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ASSESSMENT OF THE PERCEPTION OF INTONATION BY SEVERELY AND PROFOUNDLY HEARING-IMPAIRED CHILDREN

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ASSESSMENT OF
THE PERCEPTION OF INTONATION BY SEVERELY AND PROFOUNDLY HEARING-IMPAIRED CHILDREN

by

TOVA MOST

A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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ABSTRACT

ASSESSMENT OF THE PERCEPTION OF INTONATION BY SEVERELY AND PROFOUNDLY HEARING-IMPAIRED CHILDREN

by

TOVA MOST

Advisor: Professor Arthur Boothroyd

Thirty severely and profoundly hearing-impaired children and ten normal-hearing children, of two age groups (3-4 years and 5-10 years) were presented with synthetic speech stimuli consisting of flat, rising and falling intonation contours carried by each of two vowels and each of two syllabic patterns. The same stimuli were used in two tests of intonation perception. The first involved an imitative task in which subjects had to imitate the stimulus. The second involved a forced-choice task in which subjects had to select the different contour out of three stimuli. The imitations in the first task were tape recorded for subsequent rating by five trained listeners on a ten-point scale.

Among the older children (=>5 years), all the severely hearing impaired (3 frequency average loss =< 90dBHL) and about 50% of the profoundly hearing impaired (3 frequency average loss > 90dBHL) passed both the forced-choice and the imitative tasks. Among the younger children (<4 years), the proportions passing the imitative task were the same as in the older group. Only one severely hearing-impaired younger child, however, was able to pass the forced-choice task. The fact that the forced-choice task was too difficult for the younger age group was confirmed by the performance of the normal-hearing children.

The imitation scores were bimodally distributed. The pure tone average was a good, but not perfect, predictor of imitation performance. In general, children with hearing loss less than 90dB had moderate and high scores, and those with hearing loss greater than 110dB had very low scores. Imitation scores for children within the 91-110dB range of hearing loss, however, varied from low to high.

The findings suggest that imitation of intonation contours is a cognitively appropriate task for children as young as three years of age, and it provides useful information on the ability to perceive at least one frequency-dependent feature of the acoustic speech signal. These data suggest that there is a high probability of the capacity for perception of intonation in children with hearing losses up to 110dB. The findings further indicate that conclusions about presence or absence of auditory capacity cannot be made until an adequate amount of training has been provided.

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Tova Most

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CHAPTER I

Introduction

This research deals with evaluation, specifically the evaluation of the auditory abilities of very young hearing-impaired children.

In order to be most effective, an habilitation program should be based on the outcomes of evaluation. Initially, the therapist must establish the child's capabilities in order to set appropriate goals. Tasks which are neither too easy nor too difficult in relation to the child's capacities and current performance will ensure the greatest opportunity for success in the least amount of time, and will minimize the amount of unnecessary frustration. Evaluation of the child's progress during therapy will validate the adequacy of the procedures that are applied and will indicate the need for more or less emphasis in specific areas. Evaluation is one of the keys to successful planning, implementation, and management of a program of intervention.

For hearing-impaired children, the evaluation of auditory capacity is particularly important, for two reasons. First the rate and quality of spoken language development is highly dependent on the child's ability to use audition for input and feedback. Second, this ability differs dramatically from child to child. Some hearing-impaired children can perceive frequency dependent cues in addition to the time and intensity patterns of the speech signal. These children may rely on audition as their primary modality. Others are capable of perceiving the time and intensity patterns only. These children cannot rely on audition as their primary modality for spoken language acquisition. If each individual is to reach his/her potential in spoken language development auditory strategies must be used with those who have the auditory capacity to benefit from them, while visual and/or tactual strategies will be necessary for those who do not. A primary role of auditory evaluation must be to determine to which category a given child belongs.

Not only is it necessary to acquire knowledge of the hearing-impaired child's auditory capabilities and limitations, but it is also important to gain this information as early as possible. One reason is the possible existence of a critical age for speech and language development (Lenneberg, 1967). Furthermore, empirical data on early intervention (Ling and Milne, 1981; Wedenberg, 1954), support the notion of early intervention by demonstrating high levels of spoken language performance in profoundly hearing-impaired children who received treatment from an early age.

Several methods are available for assessing the auditory perceptual capabilities of hearing-impaired children, with respect to the potential role of hearing in the acquisition of spoken language. The most common method is to predict the child's auditory perceptual capability from his/her sensitivity to pure tones. The advantages of this method are twofold. First, thresholds can be obtained through physiological and behavioral procedures even from a very young child. Second, research has shown significant correlation between pure tone sensitivity and various speech performance measures (Smith, 1975; Erber, 1974; Boothroyd, 1984). The second reason is, however, a weak one. Unfortunately, the correlation between the pure tone sensitivity and speech performance measures is not perfect. We can predict fairly accurately the speech performance ability of subjects with hearing losses less than 90dB and subjects with hearing losses greater than 110dB. There is, however, a considerable range of pure tone thresholds, i.e. 91-110dBHL, within which our ability to predict speech perception performance is very poor. It is common to find children having almost identical pure tone audiograms with widely varying speech perception skills, within the 91-110dB range of hearing loss. Therefore, for these children, the audiogram cannot serve as an adequate predictor of speech perception abilities (Erber, 1974; Risberg, 1977).

A few more direct tests have been developed in an attempt to gain more information on the auditory perceptual abilities of children with severe and profound hearing losses. These include speech perception tests e.g.: the Spondee Recognition Test, the Auditory Numbers Test (Cramer and Erber, 1974; Erber, 1980), and psychoacoustic tests e.g. difference limen for frequency (Risberg et al., 1975). The advantage of these tests is that their scores form a bimodal distribution of high and low scores.

It is argued that these tests effectively differentiate subjects who can perceive frequency-dependent cues from those who can perceive only time and intensty cues. It is further argued that children who are able to perceive frequency dependent cues possess true residual hearing, whereas those that are denied frequency cues and are able to perceive only time and intensity cues do not hear, but perceive acoustic speech stimuli vibrotactually. Unfortunately, the specific tests just mentioned are unsuitable for the very young preverbal hearing-impaired child because of his/her limited vocabulary and cognitive abilities.

In order to establish auditory capacity in young children a test of sensitivity to frequency dependent cues that is suitable to the child's cognitive and sensory motor abilities is needed. Materials and evaluation procedures suitable for the young preverbal hearing-impaired child should be developed so that his/her auditory perceptual strengths and weaknesses can be specified as early as possible and appropriate amplification and teaching approaches can be chosen. Materials which resemble natural speech but are not dependent on advanced language development are necessary for a young population.

The purpose of the research reported here was to investigate the possibility of using a child's ability to imitate intonation contours as a means of assessing his or her ability to perceive frequency-dependent cues via the sense of hearing.

The choice of intonation contours as stimuli, was based on the following considerations:

1. Intonation contours have linguistic content. They help to mark syntactic boundaries. They help to mark stress, and sometimes they are used to mark questions.

2. Intonation contours are produced very early by the normal-hearing child, before he/she acquires lexical and syntactic competencies (Lewis, 1951; Tonkova-Yampol'skaya, 1973; Engel, 1973).

3. Intonation contours have already been shown to be accessible to some listeners with hearing losses greater than 90dB (Boothroyd, 1978).

4. Intonation is a basic, and probably the simplest, frequency dependent feature of speech, and therefore the perception of intonation patterns may be suitable for distinguishing children who are capable of perceiving frequency information from those who are perceiving only time and intensity cues.

When developing receptive tests for a young population the choice of response task is as important as the choice of stimuli. A choice of inappropriate task will produce an erroneous picture of the subject since inferences about abilities are made from the subject's performance on a given task. The choice of imitation as the response task was based on the following considerations:

1. The task had to be within the range of cognitive and sensorimotor competence of the child. Unlike forced-choice tasks, which are often used for the evaluation of receptive abilities in older subjects, imitation is a natural and

spontaneous behavior for the very young child. Data already exist to show that young normal-hearing children imitate intonation contours (Lewis, 1951).

2. Observations by individuals who work with young hearing-impaired children (Boothroyd, 1982) suggest that one of the earliest signs of responsiveness to auditory programs of speech-language acquisition is the child's imitations of pitch changes.

In the present research, the perception of intonation contours was assessed with two response tasks. The first was imitation. The second was a three alternative forced-choice task. The same set of intonation patterns served as the stimuli in both cases. Tests employing these two tasks were administered to children in three hearing-status groups: normal hearing, severely and profoundly hearing impaired. Within each group there were two age groups: three to four years and five to ten years.

The results were used to test the following hypotheses:

1. That average performance on the imitative test would be identical for older and younger children.
2. That average performance on the imitative test would decrease with increasing hearing loss.
3. That within each hearing-status group, performance on the forced-choice test would be better in the older children than in the younger children.
4. That average performance on the forced-choice test would

decrease with increasing hearing loss.

5. That within the older children, performance on the two tasks would be similar, thus supporting the notion that both tests reflect the same receptive ability.

The long-term goal is the development of a practical diagnostic tool for use by clinicians working with very young hearing-impaired children.

CHAPTER II

Review of the literature

Definition of population and outline of chapter

This study concerns children with hearing losses that are serious enough to preclude the audibility of conversational speech, without the help of hearing-aids. This generally implies a pure tone hearing loss in exess of 60dB. For such children, given no special intervention and no hearing aids, the sense of hearing will play no role in the development of spoken language. Indeed, there was a time when all such children were thought to be deaf, i.e. lacking a sense of hearing. The current terminology for these children describes them as being severely or profoundly hearing impaired. The severely hearing impaired are generally thought to be capable of auditorily-based learning when provided with hearing aids. The profoundly hearing impaired are generally thought to be able to use hearing only as a supplement to other modalities, (or in some cases not to be able to use hearing at all). The use of pure-tone detection thresholds is the most common way to define these groups. The most widely used method is by calculating the average hearing loss in the better ear for the three frequencies 500Hz, 1000Hz and 2000Hz. Averages between 60-90dB (re ANSI S3.6-1969) describe severe hearing-impairment, while averages >90dB indicate profound deafness (e.g. Boothroyd, 1982). The exact values of these decibel boundaries vary from writer to writer (e.g. Davis & Silverman, 1976).

With the development of educational programs, hearing aids and auditory-based methods of instruction it has become clear that, within the population just defined there are wide differences of auditory capacity. The first part of the chapter will review research studies whose purpose has been to describe the auditory speech perception capabilities of severely and profoundly hearing-impaired subjects.

There is both theoretical and empirical support for the position that intervention aimed at developing spoken language skills should begin as early as possible, and should take advantage of auditory capacity, to the extent that it exists. The second part of this chapter will review the research on early auditorily-based intervention.

One danger in the application of auditorily based intervention in young hearing-impaired children is that it will be counterproductive if used with children who have insufficient auditory capacity. To avoid this danger it is necessary to obtain information on the auditory capacity before or during the early stages of intervention. The third part of this chapter will review currently available methods of assessing or predicting auditory capacity.

Most of the methods reviewed in part three, are either imprecise or unsuitable for very young children. This dissertation concerns the development of a test procedure that requires only the imitation of intonation contours. The last part of this chapter will review research whose findings suggest that such a task should be suitable for very young children.

Part 1: The effects of severe and profound hearing loss on the perception of speech

The acoustic speech signal covers a wide range of intensities and frequencies, and carries numerous cues that permit the recognition of speech units (e.g., phonemes, syllables, words). Some of these acoustic cues are found in the intensity/time domain, others are carried in the frequency/time domain. How many and which of these cues are available, auditorily, to the hearing impaired is mostly dependent on the degree and nature of the hearing loss, but other factors, such as amplification, training and age of onset of the intervention also affect performance. Since many of the hearing impaired are denied the important acoustic cues, insufficient information is available to them to perceive the speech signal adequately.

Many researchers have investigated the perception of segmental speech features by the severely and profoundly hearing impaired. Pickett et al. (1972) presented a Modified Rhyme test to severely and profoundly hearing-impaied young adults. They demonstrated that vowels were perceived much better than consonants. Among the vowels, back vowels were perceived better than front vowels. The authors suggested that the back vowels were audible to their subjects, because of their lower second formant, whereas the high second formant of the front vowels was not audible to the subjects.

Hack and Erber (1982) presented ten vowels in a bilabial /bVb/ context to children with average hearing losses between 83-123dB. The vowels were presented through auditory, visual and combined auditory-visual modalities, using a forced-choice task. The results of the auditory vowel recognition test revealed that the children confused vowels produced in neighboring articulatory positions. In addition to these errors, they frequently confused back and front vowels, with a strong tendency to label back vowels as front. The authors argue that the confusions of front/back vowels are due to the fact that these vowels have similar first formants. They further suggest that their subjects were not able to hear the second formants of the vowels and therefore were not able to distinguish between the vowels. It is noteworthy, that most of the subjects in the Hack and Erber study, had poorer hearing than those in the Pickett et al study.

Although consonant perception by the severely and profoundly hearing impaired is poorer than vowel recognition, it is still possible. Many studies (Pickett et al., 1972; Smith, 1975; Erber, 1972b; Martony et al., 1972, Risberg, 1976; Boothroyd, 1984) demonstrate that severely and profoundly hearing-impaired subjects perceive voicing and manner information better than place information. When consonants in /aCa/ context were presented auditorily to severely and profoundly hearing- impaired children by Erber, the subjects were able to discriminate voiced from voiceless consonants and nasal from nonnasal consonants. However, they could not discriminate within nasal and nonnasal voiced categories or nonnasal voiceless categories through hearing alone (Erber, 1972b). The author suggests that the children were able to perceive voicing and nasality because many of the cues to these features are carried by the lower frequencies of speech. Also, Pickett et al. (1972) demonstrated that the voiced/voiceless distinction and low frequency continuants (nasals, liquids and glides) were perceived better than place of articulation by their severely and profoundly hearing-impaired young adults. Boothroyd (1984), tested subjects aged 14-19 years with average hearing losses ranging from 75-124dB. A four-alternative, forced-choice procedure was used to measure the perception of talker's sex, the presence of natural intonation, vowel height, vowel place, initial consonant voicing, and initial consonant continuance. Boothroyd found that voicing and continuance in initial consonants were perceived better than consonant place. All the above researchers agree that identification of place of articulation is most affected by hearing loss. This is most probably because cues to place of articulation, especially second formant transitions in neighboring vowel, are carried in the higher frequencies of speech.

With respect to consonants in general, Pickett et al. (1972), in the study mentioned above, found that initial consonants are perceived better than final consonants. Smith (1975) and Gold (1978) presented the Phoneme Recognition Test, which was developed by Smith, to severely and profoundly hearing-impaired children. These researchers did not succeed in showing a tendency to incorrectly identify final consonants more frequently than initial consonants. Their explanation was that this might have been because of the way the words were presented, with a pause preceding the stimulus word, giving the final consonant more emphasis than would be the case in continuous speech. The authors suggest that when the talker is more careful at producing the targets, there is less difference between initial and final consonant.

Knowledge of the perception of suprasegmental features by severely and profoundly hearing-impaired listeners is still very limited. Stark and Levitt (1974) tested the recognition of pause, addition of syllables, question vs. statement and location of stress by severely and profoundly hearing-impaired children. The children responded at chance level on many items, but their reception of pause and sentence duration was better than that of the other features. Their performance on the question vs. statement items cued by rising vs. falling intonation contour, was the worst. Using a modification of the prosodic feature reception test mentioned above, where children were asked to identify a certain feature instead of making same/different judgements, McGarr (1976) also found that the feature of pause was most often identified correctly. With respect to the feature of stress, when the stress occurred early in the sentence it was somewhat less difficult to recognize than when it occurred towards the end of the sentence. Recognition of question (rising intonation contour) was the most difficult item. When Gold (1978) presented this modified prosodic features test to two groups of children, one with severe and the other with profound hearing loss, she demonstrated that the pattern of confusions and overall scores of the two groups were not significantly different. The children did best on items testing pause and worst on items testing stress. Gold (1978) also tested the effects of place of stress and degree of stress, as well as length of utterance and sentence type on prosodic feature reception by severely and profoundly hearing-impaired children. Once again, the two groups were not significantly different in their performance on the test. It should be noted, however, that most children in Gold's study had average hearing loss better than 95dB. Out of the 43 children only five children had average hearing loss greater than 100dB. All the children in Gold's study did best on items testing early stress and worst on late stress. When the sentence was produced with extra stress on the intended word (emphasis), it was perceived better than when it was produced with normal stress.

From the published data on the reception of segmental and suprasegmental features by severely and profoundly hearing-impaired individuals, it is evident that this population perceives low-frequency speech cues such as voicing, nasal murmurs and the first formant of vowels better than they perceive cues contained in the middle and high frequencies. In addition, severely and profoundly hearing-impaired children are more easily able to perceive cues carried in the intensity/time domain, than those carried in the frequency/time domain.

In the foregoing discussion, general problems in speech perception of both severely and profoundly hearing-impaired subjects were reviewed. No attempt was made to highlight the differences with respect to degree of hearing loss. In fact, one of the major findings of this work has been that there are wide variations in speech perception ability within this population. Some subjects, for example, are able to perceive only the changes of amplitude over time, i.e. the waveform envelope. It has been shown that for these children a similar improvement in speech reception occurs whether they receive linearly amplified speech or speech-modulated low frequency noise along with simultaneous visual cues for speech. (Erber, 1972a).

Even with very limited hearing, when only time and intensity cues are available, some speech features can be perceived auditorily. Among the segmental features, Erber (1979b) has shown that when consonants are presented in /aCa/ context, some profoundly hearing-impaired children are able to perceive manner information based on the duration and intensity of the intervocalic energy. In a different study Erber (1982) claims that, nasals and liquids/semivowels may be recognized as a distinct category (depending on the speech context) on the basis of the slow rise and decay of the syllable envelope. For example, these profoundly hearing-impaired individuals can learn to classify the envelope pattern for /mun/ as different from /but/. Vowel recognition is very poor in these children. They can be taught to distinguish between short and long vowels and they can distinguish between central vowels and front/back vowels on the basis of intensity (Hack & Erber, 1982; Boothroyd, 1984). However, vowel classification simply on the basis of intensity/time cues is less precise in word or sentence contexts, where syllable stress can modify the relative durations and intensities.

Among the suprasegmentals, when only time and intensity cues are available, normal speech patterns can be distinguished from abnormal speech patterns as well as neutral/sad speech patterns from happy/angry ones (Erber, 1979b). Also, the number of syllables in the word or phrase can be perceived (Martony et al, 1972; Marklein, 1981; Boothroyd, 1984). However, profoundly hearing-impaired children who can perceive only time and intensity information demonstrate difficulties in perceiving the number of syllables in words containing unstressed syllables or voiced continuant consonants at syllable boundaries (Erber, 1971; Martony, 1974; Zeiser and Erber, 1977; Ling, 1976).

There is strong evidence for the suggestion that subjects who can perceive only time and intensity cues are doing so, not with the sense of hearing, but with the sense of touch. Nober (1967), for example, has shown that pure tones presented to the ears and then to the hand of some profoundly deaf children yield nearly identical thresholds. In another experiment Nober (1970) established the detection threshold on a group of severely and profoundly hearing-impaired subjects before and after anesthesia of the external auditory canal and the area around the auricle. For five of the subjects in the study, no thresholds could be obtained for any frequency up to the maximum output of the audiometer during anesthesia. Nober concluded that in these subjects, the thresholds obtained before anesthesia were attributable to tactile sensations. Boothroyd and Cawkwell (1970) measured the vibratory threshold on subjects with unilateral total deafness. They believed that these subjects would be consistently able to report the difference between vibrotactile and auditory sensations and therefore could give a measure of vibrotactile threshold. Their results indicated that vibrotactile responses are very probable when testing profoundly deaf subjects with a standard clinical audiometer and that individuals vary considerably in their vibrotactile sensitivity. The authors therefore claim that vibrotactile air conduction thresholds may lead to the assumption of residual hearing, when in fact none exists.

Thus, when sound vibrations reach a sufficiently high intensity, the perception of time and intensity variations in acoustic stimuli can be perceived through the sense of touch. The air conduction audiograms of many profoundly deaf children tend to fall within the range of hearing threshold levels which allow vibrotactile response. Therefore, some researchers believe that some profoundly deaf children do not actually hear the sounds and that vibrotactile rather than auditory receptors mediate the acoustic speech signal in their ears.

One may be equally incorrect, however, in assuming that the responses of these profoundly hearing-impaired children must be vibrotactile. Ericson and Risberg (1977) collected data from hearing-impaired subjects who were able to identify and verbalize three thresholds: sensation of hearing, sensation of vibration, and sensation of discomfort. They noticed that a threshold obtained in an area which allows vibrotactile threshold is not necessarily a tactile threshold. It can be a hearing threshold as well. Furthermore, in some cases a hearing threshold can be obtained at a higher intensity than the vibratory threshold. The authors say that it is therefore not possible to distinguish between a tactile or auditory sensation only based on detection threshold measurements as in pure tone audiometry.

Other experimenters tried to demonstrate that some profoundly deaf children receive vibratory rather than acoustic information by using word stimuli. In a study by Zeiser and Erber (1977) normal-hearing adults and profoundly hearing-impaired children were compared with regard to their ability to perceive number of syllables acoustically and vibrotactually. The stimuli were names that were classified on the basis of: (1) number of syllables as defined by a dictionary and (2) number of syllable bursts observed in the pattern of each stimulus after band pass filtering. The words were presented independently to the fingers and ears. Vibratory perception by the profoundly hearing-impaired and the normal-hearing subjects and auditory perception by the profoundly hearing impaired all were similar. All detected the number of syllables as described by the time-intensity envelopes of the words. The responses obtained under the above conditions differed considerably from normal auditory perception. The normal-hearing adults perceived the number of syllables as described by the dictionary when they were presented auditorily. The authors suggested that the perception of the syllabic pattern in words by profoundly hearing-impaired children differs from normal auditory perception and is very similar to vibrotactile perception by normal-hearing adults. In a different study (Erber, 1971) spondaic words and wide band noise were presented over earphones to the hands of normal-hearing adults and ears of profoundly deaf children. Detection of words by hands and by profoundly hearing-impaired ears, both began to rise above the chance level at about the same point on the S/N dimension. The slope of the detection function was shallower for the "hand" data which suggested greater variability in response by those subjects.

The following conclusions may be drawn from the published data on the effects of severe and profound hearing loss on the perception of speech. First, it is clear that among the many features that define the speech stimulus, this population finds some features more difficult to perceive than others. In particular, suprasegmental features are perceived more accurately than are segmental features. Among the segmental features, vowels are perceived more accurately than consonants, and initial consonants more easily than final consonants. Among the vowel features, vowel height is perceived more accurately than the front/back dimension, and among the consonant features, voicing and nasality are perceived more accurately than place of articulation. At an acoustical level, it appears that cues contained in the intensity/time domain are perceived more accurately than are cues contained in the frequency or frequency/time domains, and that within the latter, cues contained in the lower frequencies are perceived more accurately than are cues contained in the higher frequencies .

Second, it is clear that among the population of severely and profoundly hearing-impaired children, there are wide variations of speech-perception ability. A minority of these children are able to perceive only those cues that are carried by the amplitude envelope of speech, their performance being indistinguishable from that obtained via the sense of touch. Indeed, it is possible that some, if not all of these extreme cases are totally deaf, and their perception of sound is mediated solely by the sense of touch.

Part 2: The importance of early appropriate intervention

The studies reviewed in the previous section demonstrate that hearing-impaired children differ widely in terms of their auditory capacity. It, therefore, seems unlikely that the same procedures in intervention will be appropriate for all hearing-impaired children. Some may progress well with strategies that place primary reliance on audition as the input and feedback modality in the acquisition of spoken language. Those who have no hearing, however, would not benefit from such "auditorily-based" approaches. Instead, they must rely on their senses of vision and touch as input and feedback modalities. Thus, knowledge of the child's auditory capabilities is crucial for planning an appropriate habilitation program.

When intervening in the speech and language development of young hearing-impaired children, not only the method is important but also the age of onset of the intervention. Lenneberg (1967) advanced the notion that children are neurologically ready to acquire speech and language skills during the first few years of life and that if advantage is not taken of the readiness, learning at a later age will be more difficult. This has been termed the "critical age" hypothesis.

The benefits of early auditorily-based intervention for children with sufficient hearing are demonstrated in a few research studies (Ling and Milne, 1981; Wedenberg, 1954). Ling and Milne (1981) have presented data from seven profoundly hearing-impaired children who started treatment at 7-18 months. The children were between the ages 6-12 years old at the time of the study, and had hearing losses ranging from 90 to 103dB. The intelligibility of the children's spontaneous speech production was measured as the percentage of words correctly recognized by unsophisticated listeners. These measures were compared with intelligibility measures that were obtained from normal-hearing children. There was not a significant difference between the two groups. The researchers argued that clear and fluent speech is a realistic goal for hearing-impaired individuals. The age of onset of intervention and the application of systematically organized speech-training procedures are important variables in the acquisition of speech skills (Ling, 1976).

Wedenberg (1954) used an auditory training procedure with 36 pre-school hearing-impaired children with hearing losses ranging from mild to profound. This author showed that auditorily-based intervention was highly effective with some children (generally with hearing losses less than 90dB). Auditorily-based intervention, however, was not effective with others (generally with hearing losses greater than 90dB). The study by Wedenberg is extremely significant in pointing out that some children can learn through the auditory modality and others cannot. It is important to note, however, that since 1954 major advances in amplification have extended the upper limit for an auditory approach.

There are, unfortunately, no research data to show that early visually and tactually based intervention is especially effective. If, however, spoken language skills are best learned in the first three or four years of life, and if certain children are unable to use audition as the primary or even a major input and feedback modality, it follows that alternative modalities must be used, and that they should be used at an early age.

It may be concluded that, in order to optimally benefit from an habilitative program, evaluation of the child's auditory capacity as early as possible is necessary.

Part 3: Methods of assessing or predicting auditory speech perception abilities

How can we assess a young hearing-impaired child's potential for auditory perception? The following reviews the results of the different procedures which are available for predicting auditory speech perception in hearing-impaired children. It will be argued that the methods that are currently used for assessment are of limited validity and beyond the linguistic and/or cognitive capacities of very young hearing-impaired children.

Pure tone sensitivity

The most commonly used predictor of speech perception ability is the pure tone threshold. The relationship between pure tone sensitivity and speech perception ability has been a subject of extensive research, especially with regard to the efficacy of different measures from the pure tone audiogram for predicting speech perception (e.g. Kryter et al., 1962; Harris et al., 1956; Markides, 1980). Studies have shown that there is a strong correlation between pure tone thresholds and speech perception performance. This relationship has been demonstrated for segmental feature perception, phoneme recognition in either open or a closed set and word recognition (Ross & Lerman, 1970; Martony et al., 1972, Risberg, 1976; Smith, 1975; Boothroyd, 1984). The correlation coefficients vary depending on the test material. For simple highly constrained test material like the

Rhyme Test (Martony et al., 1972; Risberg, 1976) or Boothroyd's Speech Pattern Contrast Test (1984) the link between the audiogram and the perception ability is strong and direct. For less tightly constrained test material (e.g., nonsense syllables or monosyllabic words) the link is less strong and it is even poorer for sentences (Levitt, 1982).

An important question to answer is, whether there is an upper limit of hearing loss at which speech perception performance falls to zero. The results of the various research studies show that the answer to this question depends on the way in which speech perception is measured. Boothroyd (1976, 1984), for example, showed that with hearing losses up to 90dB children performed well on his open-set phoneme recognition test. With hearing losses greater than 90dB, the scores were very poor. He suggests that with different material, e.g., a closed set format or highly redundant material, it is possible to demonstrate usable hearing with thresholds greater than 90dB.

Levitt (1982) noticed a high correlation between the audiogram configuration and the pattern of errors, but not with the absolute score. Data collected by Boothroyd (1984) and by Martony et al. (1972) support this finding. The authors showed that the perception of certain features can be predicted to some extent from the degree and the configuration of the hearing loss. With regard to the configuration, with usable residual hearing through 500Hz, a person can perceive temporal patterns and voicing, and with usable hearing through 1000Hz, first formant differences are perceptible. With regard to the degree of hearing loss, Boothroyd (1984) demonstrated that hearing-impaired children obtained better than chance scores for specific features as follows: With hearing loss in excess of 115dB, vowel height was perceptible. With hearing loss up to 115dB, the syllabic pattern of a word was perceptible. With hearing loss up to 105dB, talker's sex was perceptible. With hearing loss up to 100dB, front/back vowel place was perceptible. With hearing loss up to 90dB, initial consonant voicing was perceptible. With hearing loss up to 85dB, initial consonant continuance was perceptible. Finally, with hearing loss up to 75dB, consonant place was perceptible. (These were the dB values at which the probability of correct responses fell to 50%, after correction for guessing).

