eats...cake.
BOB eats cake.

28. Thank...you.
Thank you?
Thank YOU.
THANK you.

29. My new hat...is blue.
My new hat is BLUE.
My...new hat is blue.
My NEW hat is blue.

30. Bob eats CAKE.
Bob...eats cake.
Bob eats...cake.
BOB eats cake.

31. He has...one big dog.
He has one...big dog.
He *HAS* one big dog.
He has one *BIG* dog.

32. I can...run.
I...can run.
I can *RUN*.
I can run.

33. I *WANT* to see it.
I...want to see it.
I want to *SEE* it.
I want...to see it.

34. Thank *YOU*.
Thank...you.
Thank you?
THANK you.

35. My new hat is *BLUE*.
My *NEW* hat is blue.
My...new hat is blue.
My new hat...is blue.

36. I want to *SEE* it.
I *WANT* to see it.
I...want to see it.
I want...to see it.

37. My new hat...is blue.
My new hat is *BLUE*.
My...new hat is blue.
My *NEW* hat is blue.

39. *JOHN* drinks milk.
John...drinks milk.
John drinks...milk.
John drinks *MILK*.

39. John drinks *MILK*.
John drinks...milk.
JOHN drinks milk.
John...drinks milk.

40. *COME* here.
Come *HERE*.
Come...here.
Come here?

31. He has...one big dog.
He has one...big dog.
He HAS one big dog.
He has one BIG dog.

32. I can...run.
I...can run.
I can RUN.
I can run.

33. I WANT to see it.
I...want to see it.
I want to SEE it.
I want...to see it.

34. Thank YOU.
Thank...you.
Thank you?
THANK you.

35. My new hat is BLUE.
My NEW hat is blue.
My...new hat is blue.
My new hat...is blue.

36. I want to SEE it.
I WANT to see it.
I...want to see it.
I want...to see it.

37. My new hat...is blue.
My new hat is BLUE.
My...new hat is blue.
My NEW hat is blue.

39. JOHN drinks milk.
John...drinks milk.
John drinks...milk.
John drinks MILK.

39. John drinks MILK.
John drinks...milk.
JOHN drinks milk.
John...drinks milk.

40. COME here.
Come HERE.
Come...here.
Come here?

41. John drinks...milk.
John drinks MILK.
JOHN drinks milk.
John...drinks milk.

42. Oh BOY.
Oh...boy.
Oh boy?
OH boy.

43. THANK you.
Thank you?
Thank YOU.
Thank...you.

44. He HAS one big dog.
He has one BIG dog.
He has one...big dog.
He has...one big dog.

45. Oh...boy.
OH boy.
Oh BOY.
Oh boy?

46. THANK you.
Thank YOU.
Thank...you.
Thank you?

APPENDIX D-8

PROSODIC FEATURE RECEPTION TEST II

1. JOHN ran home.
John RAN home.
John ran HOME.

2. Which BOOK did you read?
WHICH book did you read?
Which book did you READ?

3. The boys walked to SCHOOL.
The boys WALKED to school.
The BOYS walked to school.

4. JOHN ran home.
John RAN home.
John ran HOME.

5. How BIG is your dog?
How big is your DOG?
HOW big is your dog?

6. Who is SMALL?
WHO is small?
Who IS small?

7. Who IS small?
Who is SMALL?
WHO is small?

8. What COLOR is your hat?
WHAT color is your hat?
What color is your HAT?

9. My new hat is BLUE.
My new HAT is blue.
MY new hat is blue.

10. He is FIVE.
HE is five.
He IS five.

11. I can run.
I can RUN.
I CAN run.

12. Which book did you READ?
Which BOOK did you read?
WHICH book did you read?

13. He is FIVE.
HE is five.
He IS five.

14. I can run.
I can RUN.
I CAN run.

15. CAN you sing?
Can YOU sing?
Can you SING?

16. The dog CHASED the cat.
The dog chased the CAT.
The DOG chased the cat.

17. The boys WALKED to school.
The BOYS walked to school
The boys walked to SCHOOL.

18. Can you SING?
Can YOU sing?
CAN you sing?

19. What COLOR is your hat?
WHAT color is your hat?
What color is your HAT?

20. Are you TIRED?
ARE you tired?
Are YOU tired?

21. The dog CHASED the cat.
The dog chased the CAT.
The DOG chased the cat.

22. ARE you tired?
Are you TIRED?
Are YOU tired?

23. MY new hat is blue.
My new HAT is blue.
My new hat is BLUE.

24. How big is YOUR dog?
How BIG is your dog?
How big is your DOG?

Practice Items:

A. I am big.
I AM big.
I am BIG.

B. Did John hit the DOG?
DID John hit the dog?
Did JOHN hit the dog?

C. Can YOU come?
CAN you come?
Can you COME?

D. JOHN hit the big dog.
John hit the BIG dog.
John hit the big DOG.

APPENDIX E-1

PHONEMIC SCORES AND INTELLIGIBILITY SCORES AND RATINGS

ID #	PHOSEN	PHOWDS	INTEL	SPONSP	SENRAN	SENRAX	PHONR
1	0.784	0.679	0.575	3.830	2.900	3.830	0.500
2	0.805	0.739	0.710	5.000	3.420	4.170	0.620
3	0.745	0.539	0.259	3.830	1.980	3.500	0.480
4	0.793	0.611	0.714	4.500	3.450	4.170	0.760
5	0.535	0.570	0.077	2.670	1.430	2.330	0.300
6	0.821	0.779	0.766	3.830	3.680	4.250	0.660
7	-0.999	-0.999	-0.999	4.170	-9.990	-9.990	0.580
8	0.746	0.627	0.578	3.830	3.350	3.920	0.660
9	0.773	0.737	0.436	4.000	2.730	3.920	0.440
10	0.719	0.669	0.528	4.170	2.900	3.420	0.460
11	0.544	0.312	0.013	1.670	1.280	1.330	0.220
12	0.754	0.641	0.333	3.330	2.180	3.420	0.380
13	0.595	0.401	0.220	3.830	2.050	3.080	0.340
14	0.713	0.633	0.173	3.170	1.600	2.750	0.280
15	-0.999	-0.999	-0.999	2.500	-9.990	-9.990	0.760
16	0.908	0.859	0.769	5.000	3.800	4.500	0.840
17	0.804	0.742	0.714	5.000	3.620	3.920	0.740
18	0.786	0.779	0.714	4.330	3.630	4.170	0.660
19	-0.999	-0.999	-0.999	4.830	-9.990	-9.990	0.620
20	0.556	0.468	0.052	1.830	1.430	2.080	0.380
21	0.816	0.877	0.661	4.000	3.550	4.420	0.440
22	0.771	0.714	0.481	4.500	2.760	3.580	0.760
23	0.806	0.777	0.723	4.670	3.800	4.830	0.560
24	0.681	0.459	0.148	3.000	1.850	2.920	0.460
25	0.675	0.520	0.413	3.830	2.670	3.330	0.660
26	0.675	0.647	0.602	4.830	3.050	3.920	0.520
27	0.746	0.600	0.342	2.670	2.360	3.670	0.620
28	0.753	0.705	0.368	4.000	2.530	3.580	0.680
29	0.692	0.527	0.281	2.830	2.370	3.580	0.460
30	0.543	0.360	0.130	1.630	1.670	2.420	0.360
31	0.863	0.828	0.868	4.170	4.150	4.500	0.760
32	-0.999	-0.999	-0.999	3.670	-9.990	-9.990	0.540
33	0.896	0.822	0.850	4.830	4.300	4.330	0.800
34	0.871	0.880	0.966	5.000	4.820	5.000	0.860
35	0.853	0.812	0.924	4.830	4.310	4.580	0.820
36	0.896	0.833	0.912	5.000	4.280	4.500	0.820
37	0.859	0.913	0.921	5.000	4.600	5.000	0.740
38	-0.999	-0.999	-0.999	3.670	-9.990	-9.990	0.640
39	0.697	0.588	0.202	3.500	1.770	3.330	0.440
40	0.850	0.810	0.775	5.000	3.660	3.830	0.720
41	0.852	0.759	0.876	5.000	4.310	4.750	0.660
42	0.899	0.919	0.877	5.000	4.230	4.920	0.800
43	-0.999	-0.999	-0.999	5.000	-9.990	-9.990	0.700

PHOSEN= Phonemic scores for sentences
PHOWDS= Phonemic scores for words
INTEL= Intelligibility scores
SPONSP= Spontaneous speech ratings
SENRAN= Intelligibility ratings, inexperienced listeners
SENRAX= Intelligibility ratings, experienced listeners
PHONR= Phoneme reception scores
-0.999= did not test

APPENDIX E-2

TEST SCORES - PROSODIC MATERIALS

ID #	PFP1	P1N	PPREN	PPOSN	PPREC	PPOSC	PFR1	PFR2
1	0.630	0.250	-1.000	-1.000	-1.000	-1.000	0.639	-0.999
2	0.648	0.590	-1.000	-1.000	-1.000	-1.000	0.722	-0.999
3	0.574	0.590	-1.000	-1.000	-1.000	-1.000	0.639	-0.999
4	0.426	0.170	0.280	0.780	0.220	0.220	0.667	-0.999
5	0.370	0.340	0.0	0.060	0.330	0.260	0.389	-0.999
6	0.463	0.750	-1.000	-1.000	-1.000	-1.000	0.417	-0.999
7	0.370	-1.000	-1.000	-1.000	-1.000	-1.000	0.361	-0.999
8	0.407	-1.000	-1.000	-1.000	-1.000	-1.000	0.472	-0.999
9	0.630	0.500	0.830	0.830	0.500	0.890	0.472	0.500
10	0.630	0.500	0.500	0.890	0.170	0.830	0.361	0.500
11	0.593	0.090	0.0	0.060	0.280	0.670	0.278	0.291
12	0.500	0.500	0.170	0.230	0.390	0.500	0.639	0.583
13	0.667	0.170	0.050	0.390	0.330	0.560	0.667	0.500
14	0.648	0.500	0.330	0.560	0.610	0.890	0.611	0.833
15	0.556	-1.000	-1.000	-1.000	-1.000	-1.000	0.833	0.750
16	0.704	0.830	0.940	0.940	0.330	0.670	0.750	0.750
17	0.796	0.910	0.880	1.000	0.220	0.610	0.778	0.666
18	0.667	0.420	0.500	0.500	0.450	0.720	0.778	0.500
19	0.315	-1.000	-1.000	-1.000	-1.000	-1.000	0.444	-0.999
20	0.519	0.090	0.0	0.0	0.560	0.830	0.444	0.458
21	0.648	0.500	1.000	0.830	0.280	0.780	0.472	0.583
22	0.833	0.590	0.330	0.280	0.170	0.720	0.444	0.500
23	0.611	0.340	0.390	0.560	0.280	0.830	0.444	0.458
24	0.463	0.0	0.220	0.280	0.450	0.390	0.417	0.417
25	0.593	0.500	0.110	0.390	0.330	0.560	0.500	0.291
26	0.741	0.590	0.720	0.330	0.450	0.830	0.389	0.500
27	0.481	0.590	0.330	0.330	0.170	0.670	0.444	0.583
28	0.630	0.340	0.720	0.440	0.170	0.780	0.861	0.708
29	0.556	0.830	0.720	0.560	0.450	0.420	0.556	0.542
30	0.648	0.0	0.0	0.110	0.220	0.610	0.389	0.542
31	0.352	0.0	0.280	0.330	0.610	0.830	0.583	0.750
32	0.741	-1.000	-1.000	-1.000	-1.000	-1.000	0.444	0.250
33	0.852	0.420	0.330	0.330	0.330	0.500	0.556	0.791
34	0.833	0.420	0.940	0.940	0.170	0.670	0.639	0.750
35	0.889	0.750	1.000	0.720	0.450	0.950	0.694	0.708
36	0.926	0.670	0.940	1.000	0.170	0.890	0.833	0.916
37	0.574	0.590	1.000	0.690	0.500	0.670	0.417	0.625
38	0.648	-1.000	-1.000	-1.000	-1.000	-1.000	0.611	0.625
39	0.704	0.420	0.330	0.330	0.390	0.670	0.639	0.750
40	0.500	0.170	0.610	0.440	0.330	0.440	0.639	0.666
41	0.704	0.750	1.000	0.830	0.500	0.560	0.667	0.750
42	0.593	0.420	0.670	0.500	0.330	0.780	0.639	0.625
43	0.481	-1.000	-1.000	-1.000	-1.000	-1.000	0.500	0.500

PFP1= Prosodic Feature Production Test I P1N= naturalness scores on PFP1
PPREN= Prosodic Feature Production Test II, naturalness scores, pretraining
PPOSN= Prosodic Feature Production Test II, naturalness scores, post-training
PPREC, PPOSC= Prosodic Feature Production Test II, coorectness scores, pre- and post-training
PFR1, PFR2= Prosodic Feature Reception Tests I and II
-1.000 and -0.999= did not test

APPENDIX F-1

CONFUSION MATRIX FOR HARD-OF-HEARING CHILDREN FOR ALL PHONEMES IN TEST SENTENCES.

