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Effects of Binaural Summation on Articulation Defective and Normal Speaking Children

June M. Imberman
Eastern Illinois University

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EFFECTS OF BINAURAL SUMMATION ON ARTICULATION DEFECTIVE AND NORMAL SPEAKING CHILDREN

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JUNE M. IMBERMAN

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CHAPTER I

STATEMENT OF PROBLEM

Discrimination may be defined as the process by means of which an organism responds to differences between stimuli (Fellows, 1968, p. 1). This process is assumed to begin with the exposure of the organism to a task situation involving stimuli to be discriminated and to end with the occurrence of a discriminating response (Fellows, 1968, p. 1). In ordinary language, to discriminate usually means the ability to detect differences between objects in our environment (Fellows, 1968, p. 1).

Discrimination learning is essential in the learning process and in the acquisition of speech and language. Discrimination learning encompasses many parameters. At first, the young child learns how to make gross visual, proprioceptive, kinesthetic, olfactory, taste, and auditory discriminations. As he progresses through life, finer discriminations are made in these areas; and, the normal child matures into adulthood having acquired the ability to make more difficult discriminations.

The young infant learns how to discriminate very early in life. The discrimination process starts at birth, and the child becomes more proficient with maturation and learning. Early in life, the child learns to make discriminations such such as, "Mama" from "chair." With maturation and learning, the child then proceeds to make finer discriminations such as, "Mama..." from "Ma, meet..."

There are many kinds of auditory discriminations. Research is still needed to explore the behaviors of auditory processing disorders related to: 1) attention to auditory stimuli; 2) differentiating sound from no sound; 3) sound localization; 4) discriminating sounds varying on one acoustic dimension; 5) discriminating sound sequences varying on several dimensions; 6) auditory figure-ground selection, and 7) associating sounds with sound sources. Without the ability to make such auditory discriminations, the child may become an an articulatory defective. The inability to discriminate speech sounds can retard the child's acquisition of speech and language (Van Riper, 1963, p. 197).

Speech sound discrimination as related to articulatory deficiency might be defined as: the ability to discriminate between phonetic elements within meaningful words (Flowers and Costello, 1963). In Flowers and Costello's (1963) study, speech sound discrimination is the auditory mechanism's ability to receive, transmit, and interpret words, sentences, and speech representing meaningful discourse. In effect, speech sound discrimination is considered the interpretation of meaningful sound stimuli by the central mechanism of hearing.

In speech pathology, the importance of sound discrimination has been emphasized by various investigators (Berry and Eisenson, 1956, p. 136; Van Riper, 1963, p. 249; Hall, 1938; Reid, 1947; Solomon, Webster and Curtis, 1960; Hansen, 1944; Travis and Rasmus, 1931; Kronvall and Diehl, 1954). It is the predominant opinion of these authors that auditory perception and particularly speech sound discrimination play a significant part in the development of normal speech articulation patterns (Berry and Eisenson, 1956, p. 136).

In helping a person acquire the concept of a standard sound, one against which he may later match his own utterance, four basic sets of techniques are used according to Van Riper (1963, p. 249): 1) isolation; 2) stimulation; 3) identification, and 4) discrimination. These are used to define the target, or the sound to be worked on. A model is hereby provided by Van Riper with which the child must match. Without such a model, it would be difficult for the child to correct himself. Ear training allows the child to define perceptually a standard pattern before the child is actually asked to attempt the new sound (Van Riper, 1963, p. 249).

Discrimination consists of comparing and contrasting the correct and incorrect sounds, both in isolation and in incorporation within regular speech. Without the ability to differentiate correct sound from error, the student becomes discouraged, and the treatment becomes blind drill (Van Riper, 1963, p. 257).

Listeners often seem to perceive intonation and stress by means of a process of "analysis by synthesis" in which they make use of their knowledge of the articulatory gestures that are involved in the production of speech (Liberman, Cooper, Harris, MacNeilage and Studdert-Kennedy, 1966). The input speech signal is decoded by listeners who use their knowledge of the constraints that are imposed by the human articulatory output apparatus. A motor theory of speech perception is suggested here, since there seems to be a close relationship between the inherent properties of the speech output mechanism and the perceptual recognition routine (Liberman, 1967).