The correlation coefficients in the studies mentioned above range from a low value of 0.52 to a high value of 0.80 (Boothroyd, 1984). Although the correlations are quite high, there is still a great deal of variance unaccounted for. In other words, pure tone threshold is by no means a perfect predictor of speech perception performance. We can make general predictions about the probability of certain speech features being perceived auditorily. We cannot, however, make absolute predictions for individual children based on the pure tone audiogram (Boothroyd, 1976).

Evidence suggests that it is often possible to predict with reasonable accuracy the performance on various speech perception measures from the pure tone sensitivity for average hearing losses less than 90dB and for those greater than 110dB. The prediction for these losses is possible because children with hearing losses less than 90dB are able to perceive most of the speech features and, therefore, score close to 100%, while children with hearing losses greater than 110dB are not able to perceive most of the speech features and, therefore, score close to zero. Within the range of 91-110dBHL, however, the performance in speech perception varies and therfore is not predicted accurately from the audiological data (Erber, 1974; Cramer & Erber, 1974; Erber & Alencewicz, 1976; Erber, 1980). Erber and his colleagues presented several different types of material (spondees, numbers and a combination of monosyllables, spondees and trochees) to hearing-impaired children. A general correspondence was observed between low scores and pure tone threshold averages (500Hz, 1kHz, 2kHz) greater than 110dBHL and between high scores and audiometric averages better than 90dBHL. The performance of the children within the 91-110dBHL range on the various speech recognition tests could not have been predicted from their pure tone thresholds. The scores within that range varied from chance to a very high value. It is interesting to note that also within the 91-110dB range of hearing loss the scores form a bimodal distribution. That is, the scores are either low or high and relatively few scores are intermediate in level. Furthermore, it has been demonstrated that individuals within the 91-110dBHL range may show almost identical pure tone audiograms with different abilities with regard to speech perception and production (Risberg, 1977; Lynn, 1975; Van tasell, 1978). It is, therefore, argued that speech perception ability should be measured directly rather than being predicted from pure tone thresholds.

Speech perception tests for the severely and profoundly hearing-impaired children

There are many commonly used speech-perception tests for children such as the Word Intelligibility by Picture Identification (WIPI) (Ross & Lerman, 1970) or various simplified monosyllabic word lists (Quick, 1953; Numbers & Hudgins, 1948; Watson, 1957). Unfortunately, these tests are often inappropriate for children with severe and profound hearing losses. Many of the stimulus words are unfamiliar to severely and profoundly hearing-impaired children and therefore introduce a confounding variable which limits the tests' value as diagnostic tools.

Several tests of speech recognition have been developed expressly with severely and profoundly hearing-impaired children in mind. Most have a single purpose, to distinguish children who can perceive only time/intensity cues from those who can also perceive frequency-dependent cues. Erber (1974, 1979a) further claims that these tests differentiate those who possess true hearing from those whose responses are probably vibrotactile.

A Spondee Recognition Test was designed by Erber (1974). Previous research showed that the identification of monosyllabic words can be a difficult auditory task for severely hearing-impaired children and that hearing-impaired children seem to recognize spondees with greater facility than they do one-syllable words (Erber, 1974; Van Uden, 1970). Erber's test consists of a closed set of 25 familiar bisyllabic words, all spoken with equal stress on the two syllables (spondees). The test is intended to measure a child's ability to perceive the spectral differences between spondaic words. During the recording of the stimuli, special time and intensity limits were adopted in order to lessen the probability that a word would be recognized from its envelope pattern. This test was presented to 72 hearing-impaired children ranging in age from 8-16 years. They were familiarized with the words prior to testing. The spondee recognition scores of the children were divided sharply into high (70-100% correct) and low (0-30% correct) groups. The author concluded that the high scores were from children who are able to perceive spectral information, while the low scores were from children who could perceive only time and intensity cues.

A simpler version of the above test, using a closed set of only 10 spondees, that could be responded to by pointing to a picture, was designed by Cramer and Erber (1974). It was intended for use with young severely and profoundly hearing-impaired children (age range 5-9 years). When the test was presented to hearing-impaired children it produced a bimodal distribution of the scores. The authors concluded that the children who achieved scores of 0-65% perceived primarily the time-intensity envelope of speech, whereas the children who received scores ranging from 66-100% made use of spectral information for word recognition.

Erber and Alencewicz (1976) described an auditory perception test whose acronym is CAT (Children's Auditory Test). This test is appropriate for children over the age of five. Stimulus items are 12 picture cards depicting four familiar nouns in each of three stress categories: monosyllabic, trochaic, spondaic. Each stimulus is presented twice in a random order, and the child's pointing responses are recorded. Scores of word recognition and word categorization by stress pattern are calculated. Thus, even if the child cannot understand the words, his ability to perceive stress patterns can be evaluated. Data collected by the authors indicated that word recognition scores were bimodally distributed. Children whose word recognition performance was generally poor demonstrated large differences in word categorization ability. The authors believed that the differences in ability to perceive the stress patterns of words may reflect basic differences in function of the sensory mechanism or differences in the amount of previous pattern perception practice in the classroom.

The Auditory Numbers Test (ANT) (Erber, 1980) is another spectral/pattern perception test that may be useful in making diagnostic decisions. Whereas the tests described above require that the child possess a vocabulary of moderate size, the ANT requires only that the child be able to count to five and be able to apply these number labels to sets of from 1-5 items. It can, therefore, be used with young hearing-impaired children providing they have appropriate number concepts. Stimulus materials consist of five cards each having a number from 1-5 and a picture of the corresponding number of ants. The child has to be familiarized with the procedure before the actual test. At the test, the examiner presents a single number from one to five. It is expected, that children who can correctly recognize the spectral quality of the isolated stimulus will point to the appropriate card. It is also possible that a child may think that he perceives another number and will point to an alternate card. In contrast, those children who can perceive only the gross temporal pattern of the stimulus (that is, one beat) will nearly always point to the number 1 card when a single number is presented. One point is given for each correct response resulting in the possibility of a score from 1-5. The scores obtained from 39 children 3-8 years of age were bimodally distributed. This indicated, according to the author, that the test groups the sample of children with regard to minimal speech perception abilities. Erber suggests that a high score on this test implies that the child is capable of perceiving at least some of the spectral qualities of words. The author adds, however, that a low score should be interpreted with caution. It may indicate that the child simply did not understand the test instructions, did not have sufficient previous auditory experience, was not paying attention, or was listening at an inappropriately low acoustic level during testing. Erber concludes that careful observation and repeated testing with the ANT and other speech materials is required before final classification.

A short speech perception test for severely and profoundly deaf children was developed by Marklein (1981). This test is similar in concept to the tests described above but, in addition to distinguishing between those who can perceive spectral information and those who cannot, it is designed to identify the frequency regions within which the former group possesses significant speech perception ability. The test is designed to assess the recognition of words that differ predominantly with respect to one speech feature. Stimulus items are represented pictorially with two response alternatives for each speech feature. The following features are included in the test:
(1) time pattern, (2) duration, (3) intensity, (4) fundamental frequency, (5) first formant, (6) second formant, (7) nasality, (8) voicing, (9) manner and (10) place. Test items are presented randomly seven times in order to avoid chance correct responses. Marklein administered the test to 128 severely and profoundly hearing-impaired children 4-19 years of age. Based on their test performance they were clustered into 3 groups. In the first group were those who scored high on test items differing on the basis of speech envelope cues (first 3 features) but could not reliably identify items which differ on the basis of spectral cues. Marklein described them as "vibrotactile" since most of them had thresholds falling in, or near the region in the

audiogram that may suggest vibrotactile response. The other two groups were described as "auditory". These children were able to identify test items requiring perception of speech-envelope cues and also those differing on a spectral basis. While some perceived only low frequency spectral cues (e.g. first formant and low frequency consonant cues), the others perceived most or all of the acoustic features including the higher frequency cues. There is, however, a serious disadvantage to this test. Only one stimulus item is provided for each feature of interest. It is difficult to make assumptions and recommendations based on this limited information. The child can make a decision based on secondary cues when he cannot actually perceive the primary ones. For example: The words dog and dig were chosen as words that differ with respect to acoustic power. Although the words may differ in intensity, they could also be said to differ with respect to duration and vowel.

Plant (1984), has also attempted to obtain more detailed information on the individual child's auditory speech perception abilities. His PLOTT test consists of nine subtests which range from the detection of individual phonemes to the discrimination of consonant place of articulation. In addition to his ability to indicate those children who are able to perceive spectral information, the test can determine the child's ability to perceive specific vowel and consonantal features of increasing difficulty. As in Marklein's test, however, the number of alternatives in each subtest is limited and the same words, presented five times in a random order, are used in each subtest.

This presents a disadvantage, because it may be possible to perceive an item based on secondary cues.

In addition to the above, other tests that search for more specific information have been developed. These tests include The Phoneme Recognition Test (Smith, 1975), The Modified Rhyme Test (Pickett et al., 1972), The Diagnostic Rhyme Test (Risberg, 1976; Martony et al., 1972) and The Speech Pattern Contrast Test (Boothroyd, 1984). All of these tests are designed to evaluate the specific features which can be perceived by the severely and profoundly hearing impaired. These include vowel features such as tongue height and advancement and consonant features such as manner, voicing and place. Most of the existing tests contain natural-speech stimuli, but some make use of synthetic speech stimuli (Fourcin, 1976). There are also tests, which have been developed to investigate the perception of the suprasegmental features: pause, stress, and intonation (Stark and Levitt, 1974; Mc Garr, 1976; Gold, 1978).

Most of the above tests are only suitable for children in the age range of 8-15 years of age, since they require reading skills. Only a couple of the tests, for example, the ANT or the simplified version of the Spondee Recognition Test, which make use of numbers or pictures, can be used with children as young as five years old. Still, all of these tests, require a certain vocabulary level which exceeds the vocabulary of many young children with congenital hearing loss.

In addition, one must be cautious in interpreting the results obtained on these speech perception tests, since there may be confounding effects of auditory capabilities and training. The child's performance on a test might not be a true reflection of his or her capacity and the performance may improve significantly with appropriate training and practice.

Other measures used for predicting speech perception ability among the severely and profoundly hearing impaired

Since the speech and language of the young hearing-impaired child are very limited, tests that evaluate the child's difference limen for frequency have been suggested. (Martony, 1974; Risberg et al., 1975). Measurements on severely and profoundly hearing-impaired children show that frequency discrimination ability varies considerably for subjects with the same degree of hearing loss, but that there is a significant correlation between frequency discrimination ability and speech perception ability (Di Carlo, 1962; Risberg et al., 1975). Frequency discrimination can, therefore, be used to evaluate the quality of a small amount of residual hearing.

Martony (1974) used pairs of synthetic vowels with the same or different first formant frequency. The first formant of one stimulus varied between 3% and 42% of the frequency of the first formant of the paired stimulus. Subjects were 16 profoundly hearing-impaired children (hearing losses varied between 91-117dB), aged 10-15. They were asked to decide whether the stimuli in the pairs were the same or different. A difference limen for frequency was obtained for each subject. The test showed a clear difference in discrimination ability between subjects with hearing loss less than 95dB and greater than 100-105dB. The difference limen for the first group was only slightly higher than normal, which indicates residual hearing with acceptable discrimination ability. Subjects with hearing losses greater than 100-105dB showed high DF1/F1, which indicates no residual hearing or severe perceptual disabilities. For subjects in between these two groups, there was a large variation in DF1/F1. While some had rather acceptable discrimination ability, others showed very poor or even no discrimination. The author states, though, that this test's practical value is limited since it requires a long training time, especially for the younger subjects.

Risberg et al. (1975) and Risberg and Agelfors (1978) also collected data on the ability of severely and profoundly hearing-impaired children to discriminate frequencies. They used pairs of sinusoidal signals in the first study and pairs of pulse trains in the second. Initially, the frequency of one stimulus differed from the frequency of its paired stimulus by 50%, and this difference was gradually reduced. The children had to judge if a pair of stimuli was the same or different. The results of the first study show large variations in the frequency discrimination ability for the same degree of hearing loss. For frequencies below 1kHz the authors noticed that it was possible to divide the audiogram area into 3 sections: normal frequency discrimination, large individual variations, and the cases whose values are about the same as those obtained from normal-hearing subjects who received the stimuli in the palm of the hand. In this study the intensity differences were not balanced, therefore, it is possible that subjects responded to a combination of frequency and intensity cues. Results from the second study showed that normal-hearing subjects could detect a repetition frequency difference of 2-3% in the pulse trains. Among 14 profoundly deaf subjects, however, only three could detect frequency differences of 7%. The others needed a frequency difference of 10-40% to give a reliable answer.

Thus, a few attempts have been made to use tasks which do not require speech recognition in order to distinguish between those who can perceive frequency information and those who cannot. These measures, however, have disadvantages. First, it is likely that more speech-like signals can give better information about the usefulness of a small amount of residual hearing. Second, like the speech tests, they do not suit young hearing-impaired children.

The above experiments report results from hearing-impaired children only from the age of ten years (Risberg et al., 1975). Even within the age range of 10-15 years, a developmental pattern was observed (Martony, 1974). It seems then, that for younger children a measure of difference limen will not be suitable. In fact, studies have shown that a discrimination task, which requires a quality judgment (same/different, higher/lower, louder/softer) should not be administered to children younger than 5 or 6 . According to the literature, the tasks which involve quality judgments cannot be performed by young children (Piaget, 1968; Carter et al., 1972; Bangs, 1975). Repina (1961) indicates that children 5 years of age often have difficulty in conceptual tasks concerned with comparisons. This is particularly true for children who are asked to compare stimuli such as pure tones. The author shows, that a child who can indicate whether a musical sound is high or low, may find it very difficult to indicate whether the second of the two tones was higher or lower in pitch than the first one.

In spite of the considerable research effort that has been invested in the evaluation of auditory capacity in the severely and profoundly hearing impaired, and in the development of diagnostic and prescriptive tests, the problem of evaluation in very young children has not been solved. Pure tone threshold has been shown to be an imperfect predictor. Verbal tests are obviously inappropriate for pre-verbal children, and traditional psychophysical procedures place excessive demands on the cognitive abilities of pre-school children. There is a clear need for a novel approach to auditory testing in this population.

Part 4: Imitation of intonation

The following section will review research whose findings suggest that a task which requires imitation of intonation may be used as an early indicator of the hearing-impaired child's auditory ability.

Normal development of intonation: production and perception

The speech sound system of a language can be thought of as consisting of three components: segmental features, suprasegmental features and rules for the combination of features (Menyuk, 1972). Suprasegmental features are "a set of features consisting of pitch, stress and quantity whose domain extends over more than one segment" (Lehiste, 1970). The present research concerns intonation, that is, the patterns of change in fundamental frequency over time.

Intonation is one of the first aspects of speech that the normal child learns to produce. As Lewis (1951) states:

> "The first meaningful element of speech behavior that can be observed in children actually occurs much earlier than from 1 to 2 years of age. In the very first months of life during the babbling state and indeed during the very first minutes of life children employ meaningful intonational signals. The cries are at first meaningful only in that they have a physiological reference. We believe that these signals which appear to be innately determined, provide the basis for the linguistic function of intonation in adult speech."

Other researchers have also noted the presence of appropriate intonation patterns in the speech of many babies born into a variety of linguistic communities (Nakazema, 1962; Weir, 1966).

Data collected in Russia also reveal that speech development in children begins with the development of intonation (Tonkova-Yampol'skaya, 1973). In this Russian study, which offers more evidence on the development of intonation, 170 infants and children up to two years were studied. Their intonations were recorded and analyzed. The author claims that a definite intonational pattern is observable even in the cry of a newborn infant, although it is devoid of linguistic meaning. After acquiring a communicative value, this intonational pattern becomes fixed as an intonation of discomfort. In contact with adults, a child acquires new forms of intonations. Intonations of "placid cooing" appear from the second month and intonations of happiness appear in the third month. During the sixth month, the happiness intonation is differentiated into happy exclamations and contented noises. From the seventh month an intonation of request appears. At the beginning of the second year the intonation of interrogation is added. The communicative content of these intonations is adequately perceived by adults. Thus, it seems that the children acquire adult-like intonation patterns before the appearance of true lexical items (Kaplan & Kaplan, 1971). Furthermore, their first words may be defined suprasegmentally rather than segmentally (Engel, 1973).

It has also been argued that children perceive intonation patterns before they understand other aspects of language (Lewis, 1951). Schafer (1922 cited in Lieberman, 1967) reported on a nine-month old child who responded to the intonation of a phrase and not to the words. At ten months of age the child responded to the words and not to the intonation. Lewis (1951) noted 3 stages in the development of language: (1) the child discriminates between different patterns of intonation, (2) when the total pattern - the phonetic form and the intonational form - is made effective by training - at first the intonational rather than the phonetic form dominates the child's response, (3) the phonetic pattern becomes the dominant feature though the influence of the intonational pattern does not vanish.

The above and other informal observations are complemented by some more systematic investigations of the child's responses to intonation in the prelinguistic period. In one experimental study (Kaplan, 1969), babies of 4 and 8 months old were presented with patterns varying in direction of pitch change alone (unstressed condition) and patterns varying in both stress and direction of pitch change (stressed condition). The patterns were superimposed on the sentence: "see the cat". Using an habituation-dishabituation paradigm Kaplan showed that 8 month old babies were able to distinguish between the rising and falling contours which included stress. However, they failed to distinguish between rising and falling contours in the unstressed condition. The 4 month old babies did not discriminate either of the two versions. Kaplan concludes that the ability to discriminate between stressed rising and falling intonation contours appears somewhere between 4-8 months. Unfortunately, the study does not include information on the time that the discrimination of unstressed patterns appears. A study by Morse (1972), however, demonstrated that infants were able to discriminate intonation patterns by 40-54 days old. By employing a sucking technique Morse showed that the infants were able to discriminate synthetic syllables /ba/ with rising and falling intonation. These syllables differed only in the terminal fundamental frequency contour. The author claims that already in early infancy the child can detect changes in fundamental frequency, when he/she is presented with a speech signal.

In summary, the data discussed in this section suggest that the normal young baby is able to perceive and produce various intonation contours at a very early stage in language development. In fact, many researchers believe that this aspect of language is the first one to be acquired.

Perception of intonation by hearing-impaired subjects

The above section discussed literature dealing with normal development of intonation. The following one will concentrate on the perception of intonation by hearing-impaired subjects.

Several studies have shown that intonation can be perceived by some hearing-impaired individuals with hearing losses greater than 90dB (Boothroyd, 1978; Engen et al., 1983). Engen et al. (1983) show, in fact, that even hearing-impaired children who can only hear the lowest frequencies at high intensities were able to perceive differences in intonation. In their study 8-16 year old children were presented with pairs of stimuli which were either the same or different. The stimuli consisted of declarative and interrogative intonation contours, which accompanied a sentence of 3 monosyllabic words. All frequencies above 510Hz were eliminated with a low-pass filter which effectively preserved the intonation contours and speech-like quality but made the words unintelligible. Additionally, this study investigated the childrens' ability to identify contours by categorizing them as declarative, interrogative, imperative or conditional. The results indicated that hearing-impaired children can perceive differences in sentence types using prosodic information. While the declarative and the interrogative contours were easily categorized, the conditional was confused with the declarative. The authors believe that this confusion is caused by similar acoustic cues of these two stimuli.

On the other hand, the hearing-impaired subjects of Stark and Levitt (1974), McGarr (1976), and Gold (1978) all performed poorly on the prosodic feature reception test, especially for items that required perception of intonation. Stark and Levitt (1974) attributed these results to the lack of emphasis in training programs on the suprasegmental aspects.

The above studies investigated the perception of intonation using speech stimuli and therefore did not distinguish the acoustic cues of time, intensity and frequency, that contributed to the perception of intonation. Other studies investigated the perception of the fundamental frequency only in non-speech stimuli. Marklein (1981) demonstrated that children with residual hearing were able to perceive the feature of fundamental frequency even when their hearing was limited to the low frequency region. Marklein's subjects had to distinguish between pure tones, which were presented at the same sensation level and differed by one octave. The pure tones selected were 125Hz and 250Hz, which fall within the fundamental frequency range for adults and children. Also they span the limits of pitch shift (8-12 half tones) which characterize normal intonation. The stimuli in this test, however, are not speech stimuli. Since the purpose of the test is to evaluate the child's speech perception abilities use of nonspeech material presents a great disadvantage.

Based on findings that show that an emphasis in a sentence is primarily signalled by a change in the fundamental frequency (Carlson et al., 1974), Risberg and Agelfors (1978) hypothesized that severely hearing-impaired subjects, who have access to frequency information, will be able to identify emphasized words in sentences. In contrast, the authors further hypothesized that some profoundly hearing-impaired subjects may not be able to perform this task because they cannot detect the intonation in the acoustic signal. The researchers presented three-word sentences with the emphasis on the first, second or third word to hearing-impaired young adults. The test was given in three modes: as a visual test with only speechreading, as an auditory test, and as an audiovisual test. The results indicated that high scores were obtained by some subjects with mean hearing losses of 92dB. Very different scores were obtained by subjects with almost identical audiograms. The ability to detect frequency changes in the signal could not have been predicted from the pure-tone audiogram. A significant correlation was found between the results on the emphasis test and the degree of hearing loss at 125Hz, but not for any other frequency or combination of frequencies. The authors suggest that this test can be improved by use of synthetic speech stimuli.

Thus, there is evidence to suggest that severely and some profoundly hearing-impaired subjects are able to perceive the variations in the fundamental frequency. Therefore, it seems that many would be able to recognize various intonation contours once they are exposed to an appropriate training program.

Vibrotactile frequency discrimination

As previously discussed, some profoundly deaf children show perceptual difficulty both for low frequency periodicity (as in the voice fundamental) and for higher frequency spectral change (as in vowel formants) (Erber, 1979b). Marklein (1981) showed that the fundamental frequency was not perceived by some of his profoundly hearing impaired, whom he classified as the vibrotactile group. These children were able to perceive only the time and intensity cues. They scored very low on the perception of the fundamental frequency. Only the children in the auditory group were able to perceive the fundamental frequency. Also, Risberg and Agelfors (1974) hypothesized that poor results were obtained by their profoundly hearing-impaired children in an audiovisual situation because they could not detect the intonation in the acoustic signal. As mentioned before, a few researchers attribute this inability to the fact that some profoundly deaf do not possess true hearing, and they are actually "feelers" (Nober, 1970; Ericson & Risberg, 1977; Erber, 1979b). Since the skin demonstrates poor frequency resolution within the normal range of speech (Rothenberg et al., 1977), information on intonation is not available to them.

In a few systematic studies of vibrotactile frequency discrimination, estimates reported for the difference limen (DL) have varied from 30% of the reference frequency (Goff, 1967) to about 3% (Franzen and Nordmark, 1975). The variations are accounted for in terms of different vibration sites, the waveform used and the experimental procedure. The DL of frequency of a sinusoidal vibrotactile stimulus at the fingertip was found to be large using two stimulus forced-choice procedure (Goff, 1967). Within the frequency range where the skin is most sensitive 200-400Hz (Verillo, 1963) Goff found the difference limen to be over 100Hz. At lower frequencies the limen was as low as 5Hz.

Rothenberg et al. (1977) believed that Goff's estimate of the frequency discrimination ability of the skin is overly pessimistic. On the other hand, Franzen and Nordmark's (1975) findings are not a true reflection of tactile sensitivity because they used a nonstandard method. Rothenberg et al. hypothesized that the fundamental frequency of voicing is suited for encoding into vibrotactile frequency since the range in normal speech, roughly 70-500 Hz, overlaps the frequency range of tactile sensitivity. They measured the ability of subjects to make frequency discriminations with vibrotactile stimuli using two different methods: (1) A constant frequency method where the subjects compared 2 vibratory bursts of different frequencies. The frequency was held constant during each burst, (2) Warble tone method - where the subjects compared a burst of constant frequency with a warbled frequency. They believed that the second method is a more valid estimate of the discrimination potential because the stimulus frequency is presented in a manner much closer to the way it would be presented when encoding the typical variations in a speech-derived parameter (such as fundamental frequency during voiced speech). Their findings showed that below 100Hz the warble-tone measurements were consistent with Goff's measurements and the constant- frequency results. Above 100Hz, the warble-tone method yielded a smaller DL than the constant frequency method. Based on their findings they concluded that the vibrotactile frequency range of 15-90Hz was the most sensitive one. Within this range they estimated at least seven potentially differentiable steps in frequency on the forearm and perhaps ten on the finger. This discriminability indicates that vibrotactile frequency could be used to encode fundamental frequency. In order to take advantage of it, however, the normal fundamental frequency range (e.g. 70-500Hz) for each individual would have to be transposed in some way to that range. In addition, it is expected that fundamental frequency variations in a more complex periodic-waveform may be less discriminable than for the simple waveforms tested in this study. The skin is not expected to have the ability of the ear to extract the periodicity of complex waveforms.

Researchers who have examined tactile perception by normal-hearing and profoundly deaf subjects using a vibrotactile aid have shown that the use of the aid is successful in cases where time/intensity cues provide sufficient information to enable identification (Plant, 1982; Hawes, 1978). For tasks that require frequency information the aid does not prove to be useful. Plant (1982) tested 4 profoundly deaf young adults with acquired hearing loss. All were experienced vibrotactile aid users. He evaluated their performance in: (1) lipreading with and without the vibrotactile supplement, (2) detection of prosodic features, (3) detection of segmental features and

(4) discrimination of common environmental sounds. He noted that the subjects scored best on tasks such as the identification of word and sentence patterns, syllable number in sentences and vowel duration. Conversely, on tasks such as word recognition and identification of consonants where time/intensity patterns are not sufficient cues for identification, the subjects scored relatively poorly. Hawes (1978) investigated the ability of subjects to perceive, tactually, changes in meanings of sentences cued by modification of intonation and stress patterns. Ten normal-hearing young adults were presented with sentences in a closed set. For the stress task the sentences varied in place of stress: initial, medial or final. For the intonation task they varied with respect to rising, steady or falling contours. Results showed that subjects perceived stress patterns at better than chance level ($p < .01$ level of significance). However, responses for intonation were no better than guessing and yielded insignificant results.

Thus, there is evidence suggesting that the vibrotactile system of man is quite sensitive to time and intensity variations in acoustic stimuli, but is relatively insensitive to frequency differences. Consequently, profoundly hearing-impaired individuals, who are denied frequency information auditorily, are unlikely to be able to detect pitch changes in the acoustic speech signal through the sense of touch.

Imitation

As previously discussed, the choice of response task when measuring auditory capacity is as important as the choice of material. This is especially true when young populations, with limited knowledge of language and limited cognitive abilities, are considered. While standard procedures for the evaluation of speech perception abilities involve tasks which rely on high cognitive capability, imitation, especially of intonational contours seems to be a simple basic task, which is learned early (Lewis, 1951). It can be accomplished by the hearing impaired and based on evidence from reasearch on the link between perception and production, it may be a suitable way to evaluate the speech perception capability by the young preverbal hearing-impaired child.

Kessen et al. (1979) have demonstrated that babies between three and six months are able to imitate pitches. The babies were presented with two or three sung tones (D, F, and A above middle C), and responded by vocalizing on the presented pitch significantly often. Lewis (1951 cited in Lieberman, 1967) has shown that mimicry of the average fundamental frequency range occurs at a very early age. A ten-month old boy and 13-month old girl were recorded under different conditions: babbling alone and in the presence of the mother or father. The average fundamental frequency of the child's babbling under these conditions was measured. It was found to be different under the different conditions. For example: the boy's average fundamental frequency was 340Hz in the presence of the father and 390Hz in the presence of the mother. Both of these fundamental frequencies were lower than that of his solitary babbling or crying. Thus, imitation appears early in normal development of speech.

Koike and Asp (1981) developed a test for young children, which requires imitation of a nonsense syllable with different suprasegmental patterns similar to those found in speech. Thus, it does not require the child to have an extensive vocabulary. The test is identified as the Tennessee Test of Rhyme and Intonation Patterns (T-TRIP). It includes rhythmical and intonational patterns. The T-TRIP was presented to three and five-year old normal-hearing children. Although the results showed better performance for the older children, the young group was also able to perform the task. Analysis of the individual test items, showed that some test items were more difficult than others. Among the intonation patterns, the rising or falling contours were easier to imitate than the combination of a fall and rise in one pattern. The combination of rising and falling contours was easier to imitate than the combination of falling-rising contours. This was true for both groups of children.