All values are entered as proportions. The intended phonemes are in the left-hand column, the phonemes produced are in the rows.

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
11	0.871	0.042	0.006	0.005	0.001	0.001	0.0	0.0	0.0	0.028	0.001	0.001	0.004	0.0	0.0	0.001	0.0
12	0.030	0.900	0.023	0.0	0.005	0.0	0.0	0.001	0.004	0.008	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.008	0.008	0.942	0.003	0.003	0.0	0.0	0.0	0.008	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.0
14	0.0	0.002	0.024	0.917	0.013	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.004	0.001	0.0	0.0	0.0
15	0.0	0.013	0.0	0.009	0.878	0.080	0.0	0.0	0.009	0.0	0.0	0.0	0.0	0.002	0.0	0.004	0.0
16	0.0	0.002	0.002	0.002	0.019	0.933	0.0	0.005	0.019	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0
17	0.0	0.0	0.0	0.0	0.0	0.009	0.954	0.009	0.0	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.002	0.002	0.0	0.0	0.0	0.008	0.941	0.011	0.016	0.0	0.0	0.0	0.0	0.0	0.010	0.0
19	0.0	0.0	0.0	0.014	0.014	0.0	0.0	0.0	0.903	0.0	0.0	0.0	0.0	0.0	0.0	0.014	0.0
20	0.002	0.026	0.001	0.002	0.011	0.001	0.0	0.001	0.067	0.739	0.0	0.001	0.093	0.0	0.0	0.001	0.0
21	0.0	0.0	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.972	0.0	0.0	0.0	0.0	0.0	0.0
22	0.004	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.533	0.002	0.317	0.0	0.0	0.0	0.0	0.0
23	0.015	0.0	0.012	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.917	0.0	0.0	0.009	0.0
24	0.0	0.0	0.0	0.0	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.904	0.002	0.0	0.002
25	0.0	0.0	0.0	0.028	0.0	0.0	0.0	0.056	0.0	0.0	0.0	0.0	0.0	0.0	0.861	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.008	0.004	0.028	0.0	0.0	0.0	0.0	0.0	0.925	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.028	0.056	0.028	0.0	0.306	0.056	0.0	0.0	0.0	0.0	0.056	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.003	0.001	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.008	0.0	0.008	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
    28      29      30      31      32      33      34      35      36      37      38      39      40      41      42      43      44
11  0.001   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.001   0.0
12  0.0     0.0     0.0     0.0     0.001   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
13  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
14  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
15  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
16  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
17  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
18  0.005   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
19  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
20  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.001   0.0     0.0     0.0     0.001   0.0
21  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
22  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
23  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
24  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
25  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
26  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
27  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
28  0.417   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
29  0.0     0.923   0.003   0.003   0.0     0.0     0.0     0.0     0.003   0.0     0.0     0.006   0.003   0.0     0.0     0.0     0.0
30  0.0     0.003   0.951   0.0     0.007   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.002   0.0
31  0.0     0.0     0.0     0.736   0.025   0.002   0.0     0.001   0.0     0.0     0.0     0.001   0.001   0.0     0.0     0.0     0.0
32  0.0     0.0     0.005   0.018   0.609   0.005   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
33  0.0     0.0     0.0     0.015   0.0     0.815   0.008   0.0     0.0     0.0     0.0     0.0     0.0     0.001   0.0     0.0     0.0
34  0.0     0.0     0.0     0.0     0.017   0.0     0.861   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
35  0.0     0.004   0.0     0.0     0.0     0.0     0.0     0.921   0.002   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
36  0.0     0.003   0.015   0.0     0.0     0.0     0.0     0.019   0.836   0.0     0.003   0.0     0.0     0.003   0.0     0.0     0.0
37  0.0     0.006   0.0     0.078   0.0     0.0     0.0     0.011   0.0     0.759   0.0     0.033   0.0     0.0     0.0     0.0     0.0
38  0.0     0.0     0.0     0.008   0.202   0.0     0.0     0.0     0.0     0.037   0.716   0.0     0.0     0.0     0.0     0.0     0.0
39  0.0     0.002   0.0     0.054   0.0     0.004   0.0     0.0     0.0     0.026   0.002   0.478   0.015   0.009   0.0     0.0     0.0
40  0.0     0.0     0.0     0.007   0.038   0.0     0.0     0.001   0.023   0.001   0.020   0.042   0.329   0.001   0.006   0.0     0.0
41  0.0     0.0     0.0     0.074   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.009   0.0     0.630   0.0     0.0     0.0
42  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
43  0.0     0.003   0.0     0.0     0.007   0.013   0.0     0.002   0.0     0.0     0.0     0.0     0.0     0.002   0.0     0.923   0.0
44  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
45  0.0     0.0     0.0     0.035   0.0     0.014   0.0     0.0     0.0     0.007   0.0     0.007   0.0     0.160   0.007   0.0     0.0
46  0.0     0.0     0.0     0.037   0.028   0.019   0.009   0.0     0.0     0.0     0.0     0.009   0.0     0.028   0.083   0.0     0.0
47  0.0     0.003   0.005   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
48  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.002   0.0     0.0     0.0     0.0     0.0     0.0     0.002   0.0
49  0.0     0.0     0.0     0.0     0.006   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
50  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.004   0.0     0.0     0.0     0.006   0.0     0.0     0.002   0.016
51  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.003   0.005   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
52  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
53  0.0     0.0     0.0     0.001   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.001   0.0     0.0     0.0     0.0
```

	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003
30	0.0	0.0	0.003	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002
31	0.003	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.0	0.0	0.001	0.009
32	0.0	0.003	0.0	0.001	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.011	0.0	0.0	0.0	0.0	0.003
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.005