Liberman and his colleagues have suggested that "... a reference to articulation helps the listener to decode the acoustic signal..." in the perception of the segmental phonemes (Liberman, Cooper, Harris and MacNeilage, 1963; Liberman, et. al., 1966). It seems that there is a more isomorphic relationship between the phoneme and articulation than the phoneme and acoustic signal. Studies of the role of proprioception in speech perception seem to substantiate this relationship.

Proprioceptive impulses originate in stretch or tension receptors in muscles, tendons, joints, and in the vestibular apparatus of the ear (Berry, 1969, p. 50). This appreciation of positions, movement, balance, and changes in equilibrium on the part of the muscular system is called proprioception or kinesthesis (Berry, 1969, p. 50).

Little attention has been given to kinesthesis in relation to comprehension and use of verbal symbols. But, it appears that this sense modality is as important as auditory perception (Berry, 1969, p. 50). As a result of extensive research of perceptual processes in language learning, Liberman and his colleagues (1962, p. 103) concluded that the appreciation of kinesthesis (proprioception) is even more important than auditory perception. They believe that the articulatory movements that the listener makes in reproducing the acoustic patterns determine the fine cues to perception of words (Berry, 1969, p. 50).

The function of proprioceptive feedback in speech should be recognized, not only in articulation, but in all aspects of speech production: postural set, gesture, respiration, and phonation (Berry, 1969, p. 52). Speech production is a neuromuscular synergy involving the entire body (Berry, 1969, p. 52). Shirley's (1963, p. 81) research indicated that the child builds fundamental movement patterns upon basic bodily postures; and, they, in turn, provoke the development of a sequence of differentiated phasic motor movements: postural shifts, directional signals, the rhythmic breath pulse associated with phonation, bodily and facial gestures, and articulatory patterns. No part of the sequence of motor learning can be ignored. If basic postures are not established, the child's appreciation of his body image--the balance and position of body parts--will be deficient (Berry, 1969, p. 53). According to Magoun (1963, p. 100), by countless synapses with cell aggregates in reticular, subcortical, and cortical areas, activation and inhibition operate to refine and elaborate the proprioceptive patterns and to integrate them with patterns of other modalities (visual, auditory) mediating discrimination of the verbal sequences.

Berry (1969, p. 54) states that proprioception is difficult to trace and to measure both in linguistic and nonlinguistic functions because muscle memory patterns are largely unanalyzable. Often young children report success in producing a series of syllables because "it feels right" (Berry, 1969, p. 54). Awareness of synergic relation and processing results from effective proprioceptive feedback (Berry, 1969, p. 54).

Experimental studies providing scientific support of the importance of proprioception in speech learning are few; these studies by speech scientists are promising but inconclusive. Work at present has been limited to the establishment of the value of tactile-kinesthetic cues in speech (McCroskey, 1958).

Auditory stimuli can be initiated by external means; the child himself must initiate proprioceptive movements of specific muscle synergies (Berry, 1969, p. 55). Auditory impulses can be measured electronically in the cochlea; no reliable measure of proprioceptive responses has been found (McCroskey, 1958). McCroskey (1958) concluded that auditory feedback was essential in monitoring duration and rate of speech; and, tactile-kinesthetic feedback was responsible for accuracy of articulation.

Multiple feedback circuits are in operation in speech learning. They must determine the priority, segregation, and integration of sensory-motor processes (Berry, 1960, p. 55). Visual, tactile-kinesthetic, and auditory impulses must be conjoined and in the appropriate sequences with respect to time and space. Feedback begins at the periphery and operates throughout every phase of linguistic coding.

A logical question now arises: If these modalities are inter-dependent, should the unisensory or multisensory approach be used in teaching the child who is severely handicapped in speech and/or language? Some educators (Buser and Rougeul, 1961, p. 553) argue that the child learns best through a unisensory approach; and, some neurological support could be advanced for this position.