Hearing-impaired individuals often show difficulties in producing various intonation contours (Stark and Levitt, 1974; Smith, 1975). Studies concerned with the production of fundamental frequency variations by the hearing impaired have found that severely and profoundly hearing-impaired children used a restricted range of fundamental frequency as compared to normal-hearing speakers (Green, 1956). Hood and Dixon (1969) found that severely and profoundly hearing-impaired subjects, on the average, used about 2/3 as much variation in the fundamental frequency as the normal subjects. The correlation between the amount of variation and the rhythm ratings of the hearing-impaired subjects was very low. Inspection of the patterns of the fundamental frequency changes suggested that the hearing-impaired subjects' intonation patterns had the same configuration as the normal subjects' patterns. Thus, although the variations were restricted, they were in the appropriate direction. It appears that as long as the intonation is in the appropriate direction judgments of speech rhythm are not severely affected. V. Williams (1978) presented the T-TRIP, which requires imitation of intonation contours, to 3-9 year old hearing-impaired and normal-hearing children. Although the hearing-impaired children scored significantly lower, they still performed well on the test. These children were involved in a verbo-tonal training program which emphasized suprasegmental skills. Like the normal-hearing children, the hearing-impaired scored better on a rising to falling than on a falling to rising contour. In addition, this author showed high correlation between age and T-TRIP scores for the normal-hearing children but a very low one for the hearing-impaired children. Low correlations were also found for T-TRIP and the degree of hearing loss and for T-TRIP and the length of time in therapy. It is important to note that the hearing loss of the children in this study was not greater than 95dB (in the better ear) and that most children had even better hearing than that.

As one should expect, the hearing-impaired child's auditory speech perception and speech production skills are interrelated (Erber, 1974; Smith, 1975; Novelli-Olmstead & Ling, 1984). As Montgomery (1967) states:

> "Given the absence of significant defect in the speech organs of the majority of the profoundly deaf, their dependence upon suitably amplified residual hearing for speech development, the continual auditory training in relation to speech development, and the constant use of powerful amplification devices in school rooms, speech production is an operational criterion more important in its own right, in some ways, than speech reception. To a great extent, the profoundly deaf speaker is able to imitate what is heard and, thus, speech production is a good guide to speech reception - not only immediate reception, but also reception of steady input over a longer period." (p. 55).

Thus, a problem in auditory speech perception may be reflected in the child's speech production.

Finally, observations of several individuals with a great deal of clinical experience indicate that those children who at an early age show the ability to imitate intonation contours, later demonstrate good skills with regard to speech perception and production (Boothroyd, 1982).

The above review of the literature suggests that a test of the perception of intonation contours may provide useful information about the auditory perceptual abilities of the young hearing-impaired child. The acquisition of intonation by normal-hearing children occurs early in the development of speech. Therefore, it might well be an adequate speech stimulus for subjects who have, at best, a minimal knowledge of speech and language. Since intonation is a component of the speech signal, the measure of its perception should correlate better than pure tone stimuli with the perception of speech. The perception of intonation is possible by severely and some profoundly hearing-impaired children. However, for some profoundly hearing-impaired children who rely mainly on the time and intensity cues in the speech signals, these pitch variations are not accessible. These children are believed to be "feelers." Since the tactile sense is not sensitive enough to perceive pitch variations well, it is assumed that these profoundly-deaf children will not be able to perceive intonation contours. Consequently, intonation contours may prove to be appropriate stimuli for distinguishing the hearing impaired who can perceive spectral information from those who cannot.

The use of imitation of intonation which involves perception and production offers an appropriate task for young hearing-impaired children. It is a basic task which can be accomplished at an early age. Hearing-impaired children are capable of imitating intonation contours, and it may prove valid to estimate perceptual abilities from the child's performance on this task.

The T-TRIP which was previously described has been used already on several different types of subjects: normal-hearing and hearing-impaired children and children with articulation problems and normal and apraxic-speaking adults (Koike and Asp, 1981; Shadden et al., 1980; D. Williams, 1978; V. Williams, 1978). The results of these studies suggest that this test is sensitive to differences among groups of subjects of different ages as well as speech proficiencies. However, the T-TRIP was not used to differentiate children who can perceive frequency information from those who perceive only time and intensity cues. V. Williams (1978) presented the test to hearing-impaired children, but her subjects had hearing losses of no greater than 96dB. In addition, only two of her subjects were younger than four years old. These two young children had severe hearing losses (their average hearing losses were 63dB and 75dB). Thus, the test was not administered to young profoundly hearing-impaired children. Finally, natural speech stimuli were used in the T-TRIP, and therefore the intensity, time, and frequency components were not controlled.

The purpose of the present study is to investigate the possibility of evaluating the auditory perception of speech by the very young preverbal hearing-impaired child through the use of imitation of intonation contours.

CHAPTER III

Method

Outline

The following study consists of two parts. In the first part data were collected from normal-hearing and hearing-impaired children of two age groups. The children were presented with synthetic stimuli which were various intonation contours superimposed on nonsense syllables. The stimuli were presented through two tasks. The first will be referred to as the imitation task. This task required imitation of the stimulus models, and it involved perception and production of speech. The second will be referred to as the forced-choice task. This task involved perception and selection from three response alternatives. While the performances of the children on the forced-choice task were scored directly by the examiner, the imitations of the children were used as stimuli for the second part of the study.

In the second part of the study, the children's imitations were paired with their respective models and used as stimuli for five experienced listeners. The listeners evaluated the accuracy of the children's imitations on a ten-point scale. These judgments were analyzed and also compared with the results of the children on the forced-choice task.

You will recall that the major purpose of this study was to investigate whether the child's ability to imitate intonation contours can be used as means of assessing the child's auditory ability to perceive frequency-dependent cues. The following were the reasons for the choice of subjects, tasks and stimuli:
Since imitation is a simple task, it was hypothesized that both young and older children would perform successfully on this task. In contrast, it was hypothesized that the forced-choice task would be appropriate for the older children but not for the young ones. The forced-choice task, however, was important in order to validate the imitation task as a perceptual task.

Normal-hearing children of the same age groups, who served as a control group, were also presented with the tasks. It was hypothesized that like the young hearing-impaired children, the young normal-hearing children would show difficulties on the forced-choice task, because of their limited cognitive ability.

Since intonation is a speech feature, it was believed that using intonation contours as stimuli would be more appropriate than using pure tone stimuli in assessing a child's ability to perceive speech. It was hypothesized that the use of imitation of intonation contours would yield additional information to the pure tone thresholds.

Finally, the use of synthetic speech allowed the experimenter to vary the frequency while keeping intensity and duration constant, making it possible to differentiate children who perceive frequency information in addition to time and intensity cues from those who perceive only time and intensity cues.

The following were the specific hypotheses:

1. That the hearing-impaired children's ability to imitate intonation contours will not be affected by their age.
2. That the hearing-impaired children's ability to imitate intonation contours will be affected by their hearing loss.
3. That within each hearing-status group, performance on the forced-choice test will be better in the older children than in the younger children.
4. That the hearing-impaired children's ability to discriminate intonation contours via the forced-choice task will be affected by their hearing loss.
5. That within the older children, the imitation and the forced-choice performances will be correlated independently of hearing loss, i.e. those children who will imitate well will perform well on the forced-choice task.

Part I: Collection of children's imitations

Subjects

A total of 40 children served as subjects for this study. The children varied in their hearing status and their age and were grouped accordingly.

There were three hearing status groups:

1. normal-hearing. Subjects in this group consisted of children having air conduction thresholds no higher than 15dB re audiometric zero (ANSI 1969) in either ear, at octave frequencies between 250Hz and 8000Hz.
2. Severe hearing loss. Subjects in this group consisted of children with pure tone averages (500Hz, 1KHz, 2KHz) in the range of 60-90dB, in the better ear.
3. Profound hearing loss. Subjects in this group consisted of children with pure-tone averages of 91dB or higher in the better ear.

Within each hearing status group, the children were divided into two age groups: young and old.

1. The "young" group consisted of children of 3.0 to 4.16 years old.
2. The "old" group consisted of children of 5.0 to 10.25 years old.

The choice of these particular age groups was based on the results of a pilot study (see Appendix D). There was no statistically significant difference between the two age groups with respect to their hearing loss ($\underline{t}(28) = .46$, $p > .05$).

Table 3.1: Distribution of subjects
by age and hearing status.

Hearing status	Young	Old	Totals
normal	5	5	10
severe	5	10	15
profound	5	10	15
Totals	15	25	40

The distribution of subjects by age and hearing status is shown in table 3.1

The 10 normal-hearing children served as a control group. These children were enrolled in public and private school programs in New York City. They were all in age-appropriate grades in school and they had no apparent physical or psychological anomaly which might have interfered with the normal development of speech and language.

All 30 of the hearing-impaired children had a congenital sensorineural hearing loss with no other known major handicapping condition. They were all fitted with personal hearing aids. The hearing-impaired subjects were recruited from 4 places: The New York League for the Hard of Hearing, St. Joseph's School for the Deaf, Lexington School for the Deaf and a private practice. Descriptive background and audiological data for each of the subjects appear in Appendices A-1, A-2.

Stimulus materials

Synthetic speech stimuli were prepared using a Syn program available on the Haskins Laboratories VAX 11/780. This program generates speech from a set of parameter values that are specified by the user. Syn computes the PCM (pulse-code modulated) waveform for an utterance from these parameters, i.e., it is a software synthesizer. Syn supports two varieties of synthesis, serial and parallel. The stimuli in the present study were created through the use of serial synthesis. They consisted of 3 different intonation contours: a flat, a rising and a falling contour. Each of the 3 contours was superimposed on one and two syllables in two phonetic contexts, the vowel /a/ and the dipthong /oʊ/.

Thus, there was a total of 12 different stimuli (3 contours x 2 syllable number types x 2 phonetic contexts). Nonsense syllables were chosen as the experimental stimuli because these materials would not be influenced by the knowledge of the language e.g. vocabulary. Therefore, they would be less subject to age effects and would minimize possible cognitive effects.

The use of synthetic materials allowed the experimenter to control the parameter values of duration, intensity and fundamental frequency independently. Duration and intensity were kept constant for the different stimuli, but fundamental frequency contours were varied. By controlling the parameters of duration and intensity it was made less likely that subjects would learn to identify specific intonation contours on the basis of cues other than the variation of fundamental frequency.

With respect to fundamental frequency, a low average fundamental frequency of 100Hz was chosen, as representative of the fundamental frequency of a male adult. This frequency offers a wide bandwidth and the harmonics are closely spaced.
For the flat contour the fundamental frequency was kept constant at 100Hz.
The rising contour started at 80Hz and rose to 200Hz.
The falling contour started at 160Hz, rose to 200Hz and then

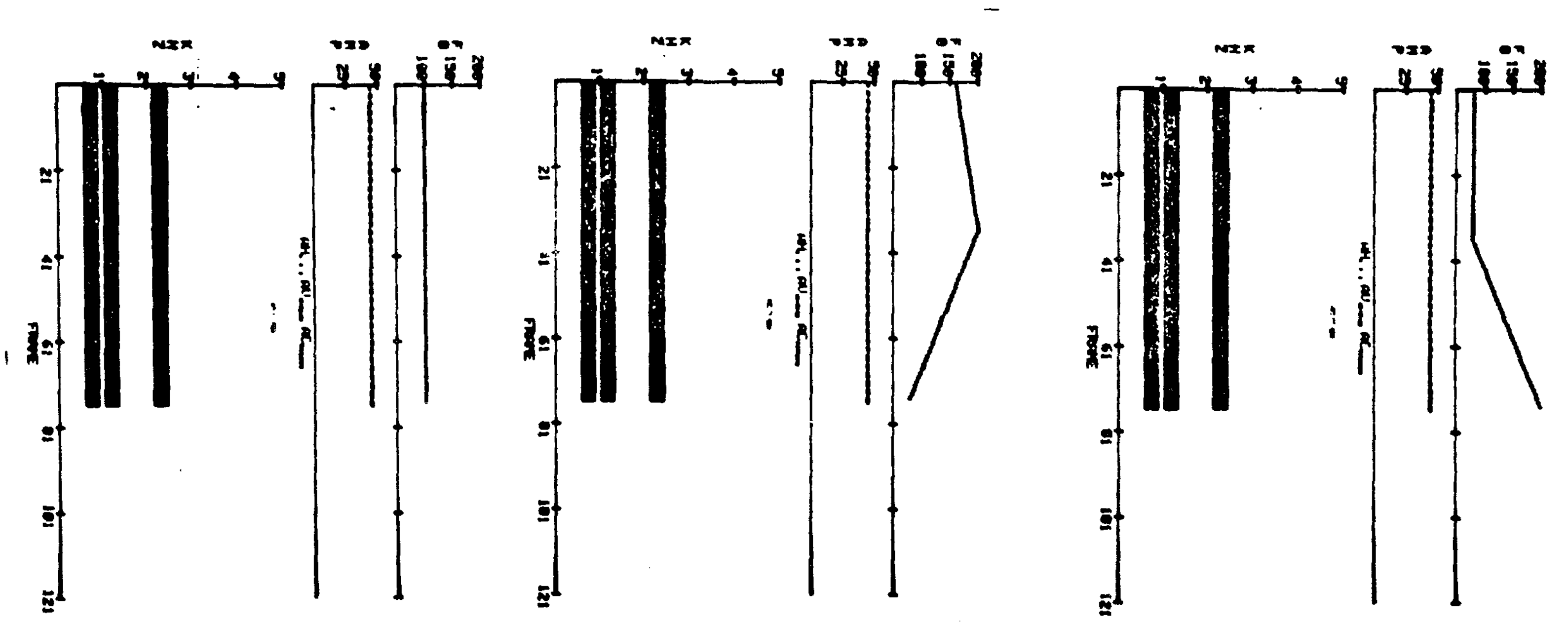
dropped to 80Hz.

For the two-syllable stimuli, the first syllable had a flat contour (100Hz) and the second syllable had either a flat, a rising or a falling contour according to the above specifications.

The duration of all one-syllable stimuli was 750 msec. The duration of all 2-syllable stimuli was 1000 msec. (200 msec. for the first syllable, and 600 msec. for the 2nd syllable with an intersyllable interval of 200 msec.)

Intensity was identical (±1.5dB) for all stimuli. Initially, because of the constraints of the synthesis program the vowel /a/ was more intense than the dipthong /oʊ/. However, the intensity was then adjusted by monitoring the V.U meter so that the output intensity of any item would not vary from the mean by more than ±1.5dB. The intensity of all stimuli was double checked using an amplitude envelope extractor program with the supporting software, available on the CUNY Laboratory's Apple computer. Diagrams of the 12 synthetic models are shown in figures 3.1 to 3.4.

Two sets of stimulus tapes were prepared. One tape contained the stimuli for the imitation task in which subjects were asked to imitate each contour. The other contained the stimuli for a forced-choice task in which subjects were asked to identify the "odd man out" in three consecutive contours. For the imitation task three different randomized lists were prepared. In each of them each stimulus appeared twice,



Flat

Fall

Rise

Figure 3.1: Fundamental frequency (Hz), amplitude (dB) and formant frequencies as a function of time (1 frame=10 msec.) for three single-syllable vowel /a/.

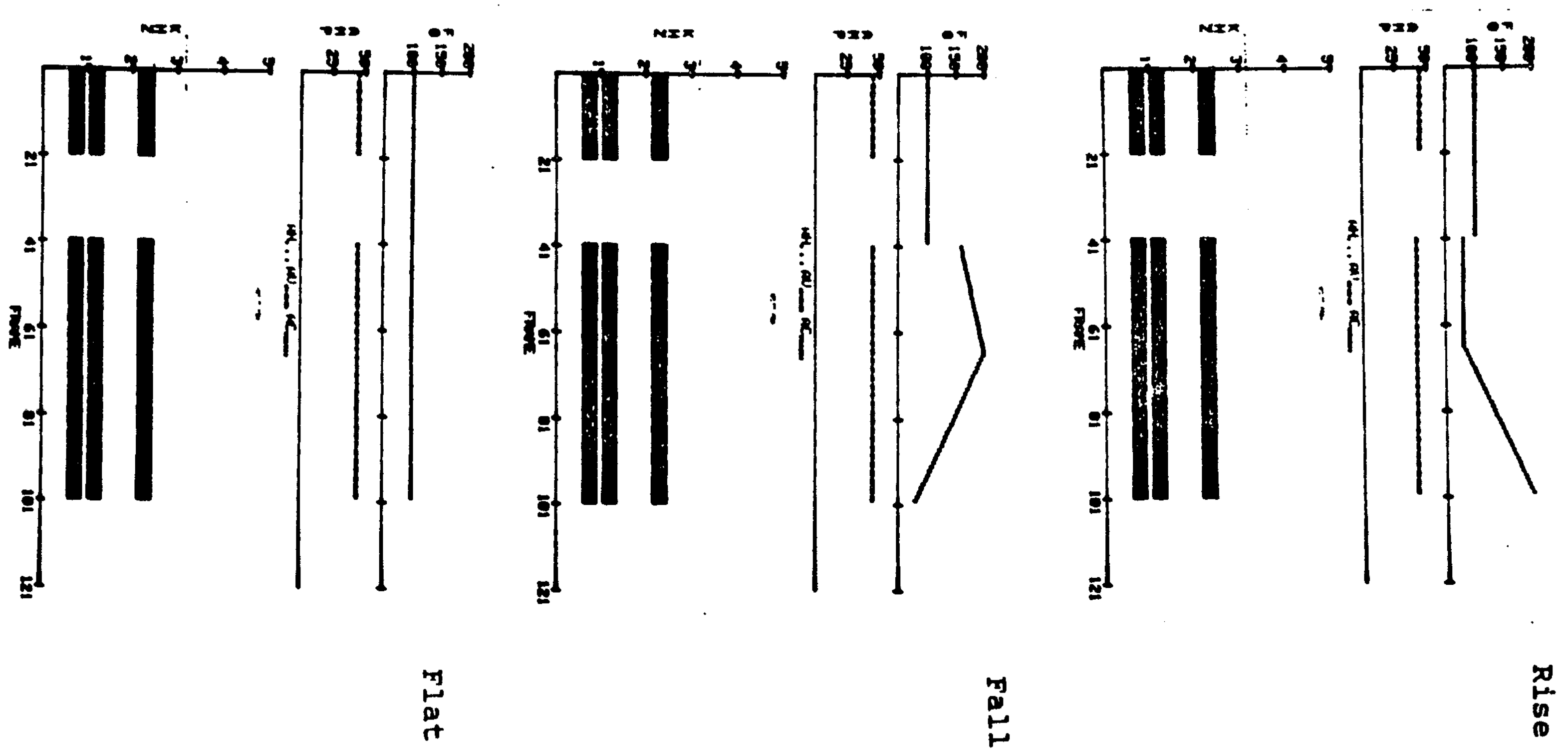
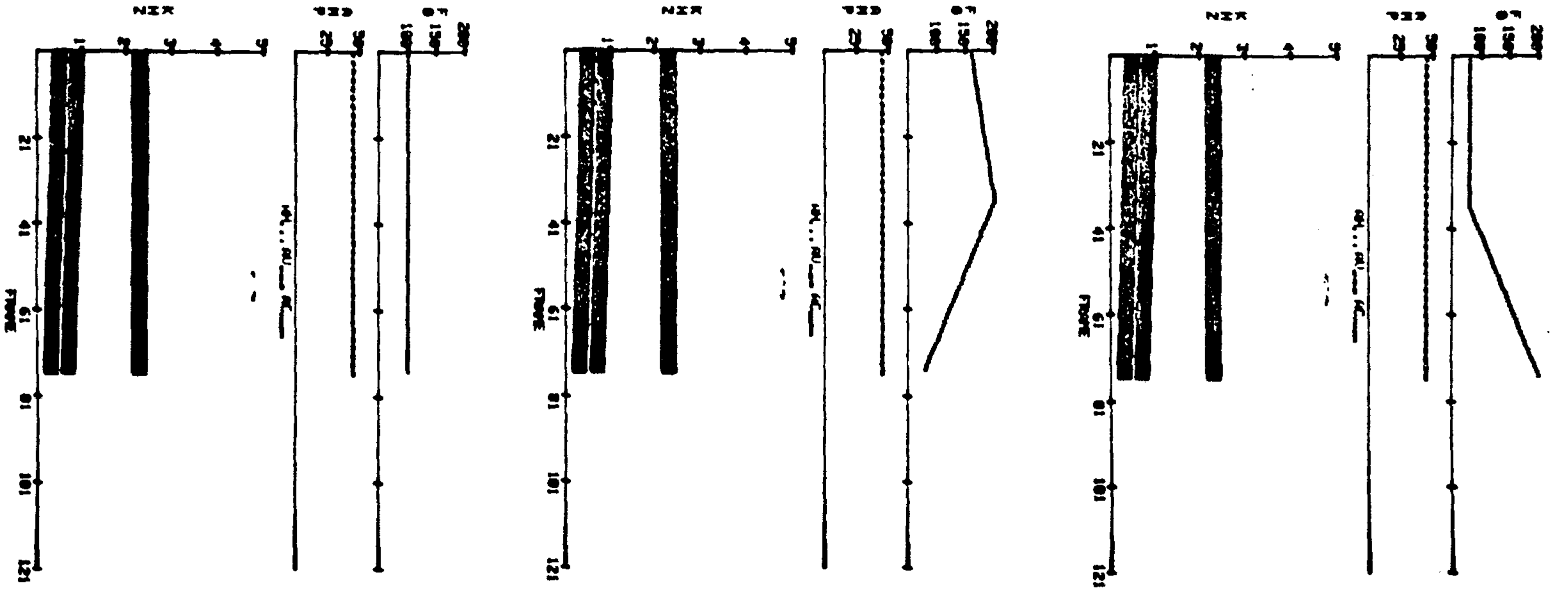


Figure 3.2: Fundamental frequency (Hz), amplitude (dB) and formant frequencies as a function of time (1 frame=10 msec.) for three two-syllable vowel /a/.



Rise

Fall

Flat

Figure 3.3: Fundamental frequency (Hz), amplitude (db) and formant frequencies as a function of time (1 frame=10 msec.) for three single-syllable diphthong /ov/.

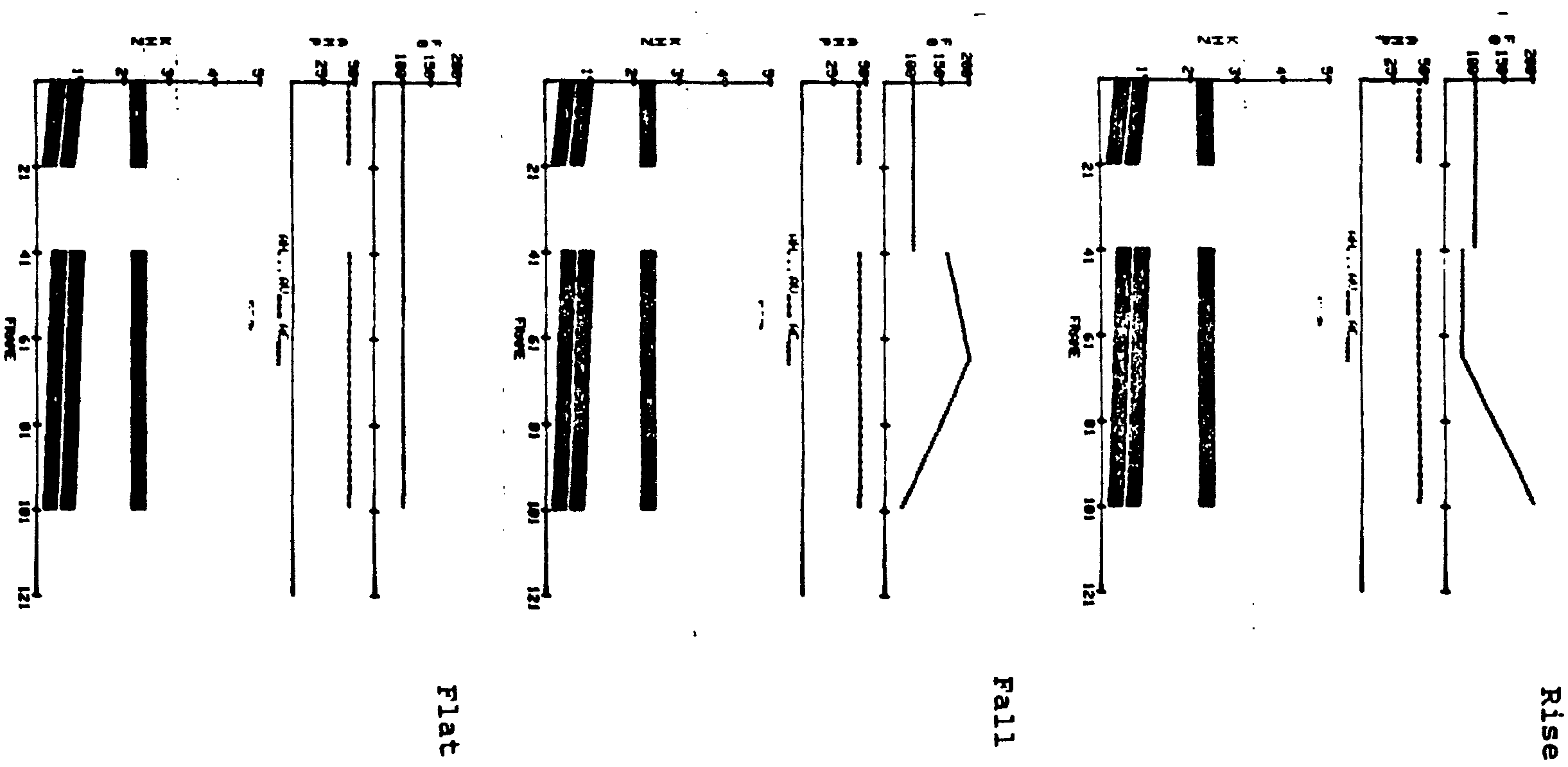


Figure 3.4: Fundamental frequency (Hz), amplitude (dB) and formant frequencies as a function of of time (1 frame=10 msec.) for three two-syllable diphthong /oʋ/.

resulting in lists of 24 items. The items were separated by an interstimulus interval of five seconds. For the forced-choice task the stimuli were arranged in a 3-forced choice paradigm. Each triad consisted of stimuli with the same number of syllables (one or two) and with the same phonetic composition (/a/ or /oʊ/). Two out of the three contours were flat ("same") and the 3rd one was either a rising or a falling contour ("different"). The different contour was placed in each of the three possible places (1st, 2nd, or 3rd) in order to control for the effect of the place of the stimulus on the subject's performance. This yielded a list of 24 series: 2 kinds of contours x 2 phonetic contexts x 2 syllable number type x 3 places. The three items within a series were separated from each other by an inter-stimulus interval of one second. Two seconds separated one series from the one that followed it. Three different randomized sequences were prepared.

For each one of the tasks a practice list was also prepared. There were six practice items for the imitation task and four practice items for the forced-choice task. These items represented a sample of the stimuli that were given in the test itself.

The stimuli were recorded on an Otari MX5050 tape deck. The input signal to the tape recorder was set so that the peak of the speech stimuli did not exceed -10dB on the V.U meter to minimize print through. A 1000Hz calibration tone was recorded at the beginning of the tape at a V.U level which was equal to that of the stimuli. The practice list for the imitation task was recorded twice. One recording was at the same level as the test lists. The other was at 15dB below the intensity of the test lists. The second recording was used for setting the test level to ensure that the test would be presented at a sensation level of at least 15dB. The tape master was dubbed onto cassette using a Nakamichi 480Z two head Cassette Deck.

Instrumentation for test administration

A Sharp stereo double cassette recorder model RD-688AV was used during the experimental testing. One deck was used for the presentation of the stimuli for either the imitative task or the forced-choice task. The other deck was used for recording of the children's imitations. A Realistic electret lapel microphone was used to record the children's imitations (see figure 3.5). The frequency response of both channels of the tape recorder was measured prior to the testing using a Bruel and Kjaer Sweep frequency sine random generator (#1024), microphone amplifier (#2603) and graphic level recorder (#2305). The obtained frequency responses are shown in figures 3.6 and 3.7. The signal/noise ratio was found to be 46dB for the right channel and 43dB for the left.