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.011
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002
36	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.003	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.003
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.017
38	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.002
39	0.002	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.031
40	0.001	0.003	0.0	0.009	0.003	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.064
41	0.167	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.056
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.002	0.002	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.003
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.618	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.007	0.0	0.0	0.0	0.0	0.049
46	0.019	0.407	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.019
47	0.0	0.0	0.935	0.023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.004	0.945	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
49	0.0	0.0	0.0	0.139	0.756	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.937	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004
51	0.0	0.0	0.0	0.0	0.0	0.015	0.732	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.030
52	0.0	0.037	0.0	0.0	0.0	0.0	0.0	0.935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.001	0.0	0.001	0.001	0.0	0.862	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003

	62	63	64	65	66	67	68	69	70	71	72	73	74	75	N
11	0.001	0.001	0.027	0.001	0.0	0.0	0.0	0.0	0.0	0.004	0.001	0.002	0.0	0.0	756
12	0.010	0.003	0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	504
13	0.008	0.003	0.003	0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	198
14	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.010	0.0	0.0	468
15	0.006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	270
16	0.005	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.002	0.0	0.0	216
17	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.0	0.0	0.0	54
18	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	306
19	0.0	0.0	0.014	0.0	0.0	0.0	0.0	0.0	0.0	0.028	0.0	0.014	0.0	0.0	36
20	0.0	0.001	0.050	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.001	0.0	0.0	522
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18
22	0.002	0.004	0.117	0.002	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	0.0	270
23	0.009	0.006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	162
24	0.0	0.002	0.0	0.0	0.056	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	234
25	0.0	0.0	0.0	0.0	0.056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18
26	0.016	0.0	0.016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	126
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.028	0.0	0.0	0.0	0.0	18
29	0.0	0.0	0.043	0.0	0.0	0.0	0.0	0.0	0.003	0.003	0.003	0.0	0.0	0.0	162
30	0.0	0.002	0.014	0.002	0.0	0.0	0.0	0.0	0.0	0.005	0.003	0.0	0.0	0.0	288
31	0.0	0.001	0.185	0.001	0.0	0.0	0.0	0.0	0.020	0.006	0.001	0.0	0.0	0.0	503
32	0.0	0.002	0.322	0.0	0.0	0.0	0.0	0.0	0.014	0.004	0.001	0.0	0.0	0.0	468
33	0.0	0.005	0.123	0.001	0.0	0.0	0.0	0.0	0.015	0.003	0.003	0.0	0.0	0.0	378
34	0.0	0.0	0.094	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.0	0.0	90
35	0.0	0.0	0.043	0.0	0.0	0.0	0.0	0.0	0.019	0.009	0.0	0.0	0.0	0.0	234
36	0.0	0.003	0.074	0.0	0.0	0.0	0.0	0.0	0.019	0.0	0.003	0.0	0.006	0.0	162
37	0.0	0.0	0.039	0.0	0.0	0.0	0.0	0.0	0.028	0.044	0.0	0.0	0.006	0.0	90
38	0.0	0.0	0.008	0.0	0.0	0.0	0.0	0.0	0.002	0.020	0.002	0.0	0.0	0.0	324
39	0.0	0.002	0.267	0.0	0.0	0.0	0.0	0.0	0.011	0.041	0.002	0.0	0.054	0.0	270
40	0.0	0.003	0.357	0.0	0.0	0.0	0.0	0.0	0.025	0.022	0.001	0.0	0.031	0.0	342
41	0.0	0.0	0.026	0.0	0.0	0.0	0.0	0.0	0.009	0.019	0.0	0.0	0.009	0.0	54
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
43	0.0	0.003	0.036	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	306
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
45	0.0	0.007	0.069	0.0	0.0	0.0	0.0	0.0	0.021	0.0	0.0	0.0	0.0	0.0	72
46	0.0	0.0	0.267	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.037	0.0	0.009	0.0	54
47	0.0	0.0	0.025	0.002	0.0	0.0	0.0	0.0	0.002	0.006	0.0	0.0	0.0	0.0	324
48	0.0	0.002	0.039	0.0	0.0	0.0	0.0	0.0	0.001	0.003	0.0	0.0	0.0	0.0	540
49	0.0	0.0	0.089	0.0	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	0.0	90
50	0.0	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.008	0.002	0.0	0.0	0.014	252
51	0.0	0.003	0.119	0.003	0.0	0.0	0.0	0.0	0.006	0.003	0.003	0.0	0.0	0.066	198
52	0.0	0.0	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54
53	0.0	0.003	0.073	0.0	0.0	0.0	0.0	0.0	0.020	0.011	0.0	0.0	0.0	0.010	396

APPENDIX F-2

CONFUSION MATRIX FOR DEAF CHILDREN FOR ALL PHONEMES IN TEST SENTENCES.

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
11	0.797	0.084	0.009	0.002	0.001	0.0	0.001	0.004	0.002	0.034	0.0	0.001	0.005	0.0	0.0	0.002	0.0
12	0.055	0.844	0.016	0.001	0.004	0.0	0.002	0.001	0.006	0.009	0.0	0.0	0.0	0.003	0.0	0.0	0.0
13	0.0	0.012	0.902	0.014	0.005	0.0	0.0	0.002	0.0	0.005	0.0	0.002	0.022	0.0	0.0	0.002	0.0
14	0.005	0.005	0.025	0.848	0.027	0.0	0.0	0.0	0.004	0.016	0.0	0.0	0.013	0.003	0.0	0.0	0.0
15	0.0	0.0	0.004	0.005	0.870	0.030	0.004	0.0	0.023	0.004	0.0	0.0	0.009	0.005	0.0	0.007	0.0
16	0.0	0.0	0.002	0.0	0.013	0.908	0.007	0.004	0.029	0.004	0.004	0.0	0.0	0.0	0.0	0.004	0.004
17	0.0	0.0	0.0	0.0	0.009	0.026	0.860	0.018	0.026	0.009	0.0	0.0	0.0	0.0	0.0	0.026	0.0
18	0.005	0.002	0.0	0.005	0.002	0.0	0.025	0.890	0.006	0.022	0.0	0.0	0.0	0.0	0.0	0.017	0.0
19	0.0	0.0	0.013	0.053	0.039	0.0	0.0	0.0	0.737	0.0	0.0	0.0	0.0	0.0	0.0	0.039	0.0
20	0.017	0.032	0.006	0.002	0.017	0.002	0.001	0.002	0.065	0.741	0.0	0.0	0.041	0.0	0.001	0.001	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.974	0.0	0.0	0.0	0.0	0.026	0.0
22	0.0	0.005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.588	0.004	0.253	0.0	0.0	0.0	0.0	0.002
23	0.003	0.0	0.064	0.035	0.0	0.0	0.0	0.0	0.006	0.006	0.0	0.0	0.822	0.009	0.0	0.006	0.0
24	0.0	0.0	0.002	0.0	0.123	0.0	0.0	0.0	0.002	0.002	0.0	0.0	0.0	0.787	0.004	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.895	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.015	0.011	0.015	0.0	0.0	0.0	0.0	0.0	0.917	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.026	0.026	0.0	0.0	0.0	0.0	0.0	0.237	0.105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.004	0.002	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.001	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.016	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.0	0.006	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.004	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.004	0.0	0.001	0.001	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.001	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0