It is known that neural assemblies in several receptor systems may use the same routes; a child with central nervous system injury or deficit may be able to accomodate only impulses from one modality in a unit of time (Eccles, 1961, p. 657). In the normal child, on the other hand, the same neurones can participate in countless specific patterns of activity (Eccles, 1961, p. 657). The reticular system of the neurologically handicapped child may be impaired so that he is unable to inhibit or to integrate the flow of sensory information from several modalities (Berry, 1969, p. 124). Berry (1969, p. 124) states that damage to neural assemblies in this and other integrative and projection systems probably result in lowered threshold at the synapses so that they are no longer selective. Diffuse perception, exaggerated responses, and feeble retention of the percept results here. Successive steps of unisensory, bisensory, and multisensory training probably should be taken in accordance with the child's developing abilities to handle neural traffic (Eames, 1956). A multisensory approach is suggested by many researchers in order to stimulate the speech defective child in as many modalities as possible (Van Riper, 1963, p. 262; Berry, 1969, p. 124; Berry and Eisenson, 1956, pp. 135-139). From this information, a training program utilizing successive steps beginning with unisensory and proceeding to multisensory stimulation for articulation defectives would be preferable. If there was some indication of neuronal breakdown, a unisensory approach would be more beneficial to the articulation defective child (Eccles, 1961, p. 657).

In speech therapy, those who possess articulatory errors are usually given extensive diagnostic examinations in order to determine the most viable modality(ies) for therapy success. The evaluation of a child's performance in the reception and processing of stimuli in single modalities should precede any attempt at measuring integrative functioning (Chalfant and Scheffelin, 1969, p. 56). At this time, there is no standardized set of clinical or experimental procedures for assessing either single sensory functioning or multiple-stimulus integration (Chalfant and Scheffelin, 1969, p. 56).

Some tests which have been used for the auditory channel also include discrimination tests (Templin, 1943; Wepman, 1958), the Auditory Decoding, Auditory Closure, and Sound-Blending subtests of the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy and Kirk, 1968). The Seashore Pitch and Rhythm Tests could be used. A test involving tapped auditory patterns may be useful to determine the ability to decode complex auditory patterns on a nonmeaningful basis (Chalfant and Scheffelin, 1969, p. 56).

Assessment of the visual channel include such tests as the Auditory Visual Pattern Test (Birch and Belmont, 1964a, 1965b), the Bender Gestalt Test (1938), the Visual Sequencing and Visual Closure subtests of the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy and Kirk, 1968), or the Developmental Test of Visual Perception (Frostig, 1964).

The assessment of the strengths and weaknesses of auditory, visual, and haptic-kinesthetic perception appears to be a necessary antecedent to testing multiple-stimulus integration (Chalfant and Scheffelin, 1969, p. 56). Little attention has been given to the assessment of kinesthetic and tactile perception. Some tests to assess kinesthetic and tactile perception are the Southern California Kinesthesia and Tactile Perception Tests (Ayres, 1965), and Werner's (1956) Tactile Figure Background Blocks. There is, therefore, a need to standardize tests for multiple-stimulus integration.

Trial therapy could also be undertaken in order to confirm diagnostic findings. Auditory training, for example, may be indicated for those who are unable to discriminate speech sounds, and for those for whom the auditory sense modality seems to be a viable route for the discrimination of speech sounds. The auditory modality may then be integrated into a bisensory approach or into a multisensory approach. Before making recommendations in therapy, more must be known about multiple-stimulus integration and all of its ramifications in relation to speech acquisition. Knowing this information would enable clinicians to make better diagnostic and treatment decisions. In this investigation, the modality of major concern is audition, and a child's ability to discriminate speech sounds.

Miller and Nicely (1955) investigated the resistance to distortion in auditory perception. They found that in low-pass filtering systems, the consonant confusions fall into consistent patterns. They also found that audibility was the problem for high-pass systems, and confusibility was the predominant difficulty in low-pass filtering (Miller and Nicely, 1955).

This distorted speech signal has been utilized in conjunction with the binaural summation principle, and has provided us with a diagnostic procedure in the investigation of central nervous system pathology, and possibly the assessment of central auditory-sound discrimination abilities (Flowers and Costello, 1963).