Experimental procedure

Prior to the administration of the tasks, each subject received an audiological evaluation. The normal-hearing children were screened with a portable audiometer Beltone 110 and TDH50

Figure 3.5: Collection of children's imitations.

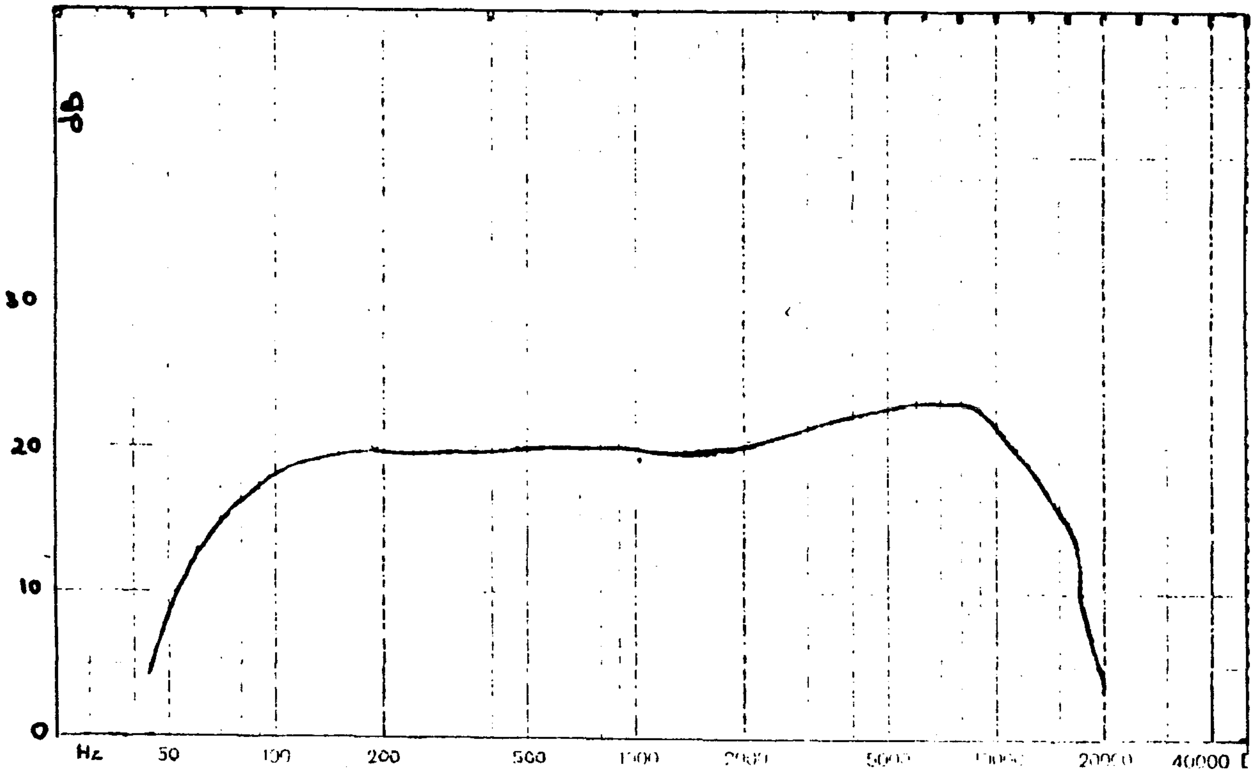


Figure 3.6: Frequency response of the left channel of the Sharp stereo double cassette recorder.

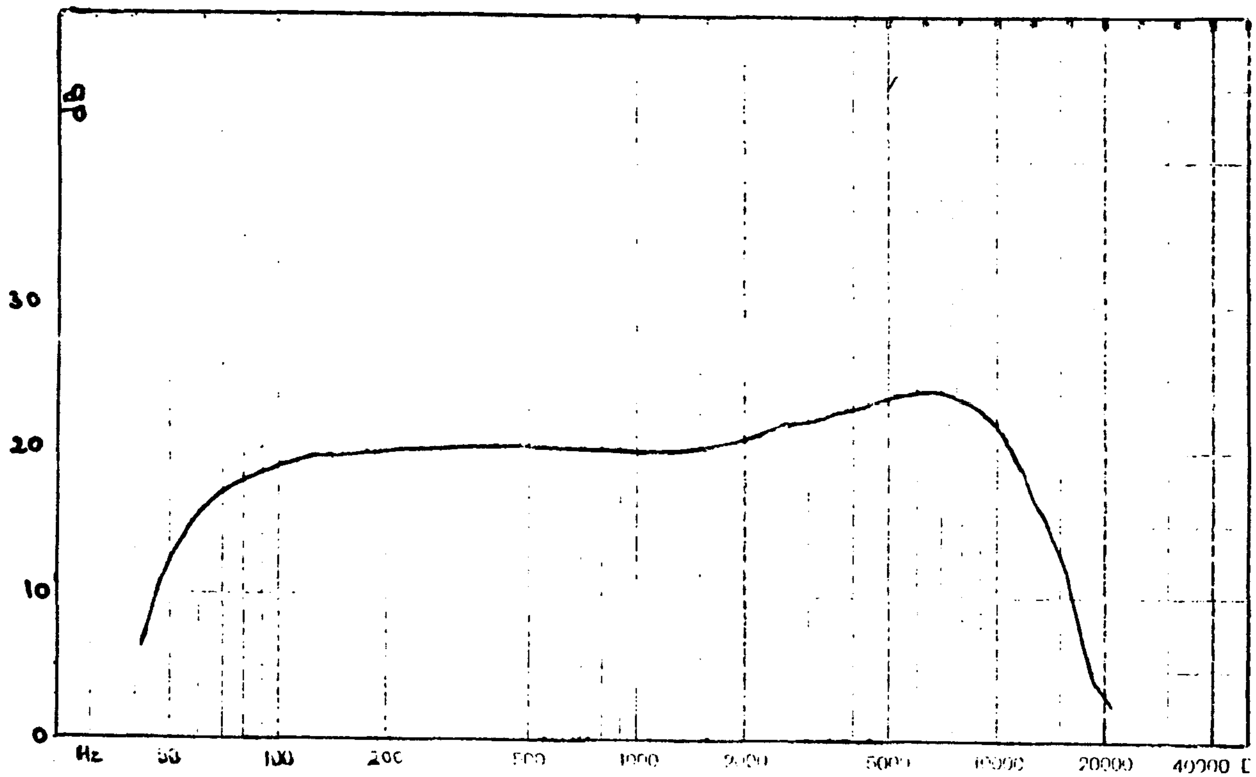


Figure 3.7: Frequency response of the right channel of the Sharp stereo double cassette recorder.

earphones at 15dBHL at octave frequencies between 250Hz and 8000Hz.

The hearing-impaired children were tested in an IAC booth at the school/ clinic that they attended. A three frequency pure-tone average was calculated for each child based on hearing thresholds at 500, 1000, and 2000Hz, in the child's better ear. Whenever thresholds at any of these frequencies were beyond the limits of the audiometer, a value of 115dBHL was assigned as threshold. The hearing evaluation was done in order to reconfirm the results of the children's previous audiograms so that they would be placed in the appropriate hearing-status group. Unaided thresholds using pure-tones and aided thresholds using warble-tones in sound field were obtained. The hearing-impaired children were retested at the end of the experimental testing, in order to make sure that their pure tone thresholds have not been changed.

The experimental testing was performed in a quiet room. Each child was tested three times. Each test session was separated from the next one by a week. The children were tested on three separate occasions in order to evaluate the possible effects of learning.

A biological check of the aids preceded each session. All the subjects but one were tested using binaural amplification. The child who was tested monaurally had been fitted with one hearing-aid because the other ear demonstrated no benefit from being aided. Twenty of the children used their own personal hearing aids which were in good operating condition. Ten of the children were tested with their group- aids which were adjusted according to their individual needs. Group-aid testing was performed when either one or both personal hearing aids were in poor condition.

A 1000Hz calibration tone was used to set the tape-recorder level for playback. The volume control was initially adjusted so that the presentation level was 72dBSPL, at the child's seat. This was measured with Bruel and Kjaer measuring amplifier (#2609), cathode follower and a one inch condenser microphone (#4145). The practice items which were recorded at 15dB below the level of the test items were used to obtain speech awareness responses from the children, to ensure that the test items which were presented at a normal conversational level were within the child's audible range. The normal hearing subjects were instructed to repeat the stimulus. The responses from the hearing-impaired children were obtained through the use of play audiometry. When the children failed to respond to that level, the volume control was manipulated until the child's speech awareness threshold was established. Then testing was administered at that particular setting of the volume control. In this way it was ensured that the test items were presented at least at 15dBSL (see figure 3.8).

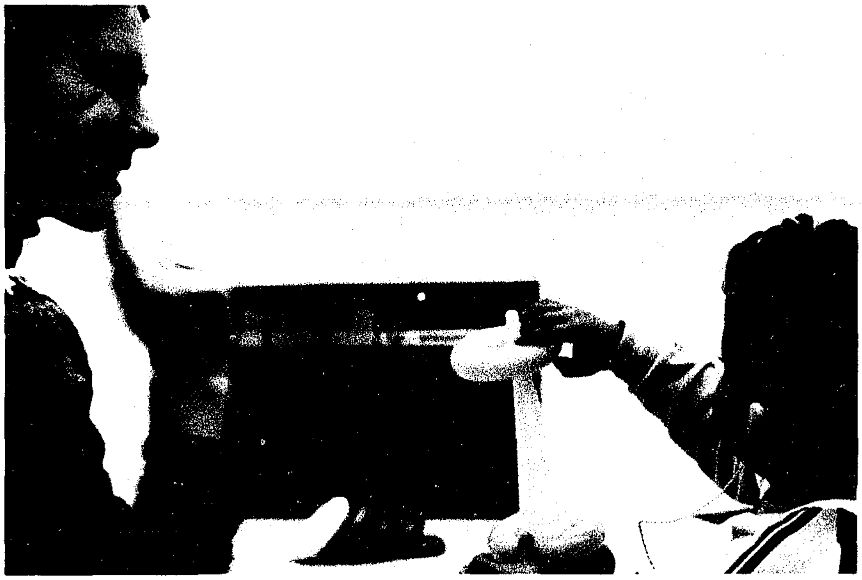


Figure 3.8: Establishing speech awareness.

After establishing presentation level, each session consisted of two tasks: imitation and forced-choice.

1. Imitation

For the imitation task the child was asked to repeat each of the stimuli. Practice items, presented first by a live voice and then through a recording, preceded the actual testing. During practice, visual cues, gestures and/or puppets were used for instruction (see figure 3.9). Testing began only after it was established that the child had understood the task. The examiner recorded the subjects' responses by holding the microphone a few inches from the child's mouth. Moving the microphone close to the child's mouth when he/she was asked to imitate appeared to help the child understand what was expected of him/her. The imitation task was always presented first since it was simpler, shorter and introduced the children to the kinds of stimuli involved in the experiment.

2. Forced-choice

For each forced-choice triad the child was asked to choose the contour which differed from the other two. This was accomplished through association of the sounds with three similar boxes. The three similar boxes were placed in front of the child. As each sound was presented the examiner pointed to each box in succession, thus, associating each of the boxes with one stimulus in the triad. The child was asked to point to the box which was associated with the non-flat contour. That box

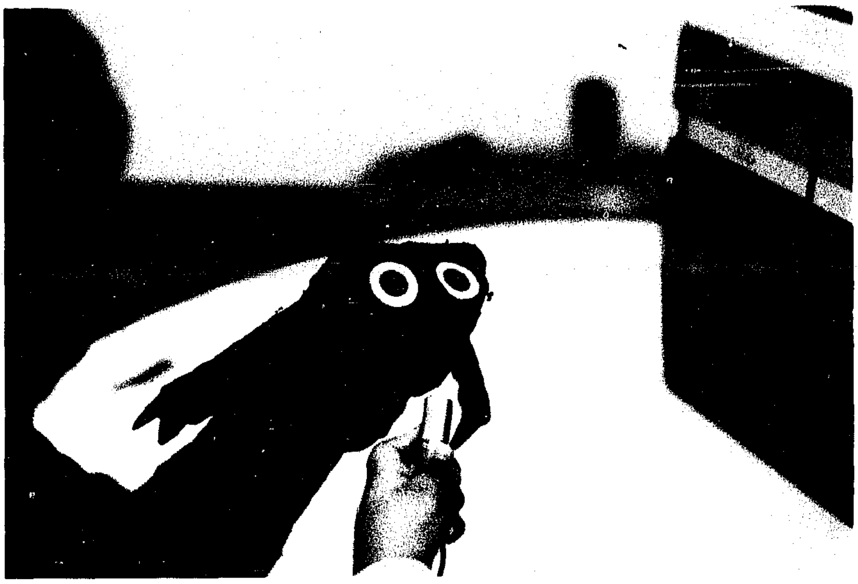


Figure 3.9: Practice for the imitation task.

contained a reward (a sticker). At the end of each triad the examiner removed the boxes from the child's visual field and changed the position of the box which contained the reward, to suit the order of presentation of the next item. In a pilot study, it was found that some children who could perform this task well with three choices were unable to do so with four choices. Therefore, discrimination among three sounds was selected for the task (see Appendix D).

Explanations and practice preceded the actual testing to ensure that the task was well understood by each child. During this time the examiner demonstrated the concept of same/different by first using same and different colored boxes and then three similar boxes associated with three stimuli, one of which differed from the other two in its duration (one syllable vs. two syllables). The use of sounds of different durations helped in explaining the task to those children who had very limited residual hearing. These children are capable of perceiving time and intensity cues while frequency information is not always perceptible to them (Erber, 1974). Therefore, these stimuli helped in differentiating cognitive ability from auditory ability as the cause for failure to perform the task (see figure 3.10).

Figure 3.10: Practice for the forced-choice task.

During testing, responses were directly scored by the examiner on an answer sheet. When a child did not respond correctly to at least three tokens, after a presentation of half of the test (12 tokens), the examiner terminated testing, since the task was tedious and frustrating and it was important to keep the children motivated for future sessions.

At the end of the session the child got a tangible reinforcement to motivate him/her for the next session. This format of the session was repeated three times. Each child was presented with the three different random order imitation lists and the three different random order forced-choice lists. The order of presentation of the imitation and the forced-choice lists was randomized across the subjects in order to prevent order effects.

The 5-7 year-old normal-hearing subjects were presented with the forced-choice list only at the first session to ensure that they were able to perform the task perfectly (i.e. 24 correct responses in 24 trials). Once this was established, the task was not presented during subsequent sessions.

Each session lasted approximately 1/2 hour. Since subjects in the present study ranged in age from three years to ten years testing time had to be kept to a minimum to accommodate the shorter attention span of the younger age group.

Part II: Evaluation of imitations

In part II of this study, the recordings of the children's imitations of the 12 different stimuli were evaluated by normal-hearing listeners.

Listeners

Five experienced listeners participated in the study. An experienced listener was defined as a person who had more than two year's experience in listening to the speech of the deaf. The listeners were speech scientists and teachers of the deaf who were recruited from CUNY Speech and Hearing Science Laboratory. None of the listeners knew the children whose speech they heard, the school at which the hearing-impaired children received their training, or any other aspect of the children's background. All listeners had normal-hearing and were native speakers of English.

Preparation of listening tapes

Each one of the children produced a total of 72 tokens (24 tokens x 3 sessions). Using an input program (12 bit A/D converter) available on the Haskins Laboratories VAX 11/780, all of the hearing-impaired children's productions and the productions from the first session of the normal-hearing children were digitized at a sampling rate of 10KHz using a Nyquist filter (upper cutoff frequency 4900Hz, 10dB/octave slope) and high frequency pre-emphasis.

Once digitized, the imitations were segmented. Segmentation was accomplished by means of a Haskins Laboratories Waveform Editing and Display program ("WENDY"). This editor provides continuously variable cursors (head and tail markers) which may act simultaneously on one channel or more. Segmentation was done by hand by the experimenter. Success at each stage of segmentation was determined both visually (by observing the waveform) and auditorily (by listening to the edited sample). In the segmentation process each of the child's imitations was extracted from the continuous recording eliminating any unnecessary noise. The rules were simply to set the head and tail markers as close as possible to the onset and offset of the child's production.

Each of the segmented items was paired with the model of which it was supposed to be an imitation. An interstimulus interval of one second separated the model and the imitation. This resulted in a total of 2400 pairs. The pairs were randomized in order to avoid learning and fatigue effects, and also to prevent listeners from identifying individual subjects and possibly judging performance on the basis of previous tokens.

The 2400 pairs of stimuli [(72 tokens x 30 hearing-impaired children) + (24 tokens x 10 normal-hearing children)] were converted to analog form and 15 listening tapes were developed. There were 160 stimuli per tape. Each pair was separated by an interstimulus interval of five seconds. The stimuli were blocked into groups of 20. Each group was separated by an intergroup interval of 10 seconds. Each tape was preceded by a practice set consisting of four pairs produced by hearing-impaired children not used in the study. The practice sets were identical on all tapes. The listening tapes were recorded using a Nakamichi 480Z two head cassette deck. These pairs of models and their imitations served as stimuli for the listeners who were expected to evaluate the accuracy of the imitation.

Listening procedure

Each of the listeners was presented with all 15 tapes separately in a quiet room at his/her convenience (each tape took approximately 20 minutes to complete). They listened to the tapes binaurally through headphones. Three pairs of TDH49 earphones were used. The frequency responses of the earphones were checked. The frequency responses of all the six earphones were within ±1.5dB of each other across the frequency range 100-7000Hz.

The listeners were instructed to set the output level to a comfortable level. They were asked to compare the two stimuli which were presented in pairs and consisted of a model, which was a computer-generated stimulus and the child's attempt to imitate the model.

The listeners were provided with a 10-point rating scale and were required to judge how closely each imitation matched its model. On the rating scale the number 1 represented no perceptible relationship between the model and the imitation and 10 represented perfect imitation. Two more anchors were given in between. The number 4 which represented poor imitation and the number 7 which represented an essentially correct imitation but with some differences, e.g. the range of the pitch changes. A scale with an even number of points was chosen so that listeners would not be tempted to choose the middle point.

The listeners were instructed to listen for the accuracy of the imitation of the intonation pattern and to consider the suprasegmental aspects of the imitation, but to ignore the accuracy of the imitation of the vowel. The instructions and rating form are shown in Appendices B-1, and B-2 respectively. Each cassette started with four practice pairs which were prerated by the examiner on the practice sheet and served as examples. Listeners were allowed to stop the tape if they needed more time to make their judgment. They were not allowed, however, to rewind the tape for repetition.

CHAPTER IV

Results

The primary purpose of this study was to investigate whether the child's ability to imitate intonation contours can be used as an early indicator of his/her auditory perceptual abilities. Specifically, we were interested in the effects of age and hearing status on the ability to perceive intonation contours as measured by an imitative task and a forced-choice task. In addition, we were interested in the relationship between the performances on the two tasks (for the detailed hypotheses, see page 59).

This chapter will present the results obtained from subjects on the imitation and the forced-choice tasks. First, the findings which are directly related to the research questions will be addressed. Next, additional findings will be presented.

Tables 4.1, 4.2 and 4.3 show the scores obtained on the imitation and the forced-choice tasks by the profound, severe and the normal-hearing children respectively. Also shown are age and average pure-tone threshold data together with group means. Note that the imitation scores in these tables are collapsed across stimulus model, test session and listener. The forced-choice scores are collapsed across stimulus model and session. In analyses of the variance in raw scores, the main effect of test session was not found to be significant, for either the imitation

Table 4.1: Performance of 15 profoundly hearing-impaired subjects on two tasks of intonation perception.

Age group	Sub. #	Age (yrs)	Better PTA (dBHL)	Mean imitation score (Max 10)	Mean forced-choice score (Max 24)
older	1	6.33	103	6.75	22
	2	5.66	112	2.65	CNT
	3	6.25	95	5.17	20.6
	4	6.33	100	2.85	CNT
	5	6.16	115	2.53	CNT
	6	5.75	95	3.70	11*
	7	5.25	110	5.72	18
	8	10.25	108	7.94	24
	9	5.5	110	2.75	CNT
	10	5.58	112	2.76	CNT
Mean (s.d.)		6.31 (1.44)	106 (7.27)	4.3 (1.97)	
younger	1	3.92	105	4.71	CNT
	2	3.75	113	3.21	CNT
	3	3.75	102	4.68	CNT
	4	3.75	107	4.91	CNT
	5	3.00	103	2.68	CNT
Mean (s.d.)		3.63 (.36)	106 (4.36)	4.00 (1.02)	
Means for all profound(s.d.)		4.37 (1.75)	106 (6.28)	4.15 (1.67)	

* number of correct responses obtained in one session only.
CNT=could not test

Table 4.2: Performance of 15 severely hearing-impaired subjects on two tasks of intonation perception.

Age group	Sub. #	Age (yrs)	Better PTA (dBHL)	Mean imitation score (Max 10)	Mean forced-choice score (Max 24)
older	1	6.25	85	8.60	24
	2	5.58	90	7.27	22.3
	3	5.5	90	7.58	24
	4	6.66	80	6.84	19
	5	6.33	78	6.07	23
	6	6.83	85	6.35	21.3
	7	6.92	78	6.62	24
	8	6.58	85	7.40	24
	9	8.08	82	8.85	24
	10	5.75	90	7.45	21.6
Mean (s.d.)		6.45 (1.76)	84.3 (4.74)	7.3 (.9)	22.72 (1.68)
younger	1	3.42	60	8.17	CNT
	2	3.92	87	6.46	CNT
	3	3.43	80	5.91	CNT
	4	3.75	87	6.44	CNT
	5	4.16	83	7.07	24
Mean (s.d.)		3.72 (.34)	79.4 (11.24)	6.82 (0.88)	
Means for all severe (s.d.)		5.08 (1.46)	81.85 (7.49)	7.06 (.89)	

CNT=could not test

Table 4.3: Performance of 10 normal-hearing subjects on two tasks of intonation perception.

Age group	Sub. #	Age (yrs)	Mean imitation score (Max 10)	Mean forced-choice score (Max 24)
older	1	5.83	8.80	24
	2	5.75	8.87	24
	3	6.00	9.29	24
	4	6.83	8.05	24
	5	6.83	9.07	24
Mean (s.d.)		6.25 (.54)	8.8 (.47)	24 (0)
younger	1	3.08	8.44	CNT
	2	3.5	7.72	CNT
	3	3.33	7.48	CNT
	4	3.58	8.07	CNT
	5	3.66	8.36	CNT
Mean (s.d.)		3.43 (.23)	8.0 (.41)	
Means for all normals(s.d.)		4.84 (1.53)	8.4 (.59)	

CNT=could not test

or the forced-choice tasks. There were, however, some significant effects of stimulus model and listener on the imitation score. Since these effects do not influence the major findings, discussion of them will be saved for later in the results chapter. The analyses of variance are included in Appendices C-1, C-2, C-3 and C-4. These analyses provide the estimates of levels of statistical significance for the comparisons of group means in the presentation that follows.

Imitation performance as a function of age

You will recall that this study was designed to test the theory that a hearing-impaired child's ability to imitate intonation contours will be demonstrated at an early age. This theory leads to the hypothesis that the performance of the younger group of subjects will not be different from that of the older group on the imitation task. Figure 4.1 shows the means for the three hearing-status groups as a function of age. Analysis of variance in the data on hearing-impaired subjects shows that the main effect of hearing loss is significant ($\underline{F}(1,26)=29.40$; $p < .01$). (This main effect will be discussed further below). There is, however, no significant main effect of age ($\underline{F}(1,26)=0.47$; $p > .05$), and no significant interaction between hearing-status and age ($\underline{F}(1,26)= .05$; $p > .05$) (see Appendices C-1, C-2). A separate analysis (Appendix C-3) of the normal-hearing children data shows that the main effect of age, though small, was statistically significant ($\underline{F}(1,8)=7.95$; $p < .05$). Thus, the data support the hypothesis that at the age range of 3.0 to 4.16 years hearing-impaired children have already reached the level of performance of imitation of intonation task that they will show by ages 5.25 to 10.25 years. This level is higher for the severely hearing impaired than for the profoundly hearing impaired. Among the normally hearing children, however, although all the children obtained high imitation scores and even the lowest score is >7 (it should be recalled that the number 7 represented correct imitation), it appears that performance on the imitation task improves slightly between ages 3.0 and 6.8 years.

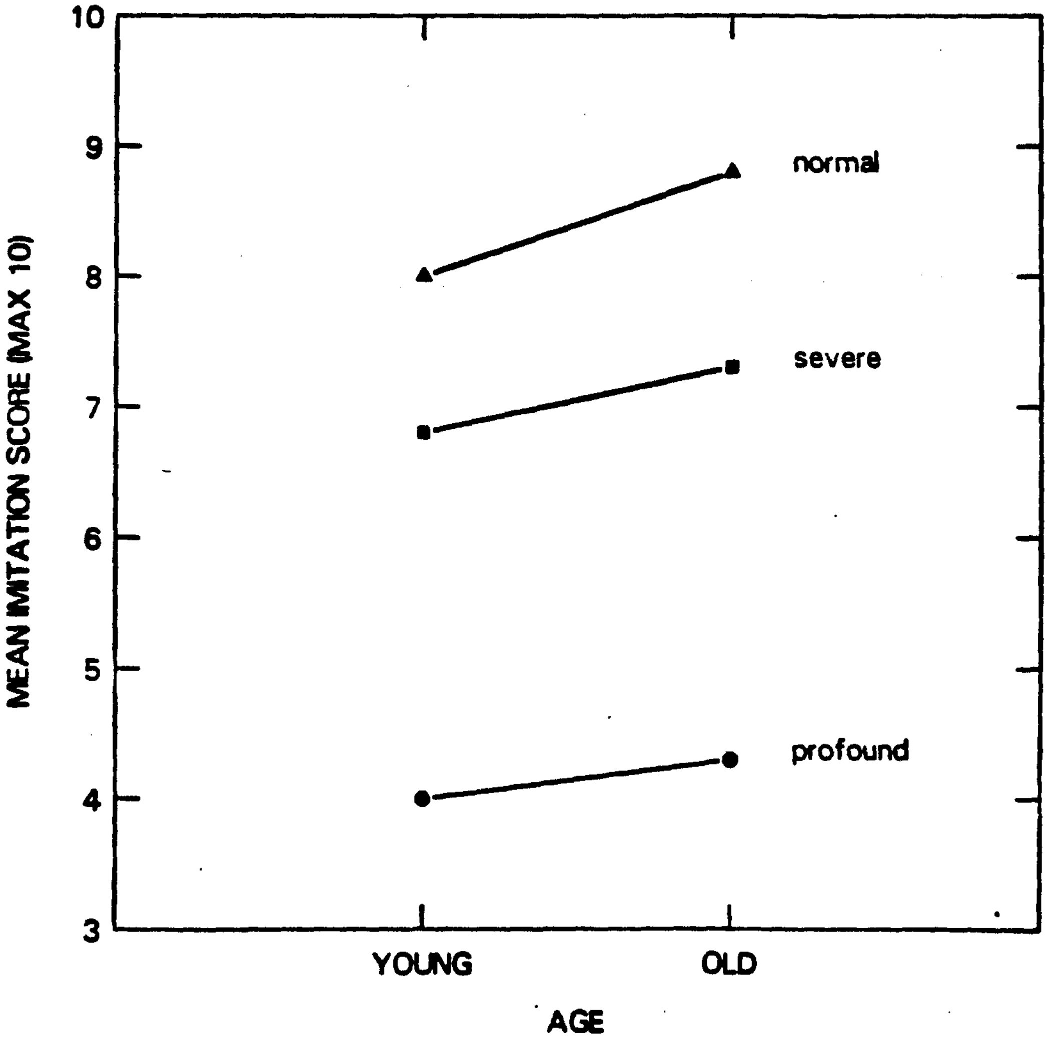


Figure 4.1:
Mean imitation scores of the three hearing status groups as a function of age.

Discrimination performance via forced-choice response as a function of age

The purpose of the forced-choice task, which required a pointing response, was twofold. The first was to validate the imitation task, as an indicator of the perception of intonation contours among the older group of children. The second was to demonstrate that the imitation task was more appropriate than the forced-choice task with respect to the cognitive ability of the younger group of children.