49	0.005	0.011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.017	0.0	0.002	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.002	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	4
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.0	0.0	0.001	0.0
12	0.001	0.0	0.0	0.004	0.003	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.002	0.002	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.003	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.579	0.0	0.0	0.0	0.0	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.921	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.015	0.908	0.0	0.020	0.0	0.003	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0
31	0.0	0.0	0.001	0.616	0.033	0.004	0.0	0.0	0.002	0.0	0.003	0.002	0.0	0.003	0.0	0.004	0.0
32	0.0	0.001	0.007	0.040	0.435	0.004	0.002	0.0	0.0	0.0	0.0	0.001	0.0	0.003	0.0	0.004	0.0
33	0.0	0.001	0.0	0.021	0.004	0.623	0.026	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.015	0.0
34	0.0	0.0	0.0	0.0	0.0	0.047	0.647	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.005	0.021	0.0
35	0.0	0.0	0.002	0.002	0.0	0.0	0.0	0.862	0.020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.023	0.0	0.0	0.0	0.0	0.020	0.804	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.011	0.005	0.121	0.032	0.0	0.0	0.0	0.0	0.553	0.037	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.007	0.243	0.0	0.0	0.0	0.001	0.037	0.665	0.0	0.003	0.003	0.0	0.001	0.0
39	0.0	0.0	0.0	0.123	0.011	0.002	0.004	0.0	0.002	0.009	0.004	0.211	0.005	0.019	0.0	0.002	0.0
40	0.0	0.0	0.0	0.017	0.043	0.0	0.0	0.001	0.001	0.003	0.021	0.022	0.150	0.001	0.004	0.001	0.0
41	0.0	0.0	0.0	0.105	0.018	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.386	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.003	0.0	0.003	0.009	0.009	0.003	0.0	0.0	0.002	0.0	0.0	0.0	0.005	0.0	0.793	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.145	0.0	0.013	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.138	0.0	0.0	0.0
46	0.0	0.0	0.0	0.035	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.018	0.0	0.035	0.079	0.0	0.0
47	0.0	0.006	0.050	0.0	0.001	0.003	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0
48	0.0	0.001	0.0	0.004	0.009	0.001	0.0	0.001	0.0	0.0	0.0	0.001	0.001	0.0	0.0	0.004	0.0
49	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	0.002	0.0	0.0	0.002	0.01
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0
52	0.0	0.0	0.0	0.0	0.009	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.001	0.0	0.005	0.0	0.0	0.0	0.001	0.0	0.002	0.0	0.0	0.0	0.0	0.001	0.0

	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
11	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003
12	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.005
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004
15	0.0	0.0	0.0	0.014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.004	0.002	0.0	0.002	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.008	0.007	0.0	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.010
31	0.002	0.0	0.002	0.004	0.001	0.0	0.0	0.001	0.001	0.0	0.0	0.016	0.0	0.0	0.0	0.0	0.026
32	0.003	0.008	0.0	0.012	0.001	0.0	0.0	0.001	0.0	0.0	0.0	0.010	0.0	0.0	0.0	0.0	0.013
33	0.004	0.0	0.001	0.005	0.001	0.0	0.0	0.0	0.001	0.004	0.0	0.010	0.001	0.0	0.0	0.001	0.030
34	0.005	0.016	0.0	0.0	0.005	0.0	0.0	0.0	0.005	0.0	0.0	0.016	0.0	0.0	0.0	0.0	0.042
35	0.0	0.0	0.004	0.002	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.012
36	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.018
37	0.0	0.0	0.0	0.016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	0.0	0.016
38	0.003	0.001	0.0	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.004
39	0.021	0.0	0.0	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.007	0.004	0.0	0.0	0.0	0.049
40	0.004	0.006	0.0	0.014	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.064
41	0.226	0.061	0.0	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.018	0.0	0.0	0.0	0.0	0.044
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.003	0.006	0.0	0.002	0.0	0.0	0.0	0.003	0.002	0.003	0.0	0.014	0.0	0.0	0.0	0.0	0.006
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.441	0.013	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.0	0.059
46	0.044	0.281	0.018	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.026
47	0.0	0.0	0.839	0.018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.006
48	0.0	0.0	0.001	0.001	0.002	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.010
49	0.0	0.0	0.0	0.095	0.505	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.005
50	0.0	0.0	0.009	0.0	0.0	0.910	0.002	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.008
51	0.0	0.0	0.0	0.0	0.0	0.017	0.647	0.0	0.0	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.038
52	0.035	0.026	0.0	0.0	0.0	0.0	0.0	0.616	0.053	0.0	0.0	0.009	0.0	0.0	0.0	0.009	0.009
53	0.0	0.0	0.001	0.006	0.001	0.0	0.0	0.002	0.613	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.016

	62	63	64	65	66	67	68	69	70	71	72	73	74	75	N
11	0.001	0.002	0.044	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.001	0.0	0.0	798
12	0.007	0.004	0.010	0.0	0.0	0.0	0.0	0.0	0.0	0.019	0.0	0.005	0.0	0.0	532
13	0.007	0.0	0.005	0.002	0.0	0.0	0.0	0.0	0.0	0.010	0.0	0.0	0.0	0.0	209
14	0.014	0.002	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.008	0.0	0.021	0.0	0.0	494
15	0.002	0.009	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.007	0.0	0.005	0.0	0.0	285
16	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.002	0.0	0.0	228
17	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57
18	0.003	0.005	0.008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	323
19	0.0	0.0	0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.053	0.0	0.026	0.0	0.0	38
20	0.0	0.002	0.059	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.002	0.0	0.0	551
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19
22	0.0	0.004	0.123	0.0	0.0	0.0	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.002	285
23	0.012	0.018	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.0	171
24	0.006	0.006	0.002	0.0	0.051	0.0	0.0	0.0	0.0	0.010	0.0	0.0	0.0	0.0	247
25	0.053	0.0	0.0	0.0	0.026	0.0	0.0	0.0	0.0	0.0	0.0	0.026	0.0	0.0	19
26	0.004	0.0	0.011	0.0	0.0	0.0	0.0	0.0	0.0	0.023	0.0	0.0	0.0	0.0	133
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19
29	0.0	0.012	0.035	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.003	0.0	0.0	0.0	170
30	0.0	0.003	0.005	0.0	0.0	0.0	0.0	0.0	0.003	0.007	0.0	0.002	0.0	0.0	304
31	0.0	0.007	0.244	0.0	0.0	0.0	0.0	0.0	0.015	0.002	0.002	0.0	0.001	0.0	532
32	0.0	0.002	0.431	0.0	0.0	0.0	0.0	0.0	0.016	0.003	0.003	0.0	0.0	0.0	492