Many observers (Seebeck, 1846; Mach, 1864; Docq, 1870; Fletcher and Munson, 1933; Churcher, 1935; Causeé and Chavasse, 1942) indicated that a definitely supraliminal auditory stimulus sounds louder when heard with two ears than with only one ear; this phenomenon is considered binaural summation of loudness (Hirsh, 1948). Other observers (LeRoux, 1875; Tarchanow, 1878; Urbantschitsch, 1883; Bloch, 1893; Gage, 1932; Sivian and White, 1933) demonstrated that in order to produce a threshold judgment, an auditory stimulus does not need to be so intense when presented binaurally as it does when it is presented monaurally (Hirsh, 1948). Binaural summation at threshold refers to these indications that the absolute binaural threshold is lower than the absolute monaural threshold.

Flowers and Costello (1963) investigated the discrimination abilities of normal speaking and articulation defective elementary school children. They found that the severe articulation defective children lacked the ability to summate a filtered speech stimulus presented in one ear with a simultaneous unfiltered speech stimulus presented to the other ear.

The normal speaking children, on the other hand, could summate or receive these two different auditory stimuli simultaneously and obtain speech discrimination scores of approximately 90% as obtained in Bocca's (1955) study. It appears that binaural summation, or two separate monaural auditory stimuli forming one whole comprehendable speech message, takes place in the central mechanism of hearing (Flowers and Costello, 1963). The normal speaking children in Flowers and Costello's (1963) study were able to summate or to make a whole speech message out of two separate auditory parts.

Bocca, Calearo, Cassinari and Migliavacca (1955) utilized a low-pass filter system at about 1000 Hz and tested patients with supratentorial cerebral tumors. In nearly all cases, the discrimination score for distorted speech in each ear separately was assymetric and the scores were significantly lower in the ear contralateral to the lesion (Bocca, et. al., 1955).

Bocca (1955) developed a procedure with the use of filtered and subthreshold auditory stimuli to test what he termed binaural summation. Bocca and Calearo (1955) found that subjects with lesions of the temporal lobe lacked the summation ability when there was impairment in the cortical auditory area. In other words, when these subjects were given filtered speech in one ear at 45 dB above the individual's threshold, and then simultaneously given unfiltered speech at -5 dB below his threshold in the other ear, there was the inability to summate or discriminate approximately 90% of the words. Subjects with no central damage were able to summate these two auditory stimuli (Bocca, 1955).

The work relative to the central mechanism of hearing has been performed with normal hearing adults and with adults with suspected specific central nervous system pathology. Flowers and Costello (1963) tested second, third, and fourth grade children and also found that the articulation defectives could not summate the two auditory stimuli. A more extensive review of the pertinent literature on the topic of filtered speech and binaural summation will follow in the next chapter.

Purpose

The purpose of this study was to assess and compare the discrimination responses of unadulterated speech discrimination, distorted speech, and binaural summation techniques of children with one or more unresponsive articulation errors who have not improved in their misarticulated phonemes after at least one year of speech therapy, and normal speaking children. This study was designed to investigate the use of unadultered speech, filtered speech, and binaural summation conditions for differentiating the discrimination abilities of individual's who have not improved in speech therapy.

Problem

Specifically, the following two questions were posed at the outset of this study and were answered by the use of statistical analysis:

1) Are there significant between group differences in the three conditions of unadulterated discrimination scores, filtered speech scores, and binaural summation scores?

2) Are there significant within group differences in the three conditions of unadulterated discrimination scores, filtered speech scores, and binaural summation scores?

A third question was answered by inference which is:

3) Can the filtered speech and the binaural summation tests be utilized as diagnostic aids in the assessment of the central mechanism of hearing as related to speech-articulation deficiency?

Statement of Hypotheses

To provide answers to questions one and two, the following hypotheses were stated in the null form:

Between Comparisons.--

1) There is no significant difference between normal speaking children and articulation defective children in their unadulterated speech discrimination scores.

2) There is no significant difference between normal speaking children and articulation defective children in their filtered speech scores.