The original intent was to obtain a percent correct score for each child on the forced-choice task. After performing the test on several children, however, it became clear that a different strategy was necessary. The children appeared to fall into one of two groups. Some of the children were able to perform the task without difficulty and obtained high scores. Other children were totally unsuccessful. That is, they pointed to a certain box randomly, either because they did not understand the task or because they could not hear the difference among the presented stimuli. For this reason, a pass/fail criterion was adopted. Those subjects who were not able to perceive successfuly at least three items from the first half of the test (12 items), were considered to have failed. As stated in the method chapter, for these children the test terminated at this point in order to avoid frustration. For those children who passed according to this criterion, the entire test was given and percent scores were obtained.

It will be seen from tables 4.1, 4.2 and 4.3 that with one exception, the children in the younger age groups were unable to complete the forced-choice task. A chi-square analysis was performed using the pass/fail data of the hearing-impaired children. Among the severely hearing-impaired children, all the older children and only one child from the younger group passed the test. It is noteworthy that the child in the younger group who passed the test was older than the rest of the young children. He was 4.16 years old, while the others were below four years old. The Pearson chi-square was statistically significant in the severe hearing loss group ($\underline{X}^2(1)=10.91$, $p < .001$), indicating that within the severe hearing loss group the performance on the forced-choice task is significantly related to age.

In the profound hearing loss group, out of the ten older children, six children failed the test and four children passed. Out of the five young children, all failed. A chi-square analysis failed to show significance for these data ($\underline{X}^2(1)=2.73$, $p > .05$). We can not, therefore, say that the proportions of passes in the profound hearing loss group are significantly related to age.

The effect of age on the forced-choice task is also demonstrated among the normal-hearing children. While all the older children passed the task and obtained 100% scores, all of the younger children failed the task.

It seems then, that the effect of age can be demonstrated within the normal-hearing and the severe hearing loss group, since there are no other confounding effects. The normal hearing and the severely hearing-impaired children had sufficient hearing in order to perceive the stimuli, and a child passed the test when his/her cognitive ability allowed him/her to understand it. Within the profound hearing loss group the hearing loss presented a confounding effect. Children did not succeed in performing the task either because they could not discriminate or had not learned to discriminate among the stimuli.

It can be concluded then, that the forced-choice task can not be used as a valid measure of intonation perception in the younger hearing-impaired children. Failure to perform is dependent on inadequate cognitive development and not necessarily on inadequate perception.

Relationship between imitation score and forced-choice score

You will recall that the imitation task is intended to reflect a child's auditory receptive abilities. If it is indeed providing such a measure, then performance on this task should be highly correlated with other measures of auditory receptive abilities, including the forced-choice task (provided the child has adequate cognitive skills for the forced-choice task). The following analysis is based on the older subjects' data, as they were the only group capable of performing adequately on the forced-choice task.

Figure 4.2 is a scatterplot of the children's imitation scores as a function of their performance on the forced-choice task. As seen from the figure, the distribution of scores is bimodal. The children who failed the forced-choice task obtained very poor scores on the imitation task. The children who passed the forced-choice task obtained moderate and high scores on the imitation task. A correlation technique was used to measure the association between the imitation and the forced-choice scores. While the imitation scores were continuous, the forced-choice scores were dichotomous (i.e. pass/fail). Pearson product moment correlation between the imitation performance and the forced-choice performance produced a highly significant coefficient ($\underline{r}(19)= .91$, $p < .001$). Furthermore, a correlation technique was used to measure the association between the performances on the two tasks only among the children who passed the forced-choice task. For this correlation the forced- choice scores were computed. Pearson product moment correlation between the two continuous variables produced a significant coefficient ($\underline{r}(14)= .62$, $p < .01$).

It can be concluded then, that to the extent that performance on the forced-choice task is a true reflection of a child's ability to discriminate among various intonation contours, the performance on the imitation task is a valid measure indicating the perception of intonation contours.

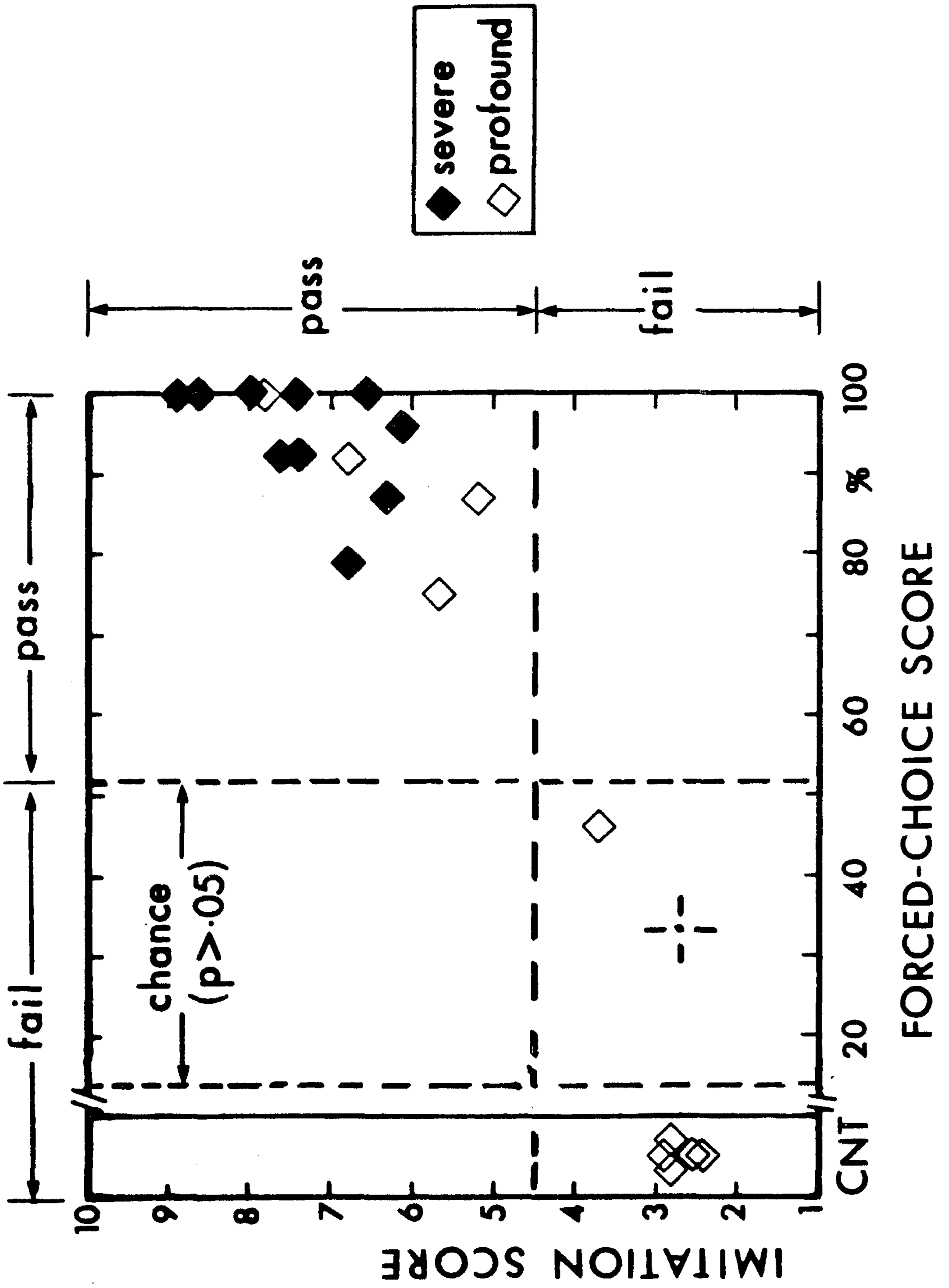


Figure 4.2:
Imitation scores of the older hearing-impaired children as a function of their forced-choice scores.

The effect of hearing loss on the imitation task

As mentioned before, the main effect of hearing loss was found to be highly significant ($\underline{F}(1,26)=29.4$, $p < .01$), on analysis of variance in the imitation scores (Appendices C-1, C-2). This relationship was further examined using correlational analysis. The correlation was performed using the pure-tone average in the better ear. A three frequency pure-tone average (PTA) was calculated for each child based on hearing thresholds at 500, 1000 and 2000Hz, in the child's better ear. Whenever thresholds at any of these frequencies were beyond the limits of the audiometer, a value of 115dBHL was assigned as threshold. Results revealed statistically significant negative correlation ($\underline{r}(19)=-0.71$, $p <.001$), i.e. pure-tone average thresholds could account for roughly 50% of the variance in the imitation scores.

A further investigation of the relationship between pure-tone sensitivity and the imitation performance revealed an important finding. Figure 4.3 is a scatterplot of the children's mean imitation scores as a function of their average hearing threshold level in the better ear. As seen in figure 4.3, all children with average hearing levels between 60-90dB obtained high imitation scores. All children with hearing threshold levels above 110dB obtained low imitation scores. The scores obtained by children with hearing threshold averages in the range 91-110dB are widely dispersed. They vary from a very low score to a very high score. To the extent that these subjects are representative of the population of severe and profound hearing losses at large, it can be said that children with hearing losses of 90dB or less will perceive and imitate intonation contours. Children with hearing losses greater than 110dB will not. The performance of children with hearing losses in the 91-110dB range cannot be predicted with accuracy based on the pure tone audiogram.

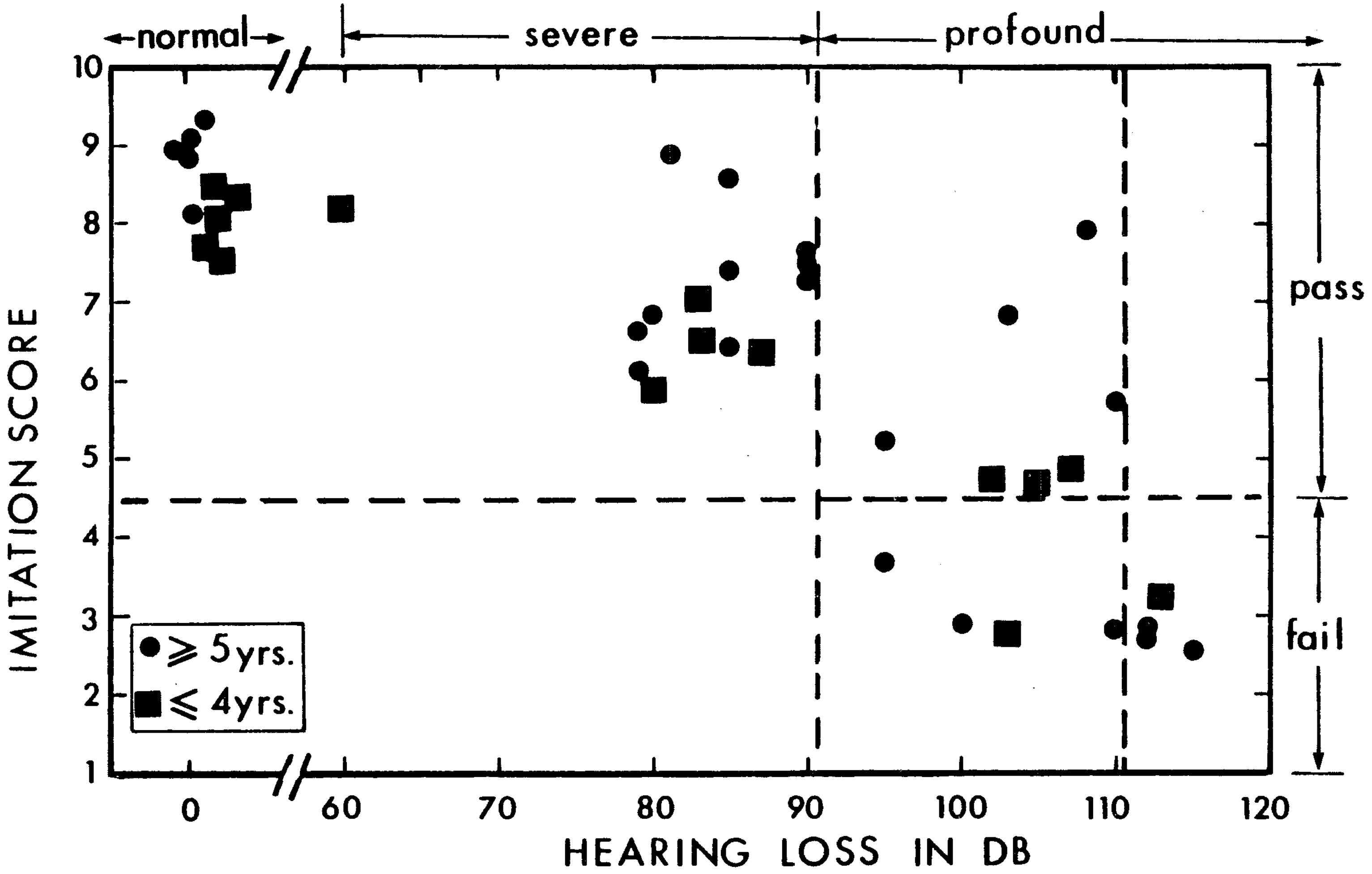


Figure 4.3: Mean imitation scores of all subjects as a function of their hearing status.

Figure 4.4 (a and b) demonstrates the distribution of the mean imitation scores of each individual collapsed across sessions and listeners.

Figure 4.4-a shows the distribution of the mean imitation scores for the severely and the profoundly hearing-impaired children. As mentioned in the method chapter a one to ten rating scale was used for scoring. A rating of ten represented a perfect imitation, while a rating of one meant that there was no relationship between the imitation and the model it attempted to imitate. As seen from figure 4.4-a, the distribution of scores for the severe hearing loss group is unimodal and is concentrated in the range of values from six to nine. For the profound hearing loss group the scores range from two to eight, and the distribution of scores is bimodal.

In figure 4.4-b, the profound hearing loss group is divided into two groups: children with hearing losses between 91-110dB, and children with hearing losses greater than 110dB. The distribution of the scores for children with average hearing losses in the 91-110 range, is wide and the mean scores range from three to eight. For children with average hearing losses greater than 110dB, the distribution is unimodal and concentrates on the values two and three. It should be recalled that scores of two and three represent a very poor performance of imitation.

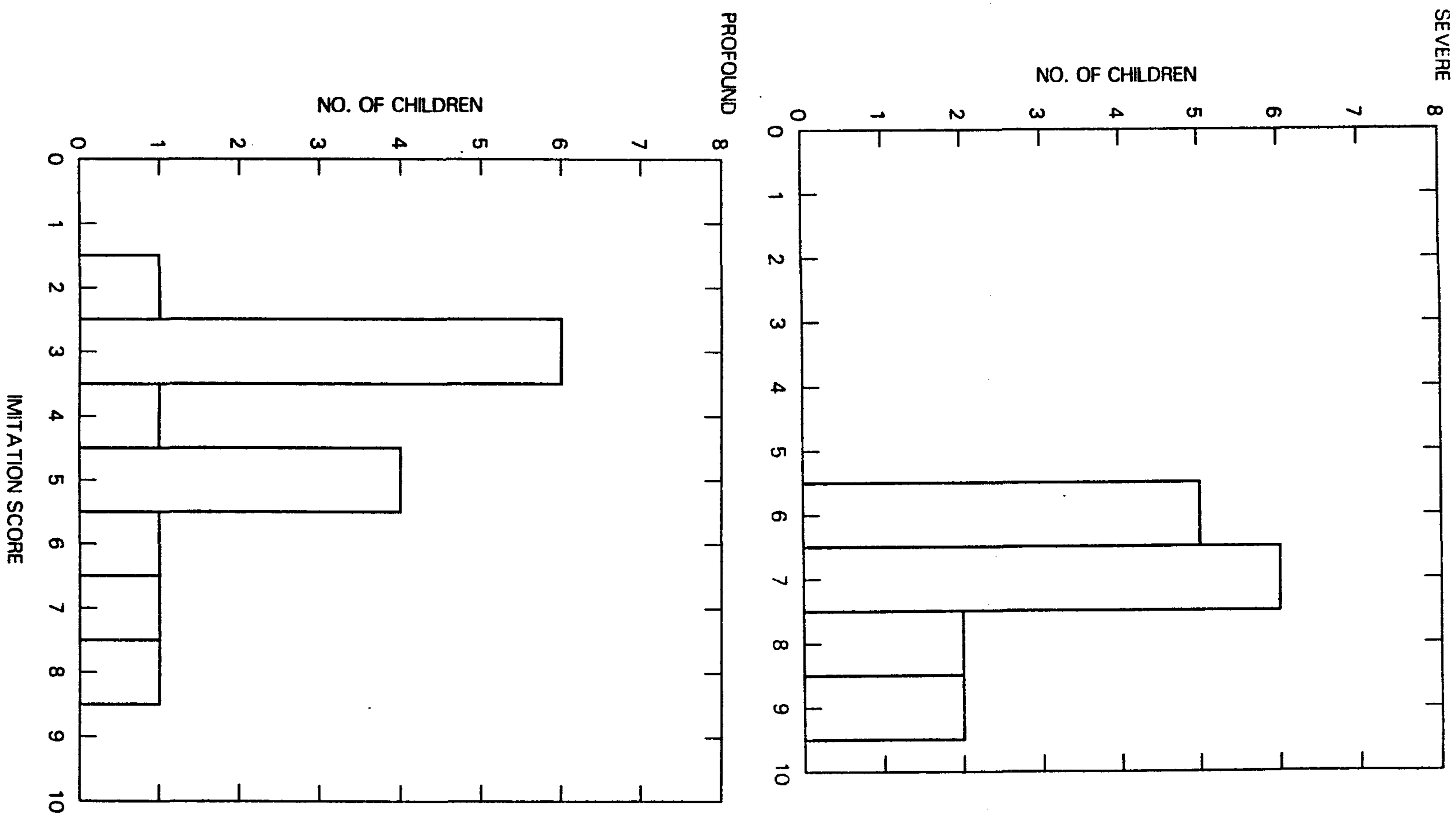


Figure 4.4(a):
Distribution of imitation ratings within the severe and the profound hearing loss ranges.

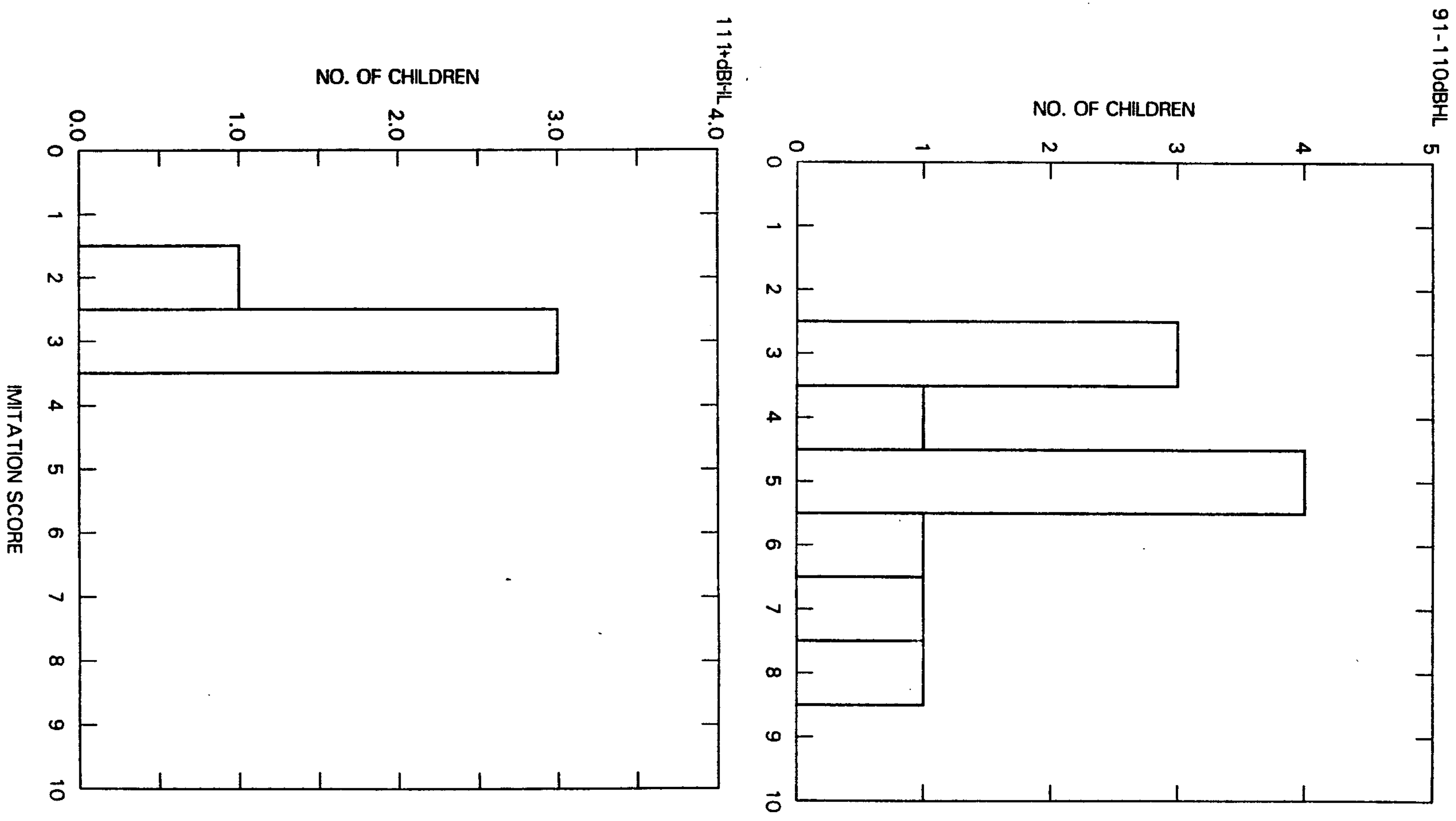


Figure 4.4(b):
Distribution of imitation ratings of the profoundly hearing impaired within two hearing loss ranges.

Training and imitation performance

As demonstrated in the previous section, within the 91-110dB range of hearing loss there is a variability in the children's performance on the imitation task. One possible cause for this variability is the training program that the children are exposed to. Although not part of the design, it turned out that the older subjects came from two programs. In one, a great deal of time is spent on imitation of suprasegmentals (program a). In the other, the focus is on language acquisition without special emphasis on any particular sensory or language modality (program b).

A chi-square analysis was performed on 11 children who had average hearing losses in the 91-110dB range to investigate if there was a significant relationship between the performance on the imitation task and the training program. Based on the bimodal distribution of the imitation scores described earlier, a pass/fail criterion was adopted. Scores which were either 4 or greater than 4 were considered as passes, whereas scores smaller than 4 were considered as fails. (You will recall that the number 4 on the rating form represented poor performance, but with some perceived relationship to the model it was attempted to imitate). Table 4.4 demonstrates the distribution of the children in each of the training programs with respect to their performance on the imitation task. The relationship between the performance on the imitation task and the training program proved to be significant ($\underline{X}^2(1) = .81$, $p < .001$). Also, a Pearson product moment correlation revealed a statistically significant negative correlation between the two variables (r(10)=-0.62, $p < .001$). Further investigation of the data illustrated in figure 4.3 revealed the following interesting findings:

1. All the children with hearing losses greater than 90dB, who belonged to program b, failed the imitation task.
2. Among the children with hearing losses in the 91-110dB range, who belonged to program a, all but one passed the imitation task.
3. There was a significant age effect among the children from program a, whose hearing losses were in the 91-110dB range: The older children performed significantly better than the young children (t(6)=2.67, $p < .05$).

Table 4.4: Effect of training program on imitation performance of 11 subjects with hearing losses in the 91-110dB range.

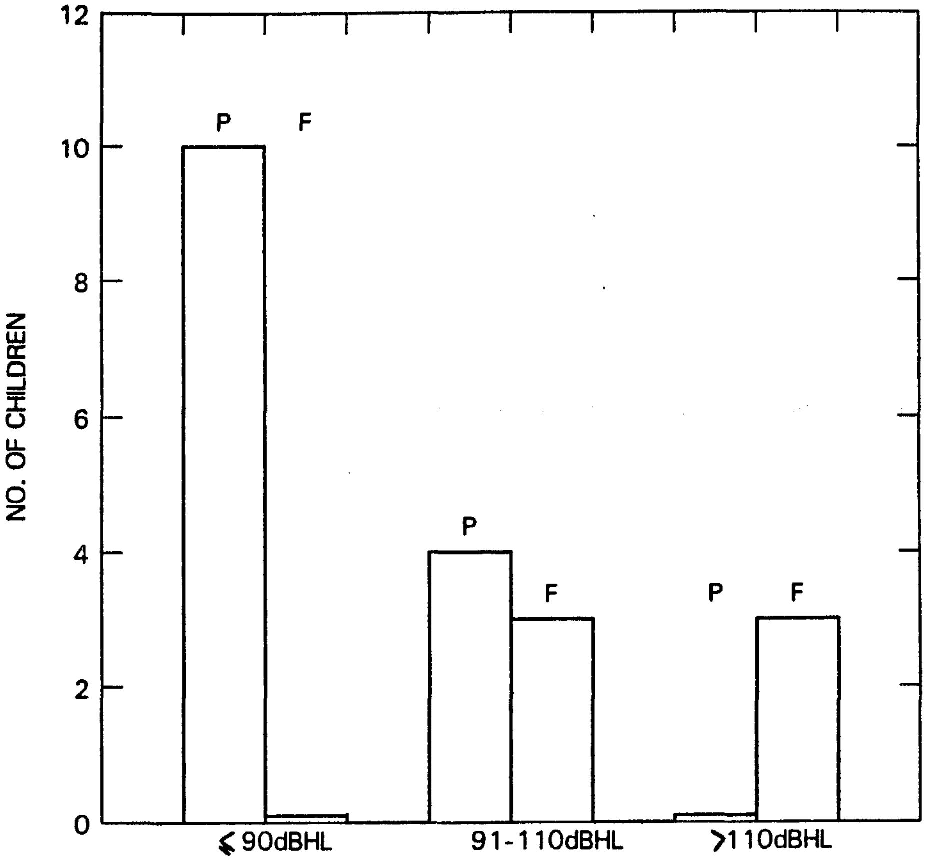
# children	auditory (program a)	global (program b)	Totals
pass	7	0	7
fail	1	3	4
Totals	8	3	11

Effect of hearing loss on the forced-choice task

In order to investigate the relationship between the hearing loss and the forced-choice performance, Pearson product moment correlation was performed using the data for the older children only. A significant correlation between hearing loss and the forced-choice performance was observed in the older group ($\underline{r}(19)=-0.65$, $p <.001$).

Figure 4.5 demonstrates the distribution of the older children with respect to their performance on the forced-choice task. The children are divided into three groups as follows: those with hearing loss less than 90dB, those with hearing loss in the 91-110dB range and those with hearing loss greater than 110dB. The scores were either pass or fail. All children with average hearing loss equal to or lower than 90dB passed the test. All those with threshold averages greater than 110dB failed the test. Children with threshold averages in the 91-110dBHL range, however, varied in their performance. While some passed, others failed. Within this range the performance on the task could not have been predicted accurately from the audiogram.

The effect of the training program was also observed for the forced-choice scores. All the children with hearing losses in the 91-110dB range who passed the forced-choice task belonged to program a.



P=pass
F=fail

Figure 4.5:
Distribution of passes and fails on the forced-choice task within three hearing loss ranges.

Summary of the main results

1. As hypothesized, the imitation scores of the older and the younger hearing-impaired children were not significantly different.

2. The imitation scores of the older and the younger normal-hearing children were significantly different. The difference, however, was small.

3. No child under the age of 4.0, hearing or hearing-impaired, passed the forced-choice task (i.e. performed at better than chance levels).

4. Among the older children, there was a high correlation between the performances on the imitation and the forced-choice tasks.

5. The main effect of hearing status was found significant for the imitation task among the hearing-impaired children. Severely hearing-impaired children performed significantly better on the imitation task than the profoundly hearing-impaired children.

6. The hearing loss accounted for roughly 50% of the variance in the imitation scores. A great deal of the remaining variance seem to be attributed to the training program the children were exposed to.

7. Within the range of 91-110dBHL, the performance on the imitation and the forced-choice tasks could not have been predicted accurately from the pure tone audiogram.

Evaluation of test procedure

While testing the experimental hypotheses, the test procedure was also evaluated. Specifically, the following questions were addressed:

1. Are the various stimulus models different in terms of their ability to reveal perceptual ability?
2. Are there significant differences among the listeners with respect to their evaluation of the children's imitation performance?