33	0.0	0.003	0.219	0.0	0.0	0.0	0.0	0.0	0.015	0.005	0.003	0.0	0.0	0.0	398
34	0.0	0.005	0.158	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	95
35	0.0	0.002	0.059	0.0	0.0	0.0	0.0	0.0	0.006	0.012	0.004	0.0	0.006	0.0	247
36	0.0	0.006	0.091	0.0	0.0	0.0	0.0	0.0	0.015	0.0	0.006	0.0	0.003	0.0	171
37	0.0	0.0	0.095	0.0	0.0	0.0	0.0	0.0	0.037	0.047	0.0	0.0	0.021	0.0	95
38	0.0	0.0	0.007	0.0	0.0	0.0	0.0	0.0	0.001	0.007	0.001	0.0	0.001	0.0	342
39	0.0	0.011	0.370	0.0	0.0	0.0	0.0	0.0	0.021	0.035	0.0	0.0	0.068	0.0	285
40	0.0	0.004	0.537	0.0	0.0	0.0	0.0	0.0	0.036	0.014	0.004	0.0	0.039	0.0	361
41	0.0	0.0	0.079	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.0	0.0	0.026	0.0	57
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
43	0.002	0.005	0.127	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	323
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
45	0.0	0.0	0.118	0.0	0.0	0.0	0.0	0.0	0.007	0.0	0.0	0.0	0.020	0.0	76
46	0.0	0.0	0.342	0.0	0.0	0.0	0.0	0.0	0.009	0.026	0.009	0.0	0.018	0.0	57
47	0.0	0.0	0.048	0.0	0.0	0.0	0.0	0.0	0.006	0.012	0.0	0.004	0.0	0.0	342
48	0.0	0.004	0.150	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.001	0.0	0.0	570
49	0.0	0.0	0.358	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0	0.0	0.0	0.0	95
50	0.0	0.004	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.002	0.0	0.026	266
51	0.0	0.0	0.178	0.0	0.0	0.0	0.0	0.0	0.010	0.005	0.002	0.0	0.0	0.075	208
52	0.0	0.0	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.018	0.0	0.0	0.0	0.0	57
53	0.0	0.004	0.102	0.0	0.0	0.0	0.0	0.0	0.008	0.002	0.0	0.0	0.0	0.008	418

APPENDIX F-3

G^2 statistic comparing articulatory comfusions made by hard-of-hearing and deaf children on the twenty test sentences.

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COMPARE       CONFUSIONS:  AVERAGE SENTENCE HOH   VS   AVERAGE SENTENCE DEAF
         MINIMUM CELL ENTRY =     6

                          DIAGONAL PRESENT                                                     DIAGONAL ABSENT
ROW          G-SQUARED     DEG. OF FREEDOM        PROBABILITY                 G-SQUARED     DEG. OF FREEDOM        PROBABILITY

 11          18.1172              7                 0.0115                     2.2046              6                 0.9000
 12          13.8672              7                 0.0536                    10.7026              6                 0.0980
 13           0.0                 0                 0.0                        0.0                 0                 0.0
 14           8.8984              7                 0.2600                     4.1973              6                 0.6500
 15           7.9092              3                 0.0479                     5.5702              2                 0.0617

 16           0.7046              3                 0.8721                     0.6156              2                 0.7351
 17           0.0                 0                 0.0                        0.0                 0                 0.0
 18           3.9648              4                 0.4108                     0.8267              3                 0.8431
 19           0.0                 0                 0.0                        0.0                 0                 0.0
 20          20.0391              7                 0.0055                    19.7280              6                 0.0031

 21           0.0                 0                 0.0                        0.0                 0                 0.0
 22           2.7783              3                 0.4271                     0.0298              2                 0.9852
 23           7.2764              3                 0.0636                     2.2129              2                 0.3307
 24          17.5322              3                 0.0005                     7.8523              2                 0.0197
 25           0.0                 0                 0.0                        0.0                 0                 0.0

 26           0.0                 0                 0.0                        0.0                 0                 0.0
 27           0.0                 0                 0.0                        0.0                 0                 0.0
 28           0.5468              2                 0.7608                     0.0                 0                 0.0
 29           0.1245              2                 0.9396                     0.0                 0                 0.0
 30           2.0366              2                 0.3612                     0.0                 0                 0.0

 31          17.5547              6                 0.0074                     4.9824              5                 0.4180
 32          34.0234              8                 0.0000                     7.2095              7                 0.4074
 33          40.2344              7                 0.0000                     9.6284              6                 0.1412
 34           3.1123              2                 0.2109                     0.0                 0                 0.0
 35           2.4136              3                 0.4911                     2.3272              2                 0.3124

 36           0.6704              4                 0.9549                     0.0853              3                 0.9935
 37           5.4229              5                 0.3665                     0.8691              4                 0.9290
 38           3.8281              4                 0.4298                     2.8418              3                 0.4167
 39          52.9155             10                 0.0000                    12.3008              9                 0.1969
 40          51.3438             12                 0.0000                    20.1577             11                 0.0432

 41           5.2012              4                 0.2673                     0.5518              3                 0.9074
 42           0.0                 0                 0.0                        0.0                 0                 0.0
 43          19.8623              3                 0.0002                     3.6758              2                 0.1592
 44           0.0                 0                 0.0                        0.0                 0                 0.0
 45           8.6484              5                 0.1239                     4.3681              4                 0.3585

 46           1.3608              3                 0.7147                     0.0940              2                 0.9541