Effect of stimulus model

The imitative data obtained from the hearing-impaired children were analyzed in order to determine if any particular stimulus model was significantly different from the others with respect to the listeners' ratings of children's imitation performance. It should be recalled that there were 12 stimulus models. They consisted of three intonation contours (fall, rise, flat), which were superimposed on two phonetic contexts (/a/,/oʊ/), and on two syllabic patterns (one syllable, two syllables). Each one of the models was repeated twice in a session, and there were three sessions. Thus, each model was imitated six times by each child. Since in an initial analysis the main effect of session was not found to be significant, the scores were collapsed across sessions. Mean scores were obtained for each model as it was produced by each child and was evaluated by each listener. Thus, each mean was computed from six imitations of a specific model.

A six-way analysis of variance with repeated measures was performed. In this analysis the factors of hearing status and age were "between-subject" variables while listener, vowel, syllable and contour were "within-subject" variables. The results of the analysis of variance are shown in Appendix C-2.

A significant main effect was found for vowel ($F(1,26)=21.56$, $p < .01$). The mean score for the vowel /a/ was slightly higher (5.85) than the mean score for /oʊ/ (5.50). There was not a significant main effect for syllable pattern ($F(1,26)=3.16$, $p > .05$), or contour ($F(2,52)= .50$, $p > .05$).

The interaction between vowel and hearing loss was also significant ($F(1,26)=9.28$, $p < .01$). Figure 4.6 demonstrates the change in scores for the two hearing loss groups as a function of vowel. The figure illustrates that the pattern for both the severe and the profound hearing loss groups is similar, i.e. higher scores for /a/ (7.41, 4.28 respectively) than for /oʊ/ (6.87, 4.12 respectively). The difference in the scores for the two vowels, however, is bigger for the severe hearing loss group.

Of the three-way and higher order interactions, only one was found to be significant. This was the three-way interaction between syllable, contour and hearing loss ($F(2,52)=11.12$, $p < .01$). Figures 4.7-a and 4.7-b illustrate the change in mean scores for each hearing loss group as a function of contour for the one-syllable stimuli and for the two-syllable stimuli

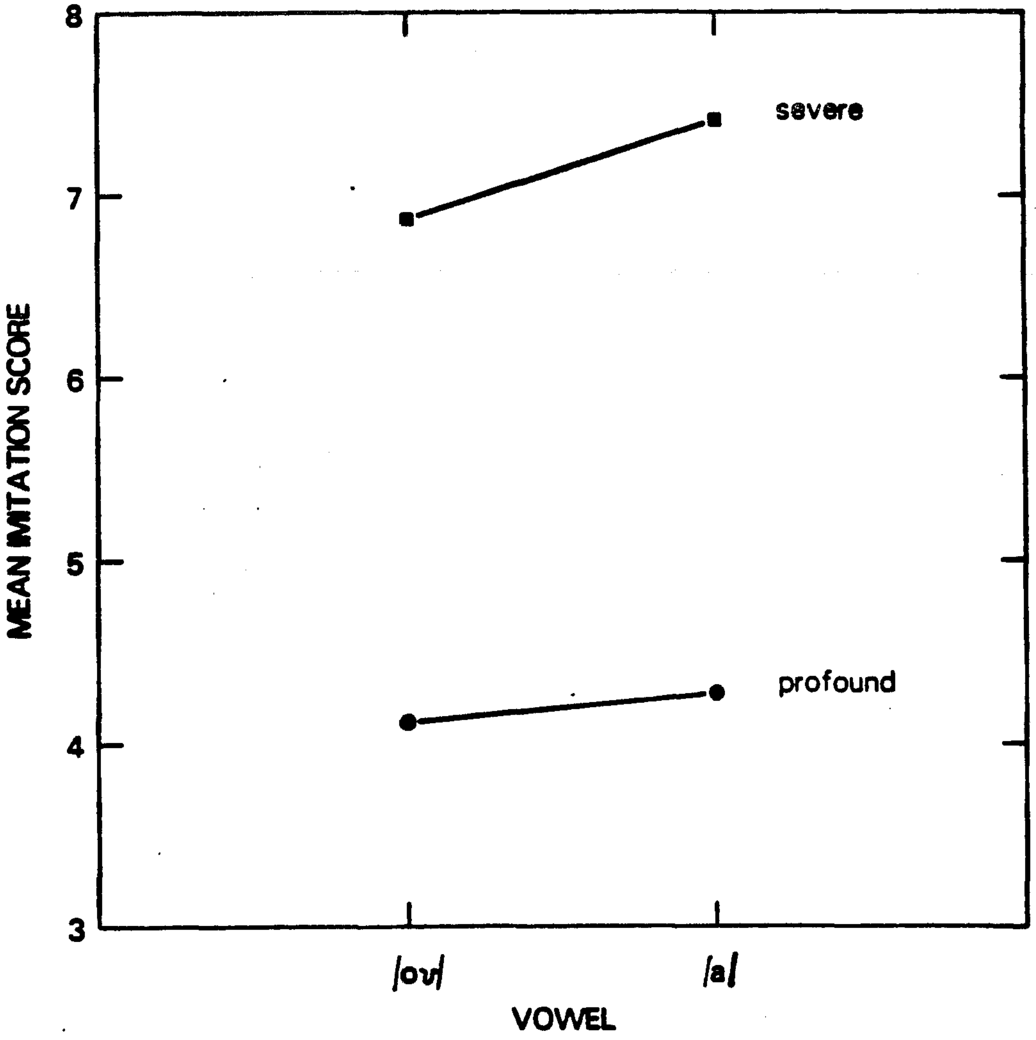


Figure 4.6:
Mean imitation scores of the severe and the profound hearing loss groups as a function of the vowel context.

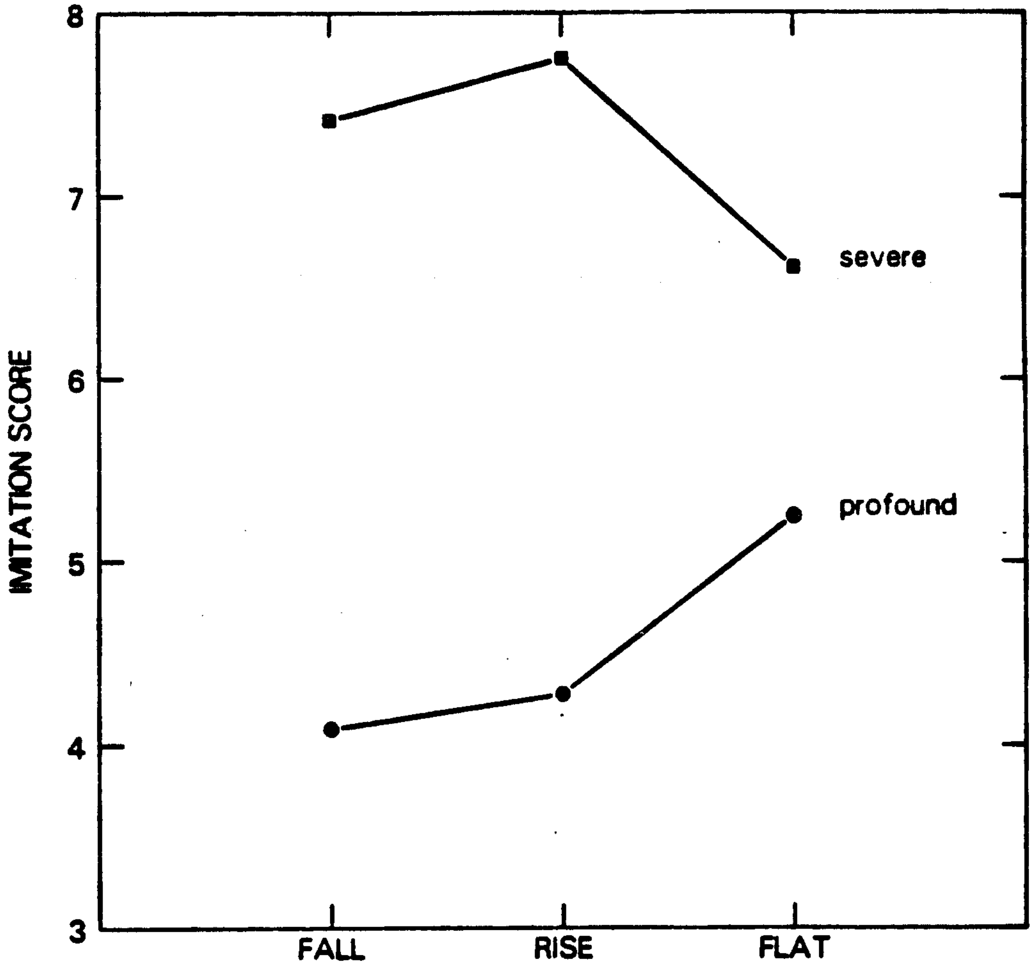


Figure 4.7-a:
Mean imitation scores of the severe and the profound hearing loss groups as a function of the intonation contour, for the one-syllable models.

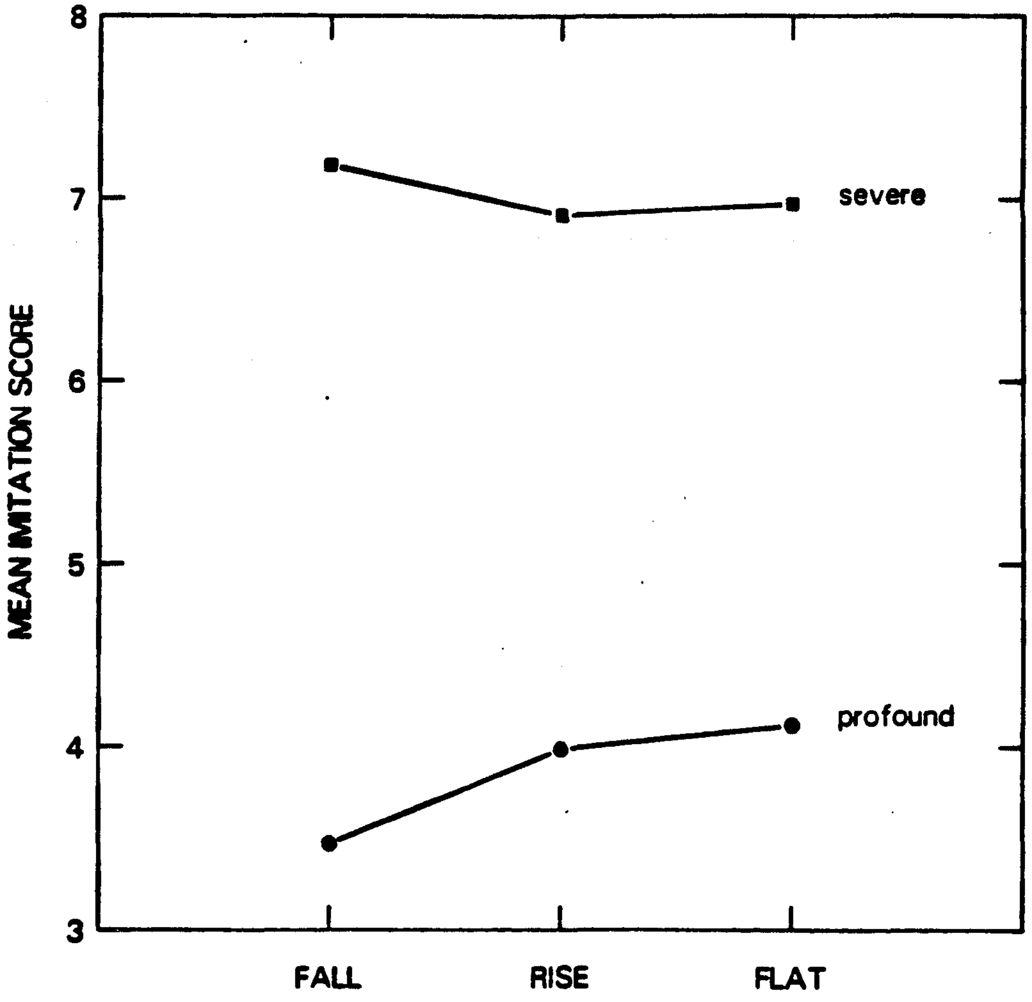


Figure 4.7-b:
Mean imitation scores of the severe and the profound hearing loss groups as a function of the intonation contour, for the two-syllable models.

Table 4.5: Mean imitation scores of the severe and the profound hearing loss groups for each contour type in each syllable pattern.

1 SYLLABLE

Hearing status	Fall	Rise	Flat
severe	7.41	7.75	6.61
profound	4.09	4.28	5.25

2 SYLLABLES

Hearing status	Fall	Rise	Flat
severe	7.18	6.91	6.97
profound	3.47	3.99	4.12

respectively. Table 4.5 provides the mean values on which the figures are based. The figures demonstrate that, in general, scores for the severe hearing loss group were higher than the profound hearing loss group for all types of contours. For the one-syllable stimuli both hearing loss groups follow similar patterns in the scores obtained for the falling and the rising contours. The flat contour, however, produces a different pattern. While the profound hearing loss group scores best on this contour, the severe hearing loss group scores the worst on this contour. For the two-syllable stimuli, both hearing loss groups follow similar patterns for the rising and the flat contour. It is the falling contour that produces a different pattern. While the severe hearing loss group scores the best on this contour, the profound hearing loss group scores the worst on the falling contour.

Since the flat contour model is unnatural for imitation i.e., it is not normally used in connected speech, it was hypothesized that the attempts to imitate this model complicated the scores. Therefore, an additional six-way analysis of variance with repeated measures was performed with only two levels of the contour variable. That is, the flat contour was excluded. This change, however, did not affect the mean scores and the analysis produced very similar results.

Listener effect

The results of the analysis of variance also revealed that the main effect of listener was significant (F(4)=48.33, $p < .01$). Figure 4.8 illustrates the mean scores for all hearing-impaired children as a function of listener. Table 4.6 provides the mean values on which the figure was based. The figure suggests that while listeners 3, 4 and 5 were similar in scoring the hearing-impaired children, listeners 1 and 2 were different from the others. They tended to give higher scores. Tukey's test of honestly significant differences ($p<.05$), confirmed this impression by demonstrating that the results of listeners 1 and 2 were significantly different from those of the other listeners.

The following interactions were found to be significant:

a) The interaction between the hearing status and listener (F(4,104)=10.08, $p < .01$).

Figure 4.9 demonstrates the change in scores as obtained from the two hearing loss groups as a function of the five listeners. Table 4.7 provides the mean values on which the figure is based. The figure illustrates that there was more variability among listeners in evaluating the severe hearing loss group, than in evaluating the profound hearing loss group. When the Tukey's test of honestly significant differences ($p<.05$), was used to determine the source of the significant findings from the ANOVA, it demonstrated that in the profound hearing loss group, listener 1 was significantly different from all the other listeners. In the severe hearing loss group both listener 1 and listener 2 were different from all the others. Listeners 3,4 and 5 were not significantly different from each other.

b) The interaction between vowel and listener ($\underline{F}(4,104)=4.40$, $p < .01$).

Figure 4.10 illustrates the change in mean scores of the two vowels as a function of the listener. Table 4.8 provides the mean values on which the figure is based. The figure demonstrates that the shapes of the two functions is similar. Listeners 1 and 2 tended to give higher scores than listeners 3,4 and 5 who were similar in their scoring. Once again the Tukey's test of honestly significant differences ($p<.05$), demonstrated that for both vowels listeners 3,4,5 were similar. Listeners 1 and 2 were significantly different from each other and from the rest of the listeners.

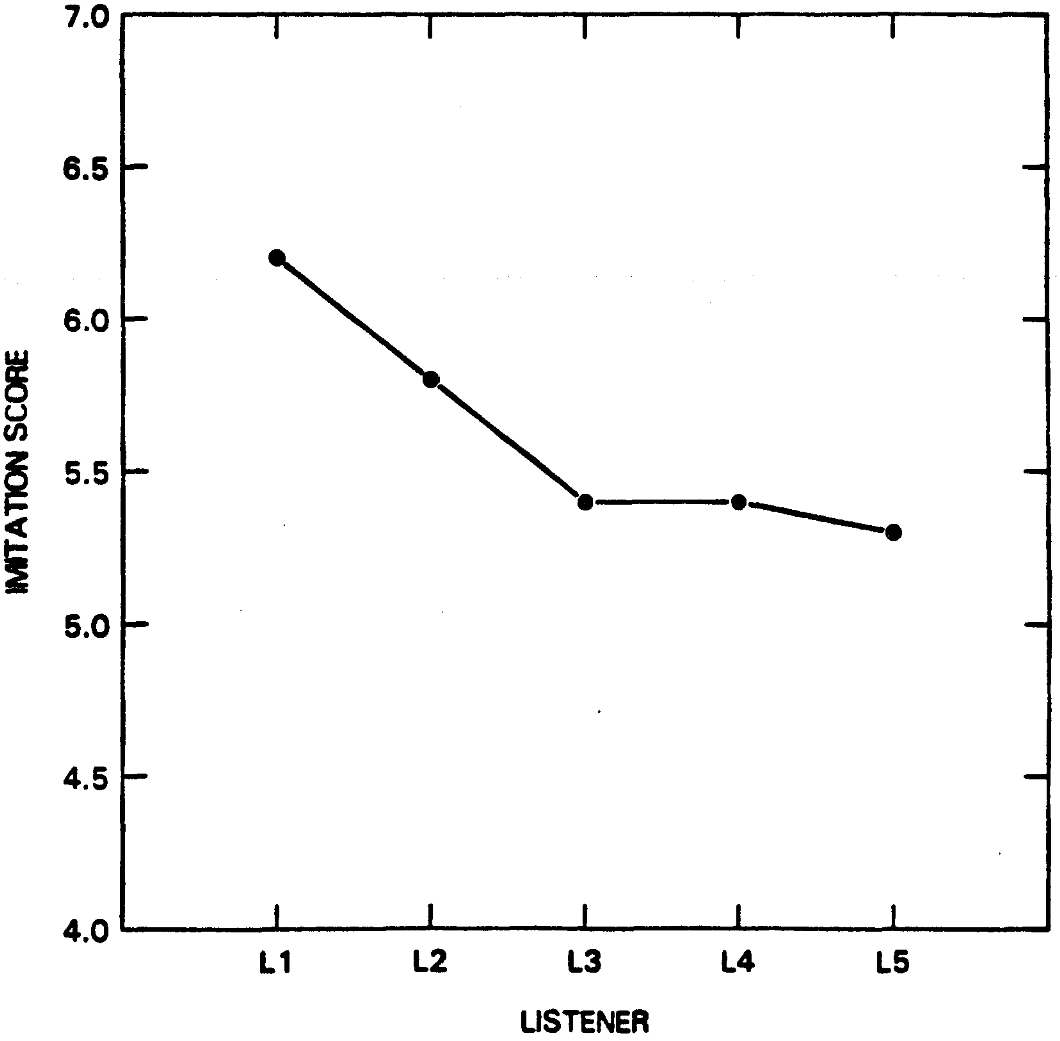


Figure 4.8:
Mean imitation scores of the hearing-impaired subjects as a function of listener.

Table 4.6: Mean imitation scores of the hearing-impaired children for all stimulus models as rated by each listener.

Listener	Mean
1	6.20
2	5.80
3	5.40
4	5.40
5	5.30

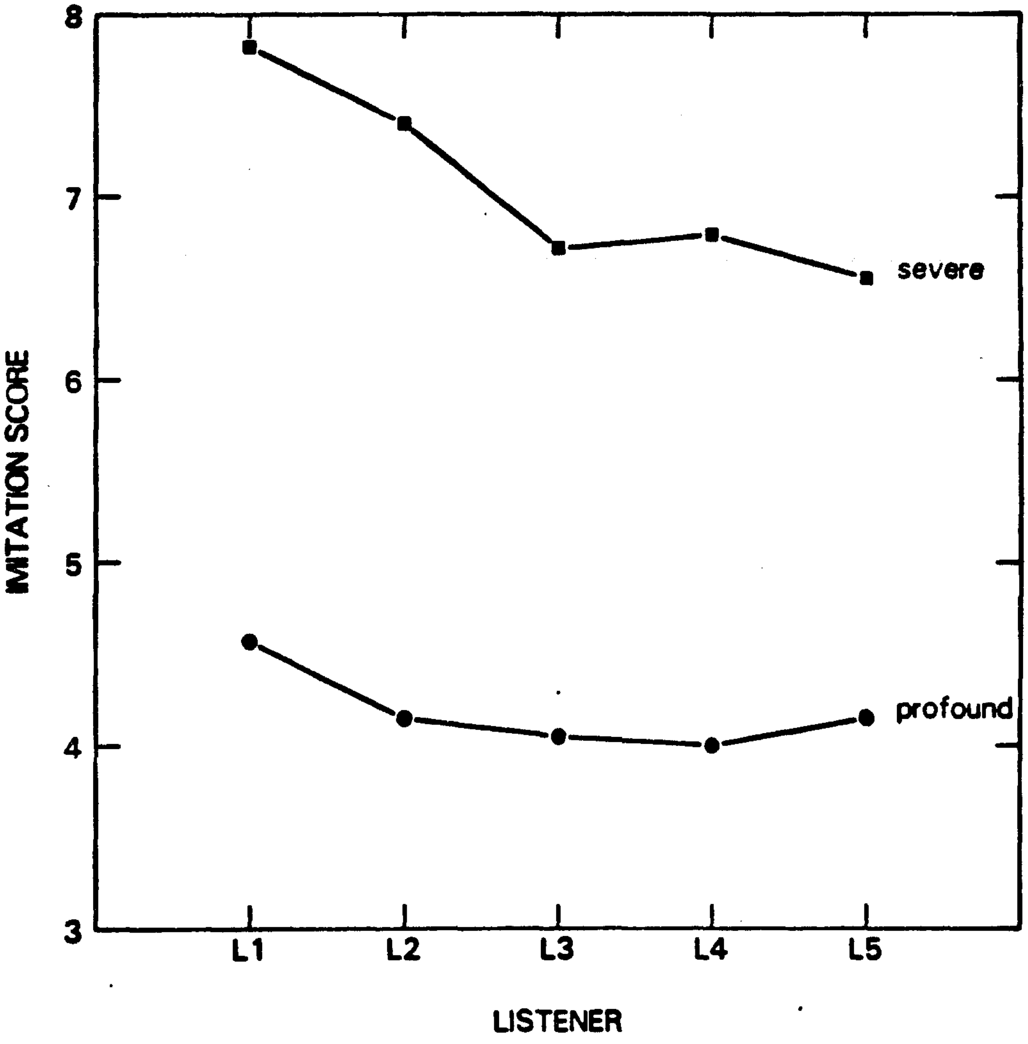


Figure 4.9:
Mean imitation scores of the severe and the profound hearing loss groups as a function of listener.

Table 4.7: Mean imitation scores of the severe and the profound hearing loss groups for all stimulus models as rated by each listener.

Listener	Severe	Profound
1	7.82	4.57
2	7.40	4.15
3	6.72	4.05
4	6.79	4.00
5	6.55	4.05

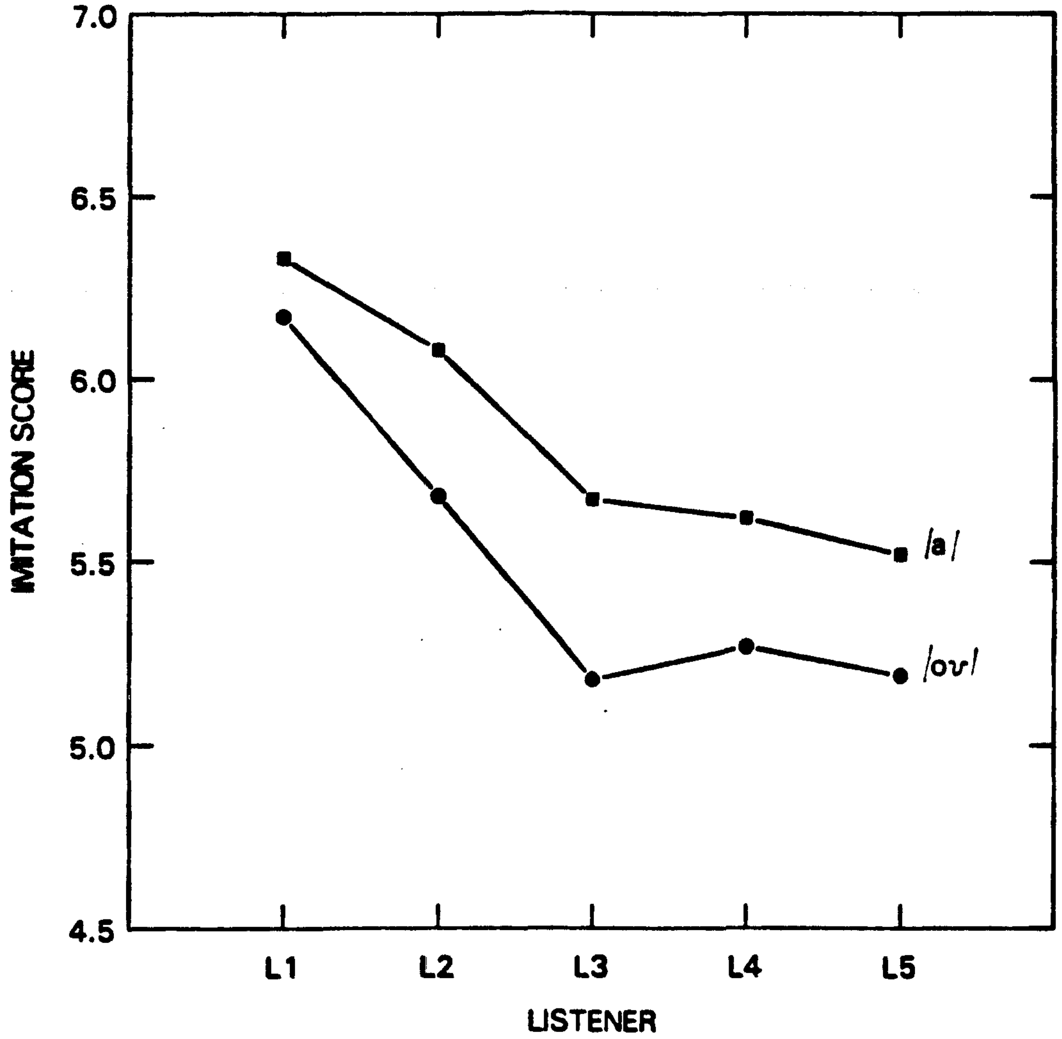


Figure 4.10:
Mean imitation scores of all hearing-impaired subjects for each vowel context as a function of listener.

Table 4.8: Mean imitation scores of all hearing-impaired children for each vowel as rated by each listener.

Listener	/a/	/oʊ/
1	6.33	6.17
2	6.08	5.68
3	5.67	5.18
4	5.62	5.27
5	5.52	5.19

c) The interaction between number of syllables and listener ($\underline{F}(4,104)=8.14$, $p < .01$).

Figure 4.11 and table 4.9 demonstrate this interaction. All the hearing-impaired children were rated higher on items involving one syllable than they did on two-syllable items. On the whole, however, the differences are small and the main effect of syllable is not significant. To consider the differences of this interaction in more detail, the Tukey test was used. The results of this analysis showed that in evaluating one-syllable stimuli listeners 3 and 5 were the same. Each one of listeners 1, 2 and 4 were significantly different from all the others. In evaluating two-syllable stimuli, listener 5 was similar to listener 3 and 4. Listener 4, however, was significantly different than listener 3. In addition, listener 2 and listener 1 were significantly different from all listeners.

d) The interaction between contour and listener ($\underline{F}(8,208)=11.13$, $p < .01$).

Figure 4.12 and table 4.10 demonstrate the change in the mean scores for the different contours as a function of listener. The pattern of the functions is different. Once again the use of the Tukey test revealed that, listeners 1 and 2 were similar in evaluating the flat contour stimuli and tended to give higher scores than listeners 3, 4 and 5 who were similar to each other. In evaluating the falling contour stimuli listener 1 was significantly different from all the others. Listener 2 is similar to listeners 3 and 4. Listener 3 is different from 4. Listener 5 is different from 2 and 4, but is similar to 3. In evaluating the rising contour stimuli listener 1 is different from all. Listeners 5, 3, 4 were the same. Listener 2 was similar to 3 but different from 4 and 5.

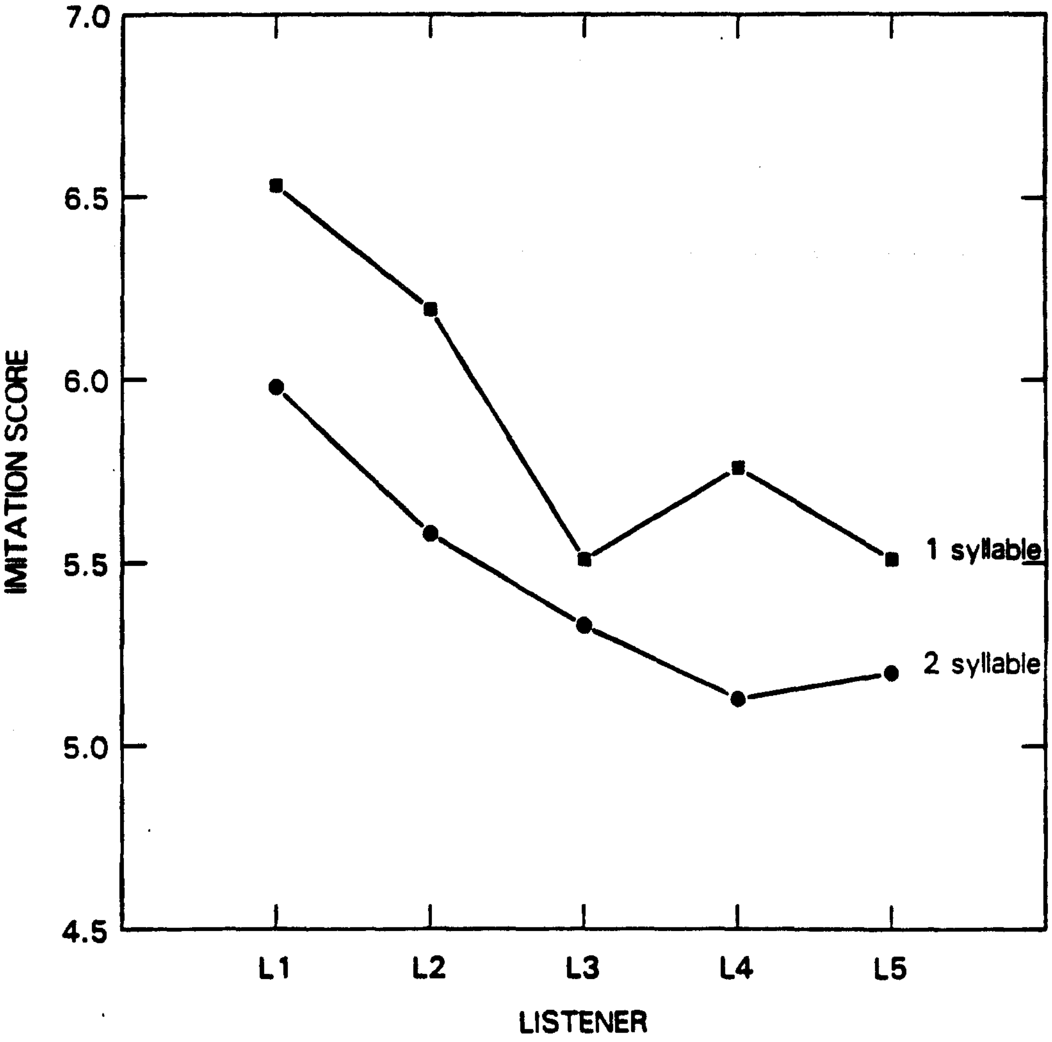


Figure 4.11:
Mean imitation scores of the hearing-impaired subjects for each syllable pattern as a function of listener.

Table 4.9: Mean imitation scores of the hearing-impaired children for each syllable pattern as rated by each listener.

Listener	One-syllable	Two-syllable
1	6.53	5.98
2	6.19	5.58
3	5.51	5.33
4	5.76	5.13
5	5.51	5.20

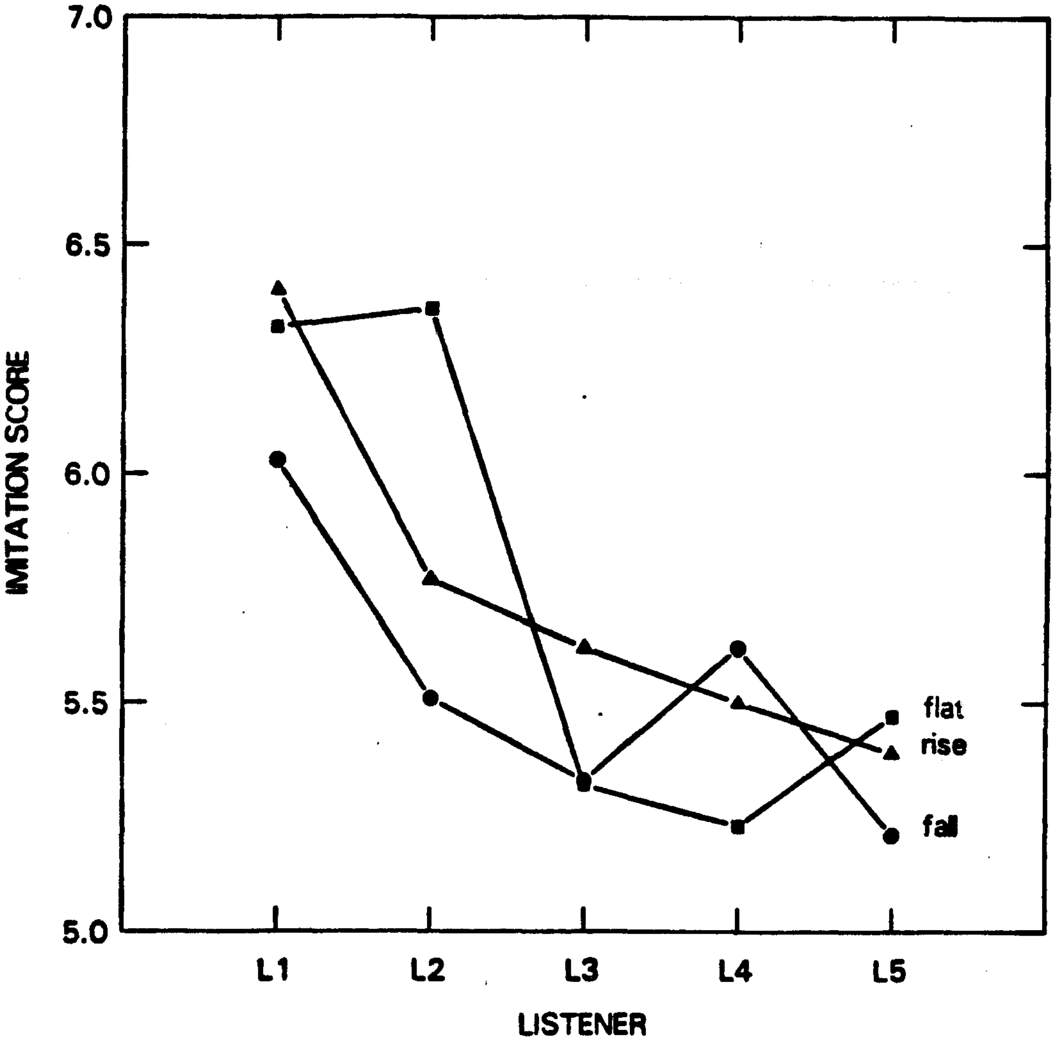


Figure 4.12:
Mean imitation scores of the hearing-impaired subjects for each contour type as a function of listener.

Table 4.10: Mean imitation scores of the hearing-impaired children for each contour type as rated by each listener.

Listener	Fall	Rise	Flat
1	6.03	6.40	6.32
2	5.51	5.57	6.36
3	5.33	5.62	5.32
4	5.62	5.50	5.23
5	5.21	5.39	5.47

Means for each of the 12 stimulus models as they were imitated by each child and were evaluated by each listener were calculated for the normal-hearing children as well. For these children each mean was computed from only two imitations of a specific model (first session only). A five-way analysis of variance with repeated measures was performed in order to measure the effect of age, listener, vowel, syllable and contour on the imitation performance. The age factor was the "between-subject" variable, while listener, vowel, syllable and contour were "within-subject" variables. The results of the analysis of variance appear in Appendix C-3. Effects with significant level of 0.05 or smaller were considered significant for the normal-hearing children.

As in the case of the hearing impaired, the main effect of listener was significant ($\underline{F}(4,32)=33.71$, $p < .01$). Figure 4.13 demonstrates the change in the mean score as a function of listener. Table 4.11 provides the mean imitation scores as evaluated by each listener. To consider these differences in more detail, post-hoc pairwise comparisons were performed using Tukey's test of honestly significant differences ($p<.05$). The results of this analysis revealed that listeners 3 and 4 were similar. Listeners 1 and 2 were similar . Listener 5, however, was different from all the others, by assigning significantly lower scores. (In the case of the hearing-impaired, in general, listeners 1 and 2 were different from the others, by assigning significantly higher scores).

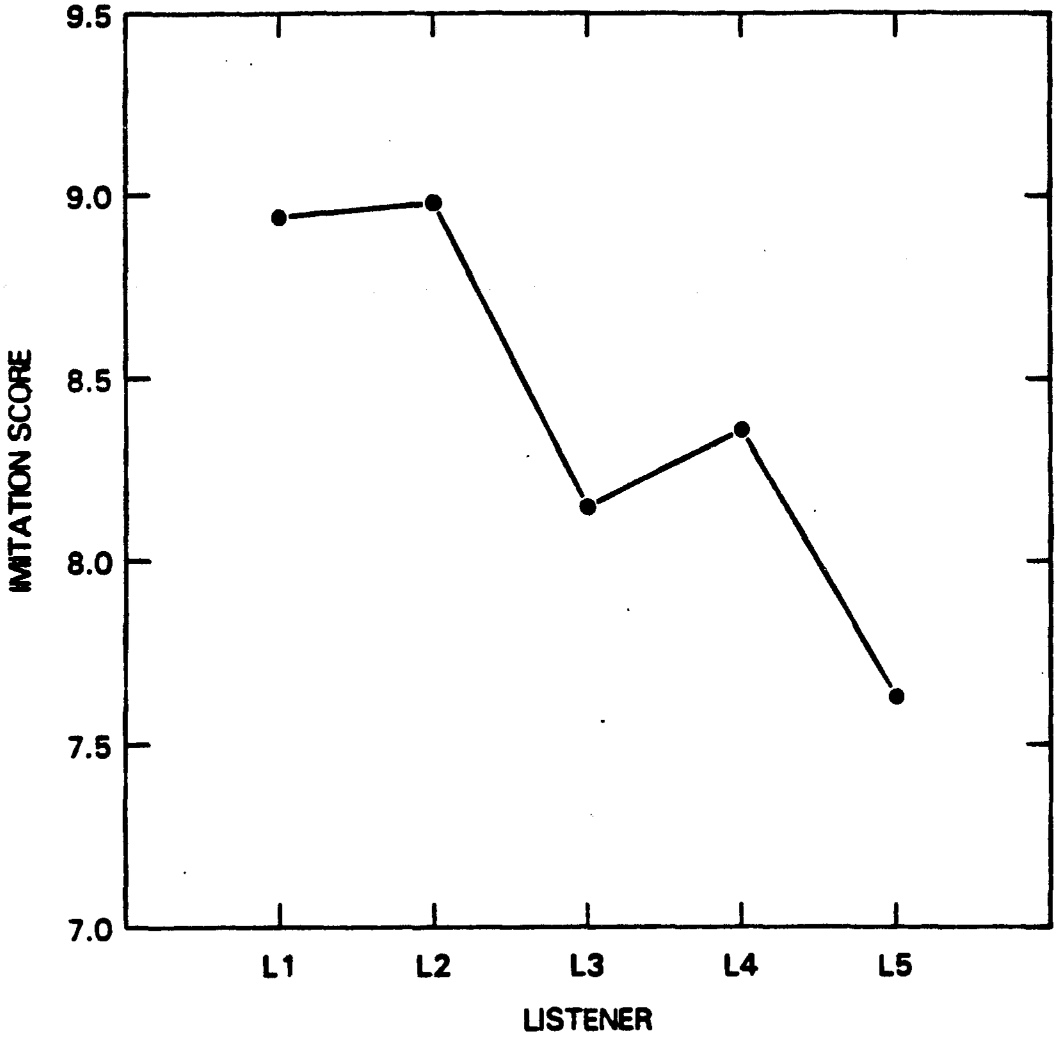


Figure 4.13:
Mean imitation scores of the normal-hearing subjects as a function of listener.

Table 4.11: Mean imitation scores of the normal-hearing children for all stimulus models as rated by each listener.

Listener	Mean
1	8.94
2	8.98
3	8.15
4	8.36
5	7.63

Only one two-way interaction , that between listener and vowel was significant ($F(4,32)=2.80$, $p < .05$). Figure 4.14 and table 4.12 demonstrate this interaction. The figure illustrates that the shape of the functions is similar for both vowels. (The shapes of the functions are similar to the ones obtained for the hearing impaired). Most listeners assigned higher scores to items involving the vowel /a/. The differences, however, are small and do not reach a level of significance. The same interaction was observed with the hearing-impaired children. The use of the Tukey test of honestly significant differences revealed the following: In evaluating imitations of the vowel /a/, listeners 1, 4, and 2 were similar. Listener 3 was different from listener 1 and 2. Listener 5 was different from all the others. In evaluating imitations involving /oʊ/, listener 1 and 2 were similar. Listener 3 was similar to listener 4 and 5. Listener 4 was different from listeners 1, 2, 5. Listener 5 was different from listeners 1, 2 and 4.

Of the three way and higher order interactions only one 3-way interaction between listener vowel and contour ($F(8)=2.55$, $p< .05$), and the 4-way interaction between listener vowel contour and age ($F(8)=2.35$, $p< .05$) were found significant.

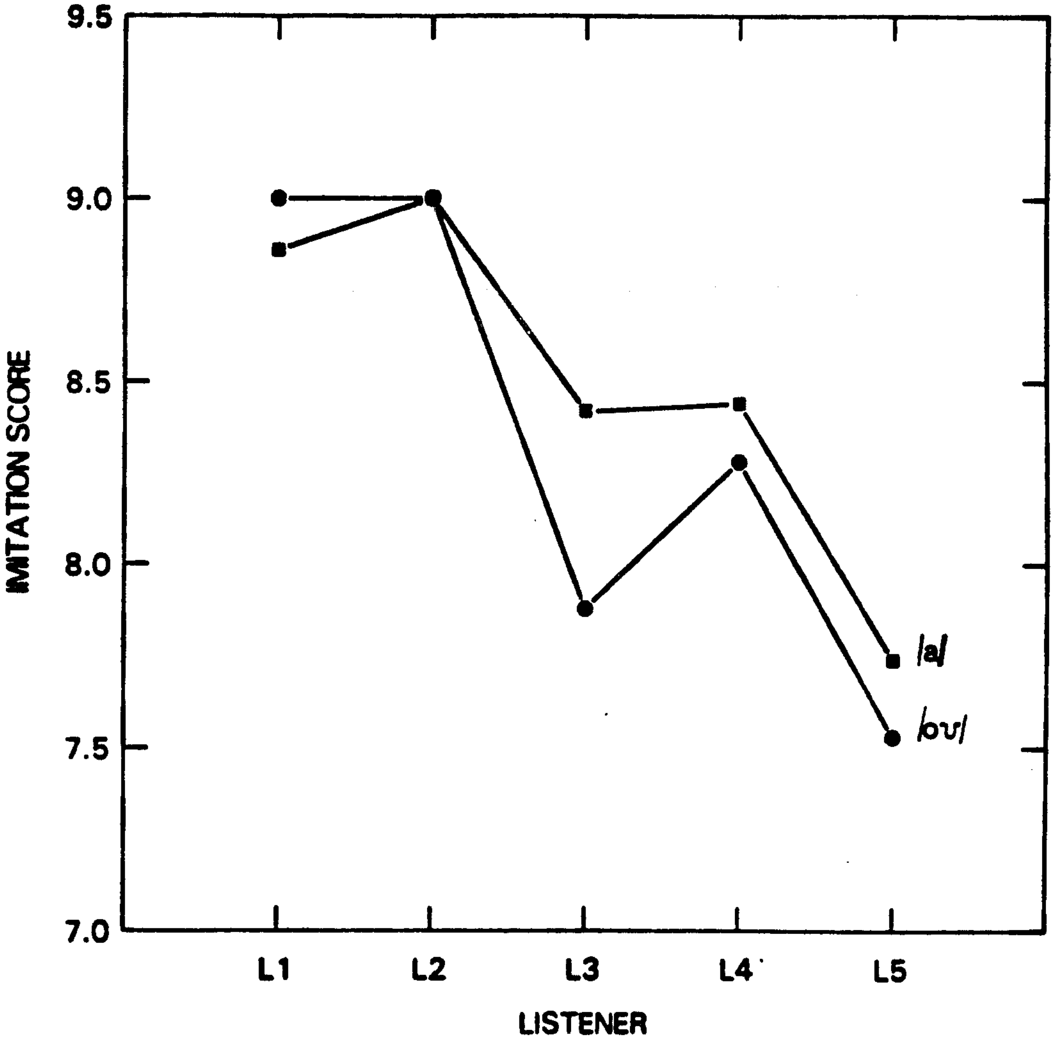


Figure 4.14:
Mean imitation scores of the normal-hearing subjects for each vowel context as a function of listener.

Table 4.12: Mean imitation scores of the normal-hearing children for each vowel context as rated by each listener.

Listener	/a/	/oʊ/
1	8.86	9.03
2	9.02	8.95
3	8.42	7.88
4	8.44	8.28
5	7.74	7.53

In summary, for the hearing-impaired children, there was a statistically significant listener effect as well as statistically significant interactions between listener and hearing loss, listener and vowel, listener and contour and listener and syllable. In general, scores obtained by listener 1 and listener 2 seem to be higher and significantly different from those obtained by listeners 3, 4 and 5.

Although listener variability was a significant factor, looking at the mean imitation scores of each hearing-impaired child as obtained from each listener (table 4.13), clearly suggests that all listeners evaluated the children similarly. The mean scores of the listeners differ by no more than 1.6 points. There was only one case (subject 4), where the difference between the lowest and the highest scores was 1.9 points. Nevertheless, both low and high scores fall within the "correct" range, i.e.>7.
From looking at the means while considering the pass/fail criterion, it is once again clear that the listeners evaluated the children in a similar way, with the exception of only one child (subject 20). This subject obtained failing mean scores from four listeners but a passing mean score from listener 2.

Table 4.13: Mean imitation scores of each of the hearing impaired as rated by each of the listeners.

Sub. #	Listener 1	Listener 2	Listener 3	Listener 4	Listener 5
1	9.29	9.08	8.35	8.47	7.82
2	8.18	7.55	6.86	6.75	7.00
3	8.46	8.19	7.18	7.30	6.75
4	9.11	8.49	7.79	8.28	7.21
5	7.35	7.32	6.65	6.62	6.25
6	6.51	6.22	5.96	5.90	5.75
7	5.58	4.61	4.80	4.08	4.47
8	7.12	7.33	6.68	6.35	6.25
9	2.78	2.94	2.14	2.62	2.78
10	3.25	2.86	3.17	3.55	3.24
11	5.75	5.40	5.25	4.55	4.89
12	3.17	2.82	2.32	3.12	2.83
13	2.50	2.67	2.35	2.79	2.35
14	5.28	4.35	4.83	4.17	4.77
15	5.51	4.67	5.17	4.57	4.61
16	7.30	6.51	5.90	5.87	6.17
17	7.42	7.00	6.30	6.11	6.26
18	7.43	6.69	6.29	5.79	6.11
19	6.60	6.29	5.61	5.71	5.36
20	3.89	4.22	3.65	3.14	3.61
21	7.01	6.68	6.07	6.37	6.08
22	6.61	5.79	5.57	5.21	5.43

Table 4.13 (continued)

Sub. #	Listener 1	Listener 2	Listener 3	Listener 4	Listener 5
23	8.82	8.44	7.18	7.64	7.61
24	3.03	2.40	2.43	3.26	2.61
25	8.26	8.01	7.14	6.86	6.72
26	2.76	2.62	2.46	2.83	2.74
27	9.53	9.35	8.39	8.78	8.22
28	7.71	7.32	6.58	7.03	6.69
29	8.44	7.85	6.99	6.83	7.17
30	2.89	2.69	2.54	2.78	2.90

CHAPTER V

Discussion

In this study, young and older severely and profoundly hearing-impaired children, as well as normal-hearing children, were evaluated through the use of two tasks. The first task was imitation, which involved perception and production. The second was a forced-choice task involving perception and selection. The main purpose of the study was to investigate whether a task of imitation of intonation contours can be used as an early indicator of a child's auditory perceptual capabilities. In addition, the study was concerned with the relationship between perceptual capabilities and the child's pure-tone sensitivity.

The discussion will focus on the above issues, and will compare the present findings with those of other investigations. Also, application of the imitation test as a clinical tool will be discussed.

The use of imitation of intonation as an early indicator of auditory speech perception ability

The present study demonstrated that imitation of intonation contours was an appropriate task for young children with severe and profound hearing loss. The results of the imitation task did not show significant difference between the performances of the two age groups, among the hearing-impaired children. (Except for the children with hearing losses in the 91-110dB range, from program a. This issue will be discussed further below). There was, however, a statistically significant difference between the young and the older normal-hearing children, the older children performing significantly better than the young ones. These results support the findings of previous studies. Koike and Asp (1981) demonstrated that five-year old normal-hearing children performed better than three-year old normal-hearing children on the Tennessee Test of Rhythm and Intonation Patterns (T-TRIP). In the Koike and Asp study the mean percentage correct for the five- year olds was 86.4%, while that for the three-year olds was 60.4%. V. Williams (1978) also demonstrated age difference in the performance of normal-hearing children on the T-TRIP. She observed a high correlation between age and the scores of normal-hearing children on the T-TRIP (r=o.82). She found, however, a low correlation (r=0.13), between hearing- impaired children's scores on this test and age.

It seems then, that although a task which requires imitation of intonation contours is simple, it is sensitive to age differences among normal-hearing children. In other words, there is a developmental pattern in performance of the task. Among the hearing-impaired, however, hearing loss is the major factor affecting performance, and subject heterogeneity masks any small age effects which may be present.

The only exception was in the case of the hearing-impaired children who belonged to the auditory program and had hearing loss in the 91-110dB range. Among these children, the older children performed significantly better than the younger children. It may be argued that these children are exposed to an auditory program and receive a great deal of auditory training and, therefore, like the normal-hearing children, their imitative performance does improve with age.

Thus, the foregoing discussion suggests that a task of imitation of intonation contours is suitable for the young hearing-impaired child.

The forced-choice task was presented for two purposes. The first was to validate the imitation task as a perceptual task among the older children. The second was to demonstrate the advantage of the imitation task over the forced-choice task among the young children.

For the older hearing-impaired children, the correlation between the imitation scores and the forced-choice scores was high ($\underline{r}(19)=0.91$, $p<0.001$). This high correlation suggests that the imitation task is a valid measure of a child's auditory perceptual capabilities. Part of the reason for this very high correlation was the poor imitative performance of the children who could not be tested via the forced-choice task. A significant correlation, however, was found between the scores of the children who passed the forced-choice task and their imitation scores ($\underline{r}(14) = .62, p < .01$). These findings support the assumption that the two tasks tap the same receptive ability.

As hypothesized, the forced-choice task was more difficult for all the young children whether normal-hearing or hearing-impaired. All of the young children except one, failed the forced-choice test. The one severely hearing-impaired child who passed the test was older than the rest of the young children. He was four years and two months old, and had only been included because of shortage of subjects meeting all selection criteria. These findings are consistent with the results of published literature. Piaget (1968) and Carter et al. (1972), for example, suggest that same/different judgements are too complicated for children of this age. According to these writers, a discrimination task involving same/different judgments should not be administered to children younger than five.

The above findings should not be interpreted as indicating that receptive abilities cannot be assessed in very young children independently of production. Studies of frequency discrimination by neonates have been obtained using habituation and dishabituation techniques. For example, Morse (1972) was able to demonstrate that infants can discriminate rising and falling intonation patterns by employing the sucking technique. In the present study, however, we were interested in a procedure which is easy to conduct, so that the test could be applied as a diagnostic tool in a therapy setting.

The data obtained in the present study provide convincing evidence of the ability of some subjects with sensorineural hearing loss in excess of 90dB to perceive intonation contours via the sense of hearing. Indeed, if we base conclusions only on those subjects who had had auditory-based training, the probability that a child will be able to perceive intonation contours appears to be very high for losses up to 110dB. These findings are in agreement with findings of previous studies which investigated the perception of intonation by hearing-impaired children (V. Williams, 1978; Engen et al., 1983).

There are other published studies, however, which were not able to demonstrate perception of intonation by severely and profoundly hearing-impaired children. (Boothroyd, 1984; McGarr, 1976). Data obtained by Boothroyd from children with hearing losses ranging between 75dB and 114dB indicated that the children performed at chance level on an intonation subtest (Boothroyd, 1984). Boothroyd, however, argued that this intonation subtest did not provide a valid measure of perceptual ability. He noticed that many of the subjects exhibited natural intonation patterns in their own speech, which strongly suggested that they had auditory access to intonation. Boothroyd suggested that the poor performance was probably due to the children's lack of experience in making conscious judgements about intonation patterns. McGarr's subjects, who were required to identify rising and falling contours, failed to do so, probably for the same reason.

It seems then, that with the use of an appropriate task, such as the imitation of intonation, it is possible to demonstrate that both severely and profoundly hearing-impaired children can perceive intonation patterns.

In the present study, all the severely hearing-impaired children performed well on the imitation task. The profoundly hearing-impaired, however, were divided into two different groups with respect to their imitation scores. While children in the first group were able to imitate intonation contours, children in the second group were not. The second group obtained very low scores, which suggested little or no relationship to the model they attempted to imitate. Thus, the imitation scores of the profoundly hearing-impaired children were bimodally distributed with clusters of scores of 4.7-7.9 and 2.5-3.7.

One may argue that passing scores were obtained by perception of secondary cues such as changes of intensity and duration that could have co-varied with fundamental frequency. We believe, however, that because of the use of synthetic speech in the present study, there was good control of stimuli. The use of synthetic stimuli allowed for strict control over each one of the variables (i.e. frequency, time, intensity) independently. It helped in maximizing similarity among the envelope patterns of the stimuli.

It seems then, that the use of imitation of intonation may help in distinguishing between hearing-impaired children who are able to imitate the intonation contours on the basis of spectral cues and those who are not able to imitate the intonation contours because their perception is limited only to the time and intensity aspects of amplified speech (provided that the child was exposed to appropriate training, an issue that will be discussed further below).

The classification of the severely and profoundly hearing-impaired children on the basis of their auditory perceptual capabilities, and not on the basis of their average hearing losses (500, 1000, 2000 Hz),has been suggested by previous researchers (Erber, 1980; Cramer and Erber, 1974; Erber, 1974; Risberg and Agelfors, 1978). In these studies, other types of stimuli and tasks which were suitable to older hearing-impaired children were used. The researchers demonstrated that while some children are able to perceive spectral information, others appear to be able to perceive only time and intensity cues from the acoustic speech signal. Marklein (1981), used a more detailed test, and therefore was able to categorize his subjects into three groups: (1) those who perceive only time and intensity cues, (2) those who perceive low frequency spectral cues in addition to the time and intensity cues and (3) those who perceive high and low frequency spectral cues in addition to time and intensity cues.

In contrast to the above studies, Gold (1978) was not able to show a statistically significant difference between the performances of her severe and profound hearing loss groups on two prosodic feature reception tests. It should be recalled though, that the boundary between her two groups was 80dBHL, and that most of her subjects had hearing losses less than 95dB. According to the findings of the present study and the published literature mentioned above, children with hearing losses up to 110dB may perform well on a test which requires perception of suprasegmental features, as long as they are exposed to an adequate training.

In summary, the results of the present study are supported by related published literature and suggest that imitation of intonation is an appropriate task for the young hearing-impaired child regardless of degree of hearing loss. Furthermore, the test produces a bimodal distribution of scores. This indicates that the test successfully groups the children with regard to their ability to use frequency-dependent cues, provided there has been adequate training.