 47          19.4141              5                 0.0016                     9.2257              4                 0.0557
 48          49.5781              3                 0.0000                     0.5713              2                 0.7515
 49          21.3271              3                 0.0001                     9.7476              2                 0.0076
 50           1.1353              3                 0.7686                     0.7203              2                 0.6976

 51           3.9219              5                 0.5607                     0.3833              4                 0.9838
 52           0.0                 0                 0.0                        0.0                 0                 0.0
 53          10.0781              6                 0.1214                     7.4170              5                 0.1914
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BIBLIOGRAPHY

Angelocci, A., Some observations on the speech of the deaf. Volta Rev., 64, 403-405 (1962).

Angelocci, A., Kopp, G., and Holbrook, A., The vowel formants of deaf and normal-hearing eleven-to-fourteen year-old boys. J. Speech Hearing Dis., 29, 156-170 (1964).

Aston, C., Hearing-impaired children's discrimination of filtered speech. J. Aud. Res., 12, 162-167 (1972).

Bell, A., The Mechanism of Speech. New York: Funk and Wagnalls (1916).

Bennett, C., Discrimination of stop consonants by severely hearing-impaired children. Ph.D. thesis, McGill Univ. (1973).

Bilger, R., and Wang, M., Consonant confusions in patients with sensorineural hearing loss. J. Speech Hearing Res., 19, 718-748 (1976).

Bishop, Y., Feinberg, S., and Holland, P., Discrete Multivariate Analysis. Cambridge, Mass.: MIT Press (1975).

Bodycomb, M., The speech of the deaf and normal speaker. Volta Rev., 48, 637-638 (1946).

Boone, D., Modification of the voices of deaf children. Volta Rev., 68, 686-692 (1966).

Boothroyd, A., Audiological evaluation of severely and profoundly deaf children. In G. Fant (Ed.), International Symposium on Speech Communication Ability and Profound Deafness-Stockholm, Sweden, 1970. Washington, D.C.: A.G. Bell Assoc. (1972).

Boothroyd, A., Distribution of hearing levels in the student population of Clarke School. Northampton, Mass.: Clarke School for the Deaf (1970).

Boothroyd, A., Nickerson, R., and Stevens, K., Temporal patterns in the speech of the deaf - a study in remedial training. Northampton, Mass.: Clarke School for the Deaf (1974).

Brannon, J., The speech production and spoken language of the deaf. Lang. Speech, 9, 127-136 (1966).

Brannon, J., Visual feedback of glossal motions and its influence upon the speech of deaf children. Ph.D. thesis, Northwestern Univ. (1964).

Calvert, D., Deaf voice quality: a preliminary investigation. Volta Rev., 64, 402-403 (1962).

Calvert, D., Some acoustic characteristics of the speech of profoundly deaf individuals. Ph.D. thesis, Stanford Univ. (1961).

Carr, J., An investigation of the spontaneous speech sounds of five-year-old deaf-born children. J. Speech Hearing Dis., 18, 22-29 (1953).

Colton, R., and Cooker, H., Perceived nasality in the speech of the deaf. J. Speech Hearing Res., 11, 553-559 (1968).

Cooper, F., Delattre, P., Liberman, A., Borst, J., and Gerstman, L., Some experiments on the perception of synthetic speech sounds. J. Acoust. Soc. Am., 24, 597-606 (1952).

Danaher, E., and Pickett, J., Some masking effects produced by low-frequency vowel formants in persons with sensorineural hearing loss. J. Speech Hearing Res., 18, 261-271 (1975).

Delattre, P., Liberman, A., and Cooper, F., Acoustic loci and transitional cues for consonants. J. Acoust. Soc. Am., 27, 769-773 (1955).

Denes, P., Effect of duration on the perception of voicing. J. Acoust. Soc. Am., 27, 761-764 (1955).

Engelberg, M., Correction of falsetto voice in a deaf adult. J. Speech Hearing Dis., 27, 162-164 (1962).

Erber, N., Discussion in R. Stark (Ed.), Sensory Capabilities of Hearing Impaired Children. Baltimore: Universtiy Park Press (1974).

Forner, L., and Hixon, T., Respiratory kinematics in profoundly deaf hearing-impaired speakers. J. Speech Hearing Res., 20, 373-408 (1977).

Green, D., Fundamental frequency characteristics of the speech of profoundly deaf individuals. Ph.D. thesis, Purdue Univ. (1956).

Heider, F., Heider, G., and Sykes, J., A study of the spontaneous vocalizations of fourteen deaf children. Volta Rev., 43, 10-14 (1941).

Hood, R., Some physical concomitants of the perception of speech rhythm of the deaf. Ph.D. thesis, Stanford Univ. (1966).

House, A., and Fairbanks, G., The influence of consonant environment upon the secondary acoustical characteristics of vowels. J. Acoust. Soc. Am., 25, 105-113 (1953).

Hudgins, C., Speech breathing and speech intelligibility. Volta Rev., 48, 642-644 (1946).

Hudgins, C., Voice production and breath control in the speech of the deaf. Amer. Ann. Deaf, 82, 338-363 (1937).

Hudgins, C., and Numbers, F., An investigation of the intelligibility of the speech of the deaf. Genet. Psychol. Monogr., 25, 289-392 (1942).

Huntington, D., Harris, K., Shankweiler, D., and Sholes, G., Some observations on monosyllalbic production by deaf speakers and dysarthric speakers. Amer. Ann. Deaf, 113, 134-146 (1968).

John, J., and Howarth, J., The effect of time distortions on the intelligibility of deaf children's speech. Language Speech, 8, 127-134 (1965).

Johnson, D., Communication characteristics of NTID students. J. Acad. Rehab. Aud., 8, 17-32 (1975).

Jones, K., and Studebaker, G., Performance of severely hearing-impaired children on a closed-response, auditory speech discrimination test. J. Speech Hearing Res., 17, 531-540 (1974).

Lawrence, D., and Byers, V., Identification of voiceless fricatives by high frequency hearing impaired listeners. J. Speech Hearing Res., 12, 426-434 (1969).

Levitt, H., Analysis of the acoustic characteristics of deaf speech. NINDB grant proposal #09252, February (1977).

Levitt, H., Speech production and the deaf child. In L. Connor (Ed.), Speech for the Deaf Child: Knowledge and Use. Washington, D.C.: A.G. Bell Assoc. (1971).

Levitt, H., and Nye, P., Sensory Training Aids for the Hearing Impaired. Washinton, D.C.: National Academy of Engineering (1971).

Levitt, H., Smith, C., and Stromberg, H., Acoustic, articulatory and perceptual characteristics of the speech of deaf children. Proceedings Speech Communication Seminar.

Stockhom (1974).

Levitt, H., Stark, R., McGarr, N., Carp, J., Stromberg, H., Gaffney, R., Barry, C., Velez, A., Osberger, M., and Freeman, L., Language communication skills of deaf children, 1973-1975. Progress Report, CREED Project, No. IV (1976).

Levitt, H., Stromberg, H., Smith, C., and Gold, T., The structure of segmental errors in the speech of deaf children. Appendix A in NINDB grant proposal #09252, February (1977).

McGarr, N., The production and reception of prosodic features. Paper presented at A.G. Bell Assoc., Boston, Mass., June (1976).

McGarr, N., Osberger, M., and Gold, T., The relationship between pitch deviancy and the intelligibility of deaf children's speech. Paper presented at Acoustical Soc. convention, Washington, D.C., April (1976).

McGarr, N., Stromberg, H., and Hochberg, I., Phonemic errors of deaf children on a nonsense syllalbe test. Paper presented at Acoustical Soc. convention, Spring (1977).

Mangan, K., Speech improvement through articulation testing. Amer. Ann. Deaf, 106, 391-396 (1961).

Markides, A., The speech of deaf and partially-hearing children with special reference to factors affecting intelligibility. Brit. J. Dis. Commun., 5, 126-140 (1970).

Martony, J., On the correction of the voice pitch level for severely hard of hearing subjects. Amer. Ann. Deaf, 113, 195-202 (1968).

Martony, J., Studies on the speech of the deaf. Quarterly Progress and Status Reports: Speech Transmission Laboratory Royal Inst. of Tech., Stockholm (1965, 1966).

Mavilya, M., Spontaneous vocalization and babbling in hearing impaired infants. In G. Fant (Ed.), International Symposium Speech Communication Ability and Profound Deafness-Stockholm, Sweden, 1970. Washington, D.C.: A.G. Bell Assoc. (1972).

Miller, G., and Nicely, P., An analysis of perceptual confusions among some English consonants. J. Acoust. Soc. Am., 27, 338-352 (1955).

Millin, J., Therapy for reduction of continuous phonation in the hard-of-hearing population. J. Speech Hearing Dis., 36, 496-498 (1971).

Monsen, R., Second formant transitions of selected consonant-vowel combinations in the speech of deaf and normal-hearing children. J. Speech Hearing Res., 19, 279-289 (1976).

Monsen, R., and Leiter, E., Comparison of intelligibility with duration and pitch control in the speech of deaf children. J. Acoust.Soc. Am., 57, S69 (A) (1975).

Montgomery, G., Analysis of pure-tone audiometric responses in relation to speech development in the profoundly deaf. J. Acoust. Soc. Am., 41, 53-59 (1967).

Nickerson, R., Stevens, K., Boothroyd, A., and Rollins, A., Some observations on timing in the speech of deaf and hearing speakers. Report No. 2905, Bolt, Beranek and Newman, Inc. (1974).

Nober, E., Articulation of the deaf. Excep. Child., 33, 611-621 (1967).

Osberger, M., Correction of deviant timing patterns in deaf children's speech using computer techniques. Paper presented at Acoustical Soc. convention, Penn., June (1977).

Owens, E., Benedict, M., and Schubert, E., Further investigation of vowel items in multiple-choice speech discrimination testing. J. Speech Hearing Res., 14, 841-847 (1971).

Owens, E., and Schubert, E., The development of consonant items for speech discrimination testing. J. Speech Hearing Res., 11, 656-667 (1968).

Owens, E., Talbott, C., and Schubert, E., Vowel discrimination of hearing-impaired listeners. J. Speech Hearing Res., 11, 648-655 (1968).

Oyer, H., and Doudna, M., Structural analysis of word responses made by hard-of-hearing subjects on a discrimination test. Archs Otolar., 70, 357-364 (1959).

Peterson, G., Influence of voice quality. Volta Rev., 48, 640-641 (1946).

Peterson, G., and Barney, H., Control methods used in a study of the vowels. J. Acoust. Soc. Am., 24, 175-184 (1952).

Phillips, N., Remillard, W., Bass, S., and Pronovost, W., Teaching of intonation to the deaf by visual pattern matching. Amer. Ann. Deaf, 113 239-246 (1968).

Pickett, J., Sound patterns of speech: an introductory sketch. Amer. Ann. Deaf, 113, 120-126 (1968).

Pickett, J., Martin, E., Johnson, D., Smith, S., Daniel, Z., Willis, D., and Otis, W., On patterns of speech feature reception by deaf listeners. In G. Fant (Ed.), Speech Communication Ability and Profound Deafness- Stockhom, Sweden, 1970. Washington, D.C.: A.G.Bell Assoc. (1972).

Raphael, L., Preceding vowel duration as a cue to the perception of the voicing characteristic of word-final consonants in American English. J. Acoust. Soc. Am., 51, 1296-1303 (1972).

Rawlings, C., A comparative study of the movements of the breathing muscles in speech and quiet breathing of deaf and normal subjects. Amer. Ann. Deaf, 80, 147-156 (1935) and 81, 136-150 (1936).

Richards, D., Statistical properties of speech signals. Proc. Institute of Electrical Engineers, 52, 941-949 (1964).

Risberg, A., and Martony, J., A method for the classification of audiograms. In G. Fant (Ed.), Speech Communication Ability and Profound Deafness-Stockholm, Sweden, 1970. Washington, D.C.: A.G. Bell Assoc. (1972).

Rosen, J., Phoneme identification in sensorineural deafness. Ph.D. thesis, Stanford Univ. (1962).

Schultz, M., Suggested improvements in speech discrimination testing. J. Aud. Res., 4, 1-14 (1964).

Schultz, M., and Kraat, A., Lack of perceptual reality of the phoneme for hearing handicapped children. Lang. Speech, 14, 178-186 (1971).

Sher, A., and Owens, E., Consonant confusions associated with hearing loss above 2000 Hz. J. Speech Hearing Res., 17, 669-681 (1974).

Siegenthaler, B., A study of the relationship between measured hearing loss and intelligibility of selected words. J. Speech Hearing Dis., 14, 111-118 (1949).

Siegenthaler, B., Perception of certain phonetic variables. Sp. Monogr., 21, 39-45 (1945).

Smith, C., Residual hearing and speech production in deaf children. Ph.D. thesis, City Univ. of New York (1972).

Stark, R., and Levitt, H., Prosodic feature reception and production in deaf children. Paper presented at

Acoustical Soc. convention (1974).

Stevens, K., Nickerson, R., Boothroyd, A., and Rollins, A., Assessment of nasalization in the speech of deaf children. J. Speech Hearing Res., 19, 393-416 (1976).

Stratton, W., Intonation feedback for the deaf through a tactile display. Volta Rev., 76, 26-35 (1974).

Stuckless, E., and Birch, J., A programmed approach to written language development in deaf children. Volta Rev., 64, 415 (1962).

Thomas, W., Intelligibility of the speech of deaf children. Proc. of the International Congress on the Education of the Deaf, Document No. 106 (1963).

Voelker, C., An experiemntal study of the comparative rate of utterance of deaf and normal hearing speakers. Amer. Ann. Deaf, 83, 274-284 (1938).

Willemain, T., and Lee, F., Tactile pitch feedback for deaf speakers. Volta Rev., 73, 541-553 (1971).