Relationship between speech perception tests and pure tone sensitivity

There was a strong correlation between the child's ability to imitate intonation contours and his/her average hearing loss for 500, 1000 and 2000Hz ($\underline{r}(19)=-0.71$, $p< .001$). The hearing loss accounted for 50% of the variance in the imitation scores.

Similar correlations were noticed by Pickett et al. (1972), by Boothroyd (1984), and by Smith (1975), when they investigated the relationship between their speech perception tests and pure tone audiograms. In the Pickett et al. study, the correlation between the Rhyme score and the average pure tone threshold was -0.66 ($p< .01$). Boothroyd found a correlation of -0.78 between his open-set phoneme recognition test and the pure tone average. Smith (1975) demonstrated a correlation of -0.61 ($p< .001$), between her closed-set phoneme recognition test and the average pure tone audiogram.

All of these studies, as well as the present study, demonstrate that the correlation between the pure tone audiogram and speech performance skills is far from unity. Therefore, pure tone sensitivity cannot be used as the sole predictor of speech perception performance in an individual subject.

The present study demonstrated that the imitation scores of children with average threshold levels lower than 90dB were high. They ranged from 5.9-8.8. The scores were uniformly low for children with hearing losses greater than 110dB. They ranged from 2.5-3.2. The scores of children with hearing losses in the 91-110dB range, however, varied from a very low value (2.8) to a high one (7.9). Within this middle range, scores could not have been predicted from the pure tone audiogram. These findings are similar to results of other comparable tests that have been developed for older severely and profoundly hearing-impaired children (Erber, 1980; Cramer and Erber, 1974; Erber, 1974;

Erber and Alencewicz, 1976). The range of average hearing losses, where the predictive power of the audiogram was poor, and scores varied from a very low value to a high value, is different in each study. It was 85-100dBHL when The Spondee Recognition Test (Erber, 1974) was used, and 93-103dBHL when The Spondee Recognition Test version for the young child (Cramer & Erber, 1974) was used. When the CAT test (Erber & Alencewicz, 1976) was used, the range of extremely different scores was 95-110dBHL, and when the Auditory Numbers Test (Erber, 1980) was used the range was 100-113dBHL. These differences are, presumably, accounted for by the different stimuli, tasks, and presentation procedures that were used in the different studies.

V. Williams (1978), who presented the T-TRIP to hearing-impaired children, did not demonstrate a high correlation between the T-TRIP and average hearing loss of her subjects (r=-0.32). It should be recalled, however, that the range of hearing loss among her subjects was narrower than that in the present study and the previously discussed studies. All of the subjects in Williams's study had hearing losses less than 95dB, and over any narrow range prediction is poor.

Performance vs capacity

As discussed in the previous section, the hearing loss accounted for 50% of the variance in the imitation scores. The remaining variance may be a result of various sources. One important variable, which has been mentioned before, is the training program the child was exposed to. Speech perception tests, including the imitation test, measure the child's auditory performance on the tests and not necessarily his/her auditory capacity. Poor auditory performance can result from either poor auditory capacity or inadequate learning opportunity. It is possible that with more appropriate intervention or with training on a specific task, higher mean scores would have been obtained. The probable effect of training on the performance was, in fact, expressed in the findings of the study. Within the hearing loss range of 91-110dB, subjects from an auditory-based program performed better on the imitation task than subjects from a total communication program. In fact, within the 91-110dB range of hearing loss, all the subjects who belonged to the auditory-based program except one, passed the imitation task, while all the subjects from the total-communication program failed the imitation task. It should be recalled, however, that these findings were based on a small sample. Replication and expansion of this aspect of the research is clearly called for. Note also, that these data show only an association between training program and performance. Until confirmed by intervention studies, we must be careful not to assume a direct cause-effect relationship. Other factors such as parental involvement may have influenced both program selection and auditory development.

It is concluded that because of the significant effect of training program, failure on the imitative task cannot be interpreted as showing inability to perceive intonation unless the previous experience of the child is taken into account.

These results, however, do not necessarily suggest that one program is generally superior to the other. Since within the auditory program much time is spent on imitation tasks, it is not surprising that the children from this program performed better on this specific task. The total-communication program puts great emphasis on the language acquisition process. It is possible that on other measures of language ability the findings would be different.

Another variable that may account for some of the unexplained variance is the amplification used by the subjects. It is possible that better performance of all or some children would have been obtained with the use of more suitable amplification, and with the presentation of stimuli at optimal level for each individual.

The demonstration of the ability of profoundly hearing-impaired children to imitate intonation contours, which were only accessible auditorily, supports the concept of an auditory approach to habilitative intervention with profoundly hearing-impaired children. The results, however, do not suggest that this is the only approach that should be applied. There are profoundly hearing-impaired children who cannot benefit from an auditory-based approach. These children are not capable of perceiving frequency-dependent information and therefore, habilitation for them should emphasize other sensory channels. Also, among those children who are able to perceive changes in the fundamental frequency, non-auditory approaches may be necessary for the perception of segmental features.

Application of the test as clinical tool

A test which requires imitation of intonation contours may guide the clinician in setting appropriate goals at a very early stage of the child's development. The procedures used in this study might provide the basis for such a test, but some modifications are suggested:

1. The monotone contour was observed to be confusing for both producers and listeners. A possible explanation is that it is not a normal intonation pattern. The significant interaction between syllable contour and hearing loss, which was found among the results of the analysis of variance, supports this observation. The interaction indicated that for the one-syllable stimuli, imitation scores obtained by the severely and the profoundly hearing impaired followed the same pattern for the falling and rising contours. Nevertheless, the profound hearing loss group performed best on the flat contour, whereas the severe hearing loss group performed the worst on this contour. Better scores by the profound hearing loss group for the flat contour were not obtained when it involved two syllables.

We believe that for the one-syllable stimuli, imitations of profoundly hearing-impaired children were scored highly for the flat contour, partly because responses to all stimuli often resembled the flat contour. For the two-syllable models, this did not happen, probably because of the fact that just a flat contour spoken on only one syllable, was not scored highly when the stimulus had two syllables. When the analysis of variance was performed without the flat contour data, the interaction between syllable, contour, and hearing loss was not significant.

The above findings suggest that a test for clinical use should exclude the flat contour models.

2. Another problem was caused by recording the children with a microphone. The use of a microphone intimidated the young children. Their imitations were very faint and hesitant. For research purposes it was important to record the children's imitations with a microphone held close to their mouths. However, this does not seem to be necessary in a clinical situation, where the clinician can score the child directly. It can be argued that since the main effect of listener was found significant, an evaluation by a single listener may not be reliable. It may be recalled, however, that the mean scores of the subjects, as recorded by the listeners did not vary in their relative standings among the listeners, and were basically in agreement with each other. The significance was due rather to the more lenient criterion used by some listeners as compared to others.

In order to be able to apply the test to very young children (younger than three), it is recommended that the test be administered without a microphone.

3. The results of the present study suggest that the training program that the children were exposed to, affected their performance. Therefore, the test should be administered after training, as part of a diagnostic intervention program.

4. Finally, the results obtained on the test should be interpreted with caution. A high score on the imitation test implies that a child is capable of perceiving fundamental frequency contours. This knowledge may help the clinician in applying appropriate auditory training goals without wasting time on tasks that are too easy. A low score, however, may not necessarily indicate inability to perceive spectral information. It is also possible that a child did not have sufficient previous auditory experience, was not paying attention or was listening at an inappropriately low acoustic level during testing. Careful observation and repeated application of the test and other materials later on, is required before final classification.

This interpretation of the obtained scores is supported by the findings of Stark and Levitt (1974). In looking at the individual scores of their subjects on the prosodic feature tests (perception and production), they noticed that children who scored high on the reception test did not necessarily score high on the production test. Children, who did well on the production test, however, always scored at an average or above average level on the reception test. Thus, good producers were always good receivers, but good receivers were not always good producers.

Conclusions

1. Because of the high correlation between imitative and forced-choice performances in the older hearing-impaired children, we conclud that imitative performance has high validity as a measure of intonation perception.

2. Because of the absence of a significant age effect in the imitative data for the hearing-impaired children and only a small age effect in normal-hearing children, it is concluded that the imitative task is cognitively appropriate for children as young as three years of age.

3. Because of the failure of any child below four years of age to pass the forced-choice test, regardless of hearing status, it is concluded that this particular task is cognitively unsuitable for this age group.

4. The probability that a child will be able to imitate intonation contours is high for subjects with hearing losses of 90dB or less (regardless of the training program).

5. The probability that a child will be able to imitate intonation contours is low for subjects with hearing losses in excess of 110dB (regardless of the training program).

6. The probability that a child will be able to imitate intonation contours is roughly 50% for subjects with hearing losses in the 91-110dB range.

7. A major factor in the performance of children in the 91-110dB range of hearing loss is the amount of previous auditory training, with more training yielding higher scores.

8. Because of the significant effect of training program,

failure on the imitative task cannot be interpreted as showing inability to perceive intonation unless the previous experience of the child is taken into account.

9. Because of the agreement among listeners with respect to their evaluation of the child's imitative performance, the evaluation method is believed to be reliable.

Further research

If performance on the imitative task is to be used to supplement predictive power of pure tone thresholds, it is necessary to collect speech samples for intelligibility testing from older children and to correlate speech intelligibility with their imitation scores. Also, administration of another speech perception test which involves frequency-dependent stimuli to the older children, will enable the researcher to investigate how imitation of intonation contours correlates with another frequency-dependent perceptual test.

A longitudinal study involving children from three to ten years old will provide important findings. In this type of study, the imitation task could be administered in the early years. Collection of speech samples for intelligibility testing and the administration of other perceptual tests which require more knowledge of the language and more cognitive ability, could be accomplished in later years. In this way, the relationship between the imitation task and the child's speech intelligibility score could be further examined.

A second idea that evolved during the course of the study was to evaluate imitations in a forced-choice paradigm. That is, the listener would have to judge whether the attempted imitation was a rising or a falling contour, whether it was one-syllable or two-syllable utterance and whether it was the vowel /a/ or /oʊ/. Such a test would be more objective than a rating scale and might prove to be at least as valid and reliable.

A subjective impression of the examiner was that the voice quality of the young hearing-impaired children was better than that of the older hearing-impaired children, and many times even close to normal voice quality. This impression can be investigated by asking listeners to judge each imitation in terms of its producer: normal-hearing or hearing-impaired child.

Finally, the accoustic correlates of listeners' accuracy judgements should be investigated using spectrographic analysis. Although this method of evaluation is not practical for clinical use, it would help to establish the acoustic correlates of listener judgements of intonation contours.

APPENDIX A-1

Background data

CHILD	AVERAGE dBHL	AGE(years;months)	TRAINING PROGRAM
1.	90	5;7	B
2.	100	6;4	B
3.	90	5;6	B
4.	115	6;2	B
5.	85	6;7	B
6.	85	6;10	B
7.	110	5;6	B
8.	112	5;8	B
9.	95	5;9	B
10.	80	6;8	B
11.	87	3;9	A
12.	83	4;2	A
13.	60	3;5	A
14.	87	3;11	A
15.	80	3;4	A
16.	78	6;11	A
17.	85	6;3	A
18.	90	5;9	A
19.	82	8;1	A
20.	78	6;4	A
21.	113	3;9	A
22.	103	3;0	A

CHILD	AVERAGE dBHL	AGE(years;months)	TRAINING PROGRAM
23.	105	3;11	A
24.	102	3;9	A
25.	107	3;9	A
26.	112	5;7	A
27.	95	6;3	A
28.	108	10;3	A
29.	110	5;3	A
30.	103	6;4	A
31.	Normal hearing	5;10	
32.	Normal hearing	5;9	
33.	Normal hearing	6;0	
34.	Normal hearing	6;10	
35.	Normal hearing	6;10	
36.	Normal hearing	3;1	
37.	Normal hearing	3;6	
38.	Normal hearing	3;4	
39.	Normal hearing	3;7	
40.	Normal hearing	3;8	

Training program A=auditory

Training program B=total communication

APPENDIX A-2

Pure tone air conduction responses for all hearing-impaired subjects in dBHL.

CHILD	EAR	Frequency in Hz					
		250	500	1000	2000	4000	8000
1.	R	85	90	90	90	100	110
	L	105	105	95	95	95	NR
2.	R	90	100	100	105	90	100
	L	70	85	90	95	85	105
3.	R	105	100	95	95	85	75
	L	70	80	85	90	80	75
4.	R	95	95	95	100	90	90
	L	75	80	85	90	95	90
5.	R	70	75	85	80	70	75
	L	85	90	90	80	75	75
6.	R	85	95	105	110	NR	NR
	L	80	85	100	100	100	NR
7.	R	95	110	110	110	105	110
	L	100	125	125	125	120	NR
8.	R	95	100	105	120	125	NR
	L	75	90	105	105	125	NR
9.	R	100	120	NR	NR	NR	NR
	L	90	115	115	115	110	NR
10.	R	90	100	120	NR	NR	NR
	L	90	105	115	115	NR	NR
11.	R	90	100	105	NR	NR	NR
	L	55	75	95	90	90	80
12.	R	85	105	110	100	100	NR
	L	80	90	85	75	95	70
13.	R	40	50	65	70	70	DNT
	L	45	50	60	70	70	DNT
14.	R	80	85	90	85	75	NR
	L	NR	105	100	90	80	NR

15.	R	70	75	85	90	90	NR
	L	65	80	90	90	90	NR
16.	R	75	65	85	90	85	NR
	L	75	70	80	90	80	NR
17.	R	NR	100	90	100	95	75
	L	60	85	85	85	80	70
18.	R	70	85	95	90	80	NR
	L	80	90	105	110	115	NR
19.	R	45	70	90	85	80	70
	L	50	90	95	90	80	60
20.	R	70	85	80	70	70	75
	L	75	85	90	80	80	NR
21.	R	NR	110	NR	NR	NR	NR
	L	90	110	NR	NR	NR	NR
22.	R	85	90	105	NR	NR	NR
	L	80	100	NR	NR	NR	NR
23.	R	85	90	110	NR	NR	NR
	L	85	95	105	NR	NR	NR
24.	R	85	90	100	NR	NR	NR
	L	85	95	100	NR	NR	NR
25.	R	90	95	110	NR	NR	NR
	L	NR	100	105	NR	NR	NR
26.	R	95	115	NR	NR	NR	NR
	L	90	105	NR	NR	NR	NR
27.	R	85	100	90	95	75	80
	L	90	95	100	110	NR	NR
28.	R	85	95	115	NR	105	NR
	L	85	95	115	NR	100	NR
29.	R	90	110	NR	NR	NR	NR
	L	85	100	NR	NR	NR	NR
30.	R	80	85	105	NR	NR	NR
	L	75	95	105	110	NR	NR

NR=no response at maximum output of audiometer
DNT=did not test

APPENDIX B-1

INSTRUCTIONS FOR LISTENERS

Research objective: to investigate how well children imitate intonation patterns.

Procedure:

You will be listening to pairs of stimuli and asked to compare between the two stimuli on the basis of how closely the second stimulus matches the first. The first stimulus is computer generated and serves as the model. The second stimulus is the child's attempt to imitate the model.

Before starting the listening process please set the output level to a comfortable level and then continue with the rating of the imitations according to the following scale (rating sheets are attached for each cassette):

10	"Perfect"	-sounds like an echo
9		
8		
7	"Correct"	-The imitation is basically correct but there are differences between the imitation and the model (e.g. the range of the pitch changes).
6		
5		

4	"Poor"	-The imitation is very poor but the child does seem to have an idea of what is requested.
3		
2		
1	"No relationship"	-There is no perceptible relationship between the model and the imitation.

Special attention:

You are judging the accuracy of the imitation of the intonation pattern and therefore you should:

A. Ignore the accuracy of the imitation of the vowel (i.e. if the intonation is perfect and the vowel is wrong the imitation should be rated as "perfect"-10).

B. Consider the suprasegmental aspects in the imitation (i.e. one vs. two syllables. If the model consists of two syllables and the imitation consists of only one syllable, it should not be judged as a perfect imitation. Or, if the imitation is much shorter in duration than the model, it should not be judged as a perfect imitation).

C. Note that each of the cassettes will start with four practice pairs which are prerated on the practice sheets.

Each cassette contains 160 pairs which are presented in groups of 20. Each cassette lasts approximately 20 minutes.

D. Note that each pair will be presented only once. You may stop the tape if you need more time to make a decision. However, the tape may not be rewound for repetition.

Appendix B-2

Rating sheet

Listener name:

Cassette #:

Pair #	No relation			Poor			Correct			Perfect
	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

APPENDIX C-1

Analysis of Variance: Effect of Hearing Status, Age, Listener and Session on the Imitation Scores of the Hearing-Impaired Subjects

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
HEARING	839.631	1	839.631	29.40	0.000*
AGE	13.495	1	13.495	0.47	0.497
HA	1.531	1	1.531	0.05	0.818
ERROR	742.601	26	28.561		
LISTENER	45.089	4	11.272	48.33	0.000*
LH	9.429	4	2.357	10.11	0.000*
LA	1.973	4	0.493	2.12	0.084
LHA	1.319	4	0.329	1.41	0.234
ERROR	24.254	104	0.233		
SESSION	0.920	2	0.460	0.38	0.683
SH	0.133	2	0.066	0.06	0.945
SA	2.145	2	1.072	0.89	0.415
SHA	0.336	2	0.168	0.14	0.869
ERROR	62.367	52	1.199		
LS	0.581	8	0.072	1.51	0.154
LSH	0.430	8	0.053	1.12	0.350
LSA	0.529	8	0.066	1.38	0.207
LSHA	0.586	8	0.073	1.53	0.149
ERROR	9.983	208	0.048		

*SIGNIFICANT AT $p < 0.01$

APPENDIX C-2

Analysis of Variance: Effect of Stimulus Type on the Imitation Scores of the Hearing-Impaired Subjects

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
HEARING	3357.990	1	3357.990	29.39	0.000*
AGE	54.059	1	54.059	0.47	0.497
HA	6.151	1	6.151	0.05	0.818
ERROR	2970.178	26	114.237		
LISTENER	180.209	4	45.052	48.29	0.000*
LH	37.630	4	9.407	10.08	0.000*
LA	7.878	4	1.969	2.11	0.084
LHA	5.291	4	1.322	1.42	0.233
ERROR	97.018	104	0.932		
VOWEL	51.282	1	51.282	21.56	0.000*
VH	22.066	1	22.066	9.28	0.005*
VA	0.503	1	0.503	0.21	0.649
VHA	6.057	1	6.057	2.55	0.122
ERROR	61.841	26	2.378		
LV	4.846	4	1.211	4.40	0.002*
LVH	3.726	4	0.931	3.39	0.012
LVA	3.023	4	0.755	2.75	0.032
LVHA	1.585	4	0.396	1.44	0.225
ERROR	28.616	104	0.275		
SYLLABLE	51.631	1	51.631	3.16	0.087
SH	2.633	1	2.633	0.16	0.691
SA	35.016	1	35.016	2.14	0.155
SHA	73.504	1	73.504	4.49	0.043
ERROR	425.263	26	16.356		
LS	13.502	4	3.375	8.14	0.000*
LSH	1.265	4	0.316	0.76	0.551
LSA	0.266	4	0.066	0.16	0.957
LSHA	0.219	4	0.054	0.13	0.970
ERROR	43.113	104	0.414		
VS	4.690	1	4.690	2.60	0.118
VSH	5.072	1	5.072	2.82	0.105
VSA	4.531	1	4.531	2.52	0.124
VSHA	0.565	1	0.565	0.31	0.580
ERROR	46.823	26	1.800		
LVS	1.739	4	0.434	2.32	0.061
LVSH	0.690	4	0.172	0.92	0.454
LVSA	2.076	4	0.519	2.77	0.031
LVSHA	0.367	4	0.091	0.49	0.742
ERROR	19.483	104	0.187		

APPENDIX C-2 (CONTINUED)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
CONTUR	22.704	2	11.352	0.50	0.608
CH	136.441	2	68.220	3.01	0.058
CA	97.561	2	48.780	2.15	0.126
CHA	8.000	2	4.000	0.18	0.838
ERROR	1178.581	52	22.665		
LC	50.509	8	6.313	11.13	0.000*
LCH	4.956	8	0.619	1.09	0.369
LCA	1.474	8	0.184	0.32	0.955
LCHA	1.174	8	0.146	0.26	0.978
ERROR	117.989	208	0.567		
VC	15.978	2	7.989	2.98	0.059
VCH	2.825	2	1.412	0.53	0.593
VCA	1.179	2	0.589	0.22	0.803
VCHA	3.528	2	1.764	0.66	0.522
ERROR	139.401	52	2.680		
LVC	3.608	8	0.451	1.88	0.064
LVCH	0.902	8	0.112	0.47	0.875
LVCA	4.879	8	0.609	2.55	0.011
LVCHA	2.537	8	0.317	1.32	0.232
ERROR	49.818	208	0.239		
SC	2.389	2	1.194	0.37	0.693
SCH	72.097	2	36.048	11.12	0.000*
SCA	0.126	2	0.063	0.02	0.980
SCHA	3.785	2	1.892	0.58	0.561
ERROR	168.517	52	3.240		
LSC	3.307	8	0.413	1.60	0.127
LSCH	3.361	8	0.420	1.62	0.119
LSCA	0.705	8	0.088	0.34	0.949
LSCHA	2.000	8	0.250	0.97	0.463
ERROR	53.840	208	0.258		
VSC	0.817	2	0.408	0.23	0.793
VSCH	4.986	2	2.493	1.42	0.250
VSCA	1.363	2	0.681	0.39	0.680
VSCHA	4.899	2	2.449	1.40	0.256
ERROR	91.311	52	1.755		

APPENDIX C-2 (CONTINUED)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
LVSC	1.683	8	0.210	0.96	0.468
LVSCH	0.356	8	0.044	0.20	0.990
LVSCA	1.509	8	0.188	0.86	0.550
LVSCHA	0.743	8	0.092	0.42	0.905
ERROR	45.590	208	0.219		

*SIGNIFICANT AT $p < 0.01$

APPENDIX C-3

Analysis of Variance: Effect of Age and Stimulus Type on the Imitation Scores of the Normal Hearing Subjects

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
AGE	94.010	1	94.010	7.95	0.022*
ERROR	94.640	8	11.830		
LISTENER	154.123	4	38.530	33.71	0.000*
LA	6.625	4	1.656	1.45	0.240
ERROR	36.576	32	1.143		
VOWEL	3.920	1	3.920	0.49	0.504
VA	0.303	1	0.303	0.04	0.850
ERROR	64.130	8	8.016		
LV	7.740	4	1.935	2.80	0.042*
LVA	0.381	4	0.095	0.14	0.966
ERROR	22.086	32	0.690		
SYLLABLE	4.250	1	4.250	2.14	0.182
SA	3.450	1	3.450	1.73	0.224
ERROR	15.920	8	1.990		
LS	0.735	4	0.183	0.52	0.718
LSA	0.660	4	0.165	0.47	0.756
ERROR	11.213	32	0.350		
VS	2.600	1	2.600	1.33	0.281
VSA	2.733	1	2.733	1.40	0.270
ERROR	15.603	8	1.950		
LVS	2.168	4	0.542	1.17	0.342
LVSA	1.793	4	0.448	0.97	0.438
ERROR	14.830	32	0.463		
CONTUR	22.710	2	11.355	1.07	0.365
CA	16.785	2	8.392	0.79	0.469
ERROR	169.295	16	10.580		
LC	13.226	8	1.653	1.42	0.205
LCA	9.585	8	1.198	1.03	0.424
ERROR	74.563	64	1.165		
VC	1.265	2	0.632	0.25	0.784
VCA	0.917	2	0.458	0.18	0.837
ERROR	41.025	16	2.564		

APPENDIX C-3 (CONTINUED)

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
LVC	12.805	8	1.600	2.55	0.017*
LVCA	11.803	8	1.475	2.35	0.027
ERROR	40.183	64	0.627		
SC	13.675	2	6.837	1.70	0.214
SCA	7.740	2	3.870	0.96	0.404
ERROR	64.525	16	4.032		
LSC	1.645	8	0.205	0.36	0.936
LSCA	5.030	8	0.628	1.11	0.367
ERROR	36.216	64	0.565		
VSC	0.010	2	0.005	0.00	0.998
VSCA	2.852	2	1.426	0.34	0.715
ERROR	66.761	16	4.172		

*SIGNIFICANT AT $p < 0.05$

APPENDIX C-4

Analysis of Variance: Effect of Session on the Forced Choice Scores of the Hearing-Impaired Subjects

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
SESSION	0.094	2	0.047	1.63	0.214
ERROR	0.811	28	0.028		

APPENDIX D

Pilot Studies

Two pilot studies preceded the primary study.

Experiment 1.

The purpose of this study was to examine the applicability of the proposed procedures to normal-hearing subjects, i.e., to determine whether the tasks are cognitively appropriate for young children.

Subjects

In this experiment data were collected from 4 normal-hearing preschoolers aged 2-4 years.

Material

Stimulus materials consisted of recordings of live utterances of six contours on two syllables:

1. high-low (╮)
2. high-low rising (‾ ╯)
3. low-low rising (_╯)
4. low-high falling (_╮)
5. low-low (– –)
6. high falling-high falling (╮ ╮)

Each was presented on 4 syllable pairs: oh-oh, ma-ma, ba-ba, boo-boo. The intonation contours of the experimenter's utterances were verified through spectrographic analysis.

Procedure

The children were presented with two tasks: 1. imitation 2. discrimination via a forced-choice response.
For the imitation task, a total of 24 tokens (4 syllable pairs x 6 contours) all of which had been produced and recorded by the experimenter, were presented to the children through a tape recorder at 72dBSPL at the child's seat. The children were expected to imitate the tokens and recordings of the children's imitations were collected.
For the discrimination via the forced-choice task, the stimuli were arranged in series. Some of the series consisted of 3 intonation contours out of which 2 were the same and one was different. All the contours in a series were superimposed on either one syllable or two syllables. Other series consisted of 4 intonation contours on one syllable, out of which 3 were flat contours and the 4th was either a rising or a falling contour. The series were presented to the children through a tape-recorder at 72dBSPL and the children were expected to identify the different contour in each series.

In order to simplify this task, 3 or 4 similar boxes were used (depending on the number of tokens in the current series). The boxes were placed in front of the child and each one of them was associated successively with the sounds in each series. The child was expected to point to the box which was associated with the different contour. That particular box contained a tangible reward (a sticker).

For the discrimination via the forced-choice response, the experimenter recorded success or failure for each token during the task presentation.

For the imitation tasks Fo contours of models and children's imitations were determined from spectrograms. Peak Fo for each syllable was measured (except for pattern 2 (high-low rising) where lowest value of 2nd syllable was measured). Ratios of peak frequency of syllable 1 to syllable 2 were calculated and finally the correlation between the model values and the imitation values was calculated.

Results and Conclusions

Imitation:

(1) Children below 3 were able to perform the task. They were, however, intimidated by the recording procedure. Their imitations were faint, which presented difficulties for further analyses.

(2) Children above 3 performed reliably on the task. Correlations between selected frequencies on the contours of the models and the imitations were as follows:

subject	r values
1	.9
2	.9
3	.94

Discrimination via forced-choice response:

(1) Children below 4 years old could not perform this task. They did not understand the concept of same/different when the sounds

were presented.

(2) Children above 5 years old were able to perform the task reliably when:

a. the series consisted of only 3 contours;

b. the two similar contours in a series were flat contours.

The children did not perform reliably when series of 4 tokens were introduced. A possible explanation was that the presentation of four items introduced a problem of confounding memory. The children did not perform reliably when the series of tokens consisted of 2 similar contours which were not flat. It is possible that this kind of series was too confusing.

Experiment 2.

The purpose of this study was to examine the applicability of the procedures to hearing-impaired subjects, i.e., to determine whether the tasks are acoustically appropriate?
In this experiment data were collected from 9 hearing-impaired children ages 3-5 years old with hearing losses ranging from 80 to 115dB.

Material and procedure

The same material and procedure were used as in the first experiment. However, for the discrimination via the forced-choice response task, the conclusions of the 1st study were applied, i.e. only series of 3 contours were presented out of which two were flat contours and the 3rd was either falling or a rising contour.

Results and conclusions

Imitation:
Children with severe and profound hearing loss were able to follow the task as judged subjectively by the experimenter and objectively by spectrographic analysis.

Discrimination via forced-choice response:
Children above 5 years old were able to perform the task.

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