3) There is no significant difference between normal speaking children and articulation defective children in their binaural summation scores.

Within Comparisons.--

1) There is no significant difference between the unadulterated discrimination scores and the filtered speech scores in normal speaking children.

2) There is no significant difference between the filtered speech scores and the binaural summation scores in normal speaking children.

3) There is no significant difference between the unadulterated discrimination scores and the binaural summation scores in normal speaking children.

4) There is no significant difference between the unadulterated discrimination scores and filtered speech scores in articulation defective children.

5) There is no significant difference between the filtered speech scores and the binaural summation scores in articulation defective children.

6) There is no significant difference between the unadulterated discrimination scores and the binaural summation scores in articulation defective children.

The remaining question was answered on the basis of inference derived from interpretation of the statistical analysis.

CHAPTER II

REVIEW OF LITERATURE

Monaural Versus Binaural Hearing

Very often the consideration of binaural hearing in general texts is limited to the phenomena of localization and binaural beats (Hirsh, 1948). The ability of the binaural apparatus to summate stimuli that are introduced in both ears is a much neglected aspect of this topic. Most of the evidence in support of the binaural summation phenomenon comes from the comparison or contrast of binaural and monaural sensitivity.

In discussing the investigations of binaural summation in the past century, the following topic is divided into two separate areas. Many observations indicate that a definitely supraliminal auditory stimulus sounds louder when heard with two ears than with only one ear; this phenomenon will be referred to as binaural summation of loudness (Hirsh, 1948). Other observations demonstrate that in order to produce a threshold judgment, an auditory stimulus does not need to be so intense when presented monaurally (Hirsh, 1948). Binaural summation at threshold refers to these indications that the absolute binaural threshold is better than the absolute monaural threshold (Hirsh, 1948).

Binaural Summation of Loudness.--The literature did not deal with experiments on binaural summation until about 1930. The topic of binaural summation was buried in the experiments on binaural localization and binaural beats before that time. For this reason, it would be impracticable to report on all the earlier experiments on binaural summation. The following review of the literature will cover the significant experiments in the area of binaural summation.

Some otologists have been interested in the problem of binaural summation at the threshold, or above the threshold level (Bocca, 1955). On the other hand, physicists, physiologists, and psychologists have approached it from many angles since the time of Seebeck in 1846 (Bocca, 1955). Seebeck (1846), in an experiment on the observation of binaural beats, reported that a given amount of sound from his siren seemed louder to two ears than to only one. He observed that if a whistle of a siren was led through two tubes to the ears, it sounded weaker if one of the tubes was obstructed (Bocca, 1955). This empiric observation received further support by the work of Tarchanow in 1878. Tarchanow (1878) used currents produced by an induction coil connected to a telephone, and noted that a subthreshold sound in one ear became audible when heard with both ears. Tarchanow's experiences were confirmed by Urbanschitsch in 1893 when he demonstrated that the induced voltage necessary to produce in a telephone a barely audible sound, needed to be twice as high in monaural hearing as in binaural hearing (Urbanschitsch, 1893).

In 1933, Fletcher and Munson reported on the difference in the loudness level at which tones heard monaurally and binaurally sound equally loud. The difference in loudness level at which the two tones, one heard monaurally and one binaurally, sounded equally loud varied as a function of the loudness level of the tone heard monaurally (Hirsh, 1948). A difference of approximately 3 dB between the monaural and binaural thresholds was found here. Fletcher and Munson (1933) held that the loudness of a tone presented to two ears is just twice the loudness of the same tone presented to only one ear.

Binaural Summation at Threshold.--With the exception of some studies of Fletcher and Munson (1933) and of Causeé and Chavasse (1942), related to binaural summation of loudness at intensities well above threshold, all recent work on the subject concerns almost exclusively binaural summation at threshold (Bocca, 1955). It has been evidenced by a majority of observers (Gage, 1932; Hughes, 1937; Causeé and Chavasse, 1942; Shaw, Newman and Hirsh, 1947; Keys, 1947; Hirsh, 1948; Pollack, 1948; Bocca, 1955) that binaural summation does exist, that it is more than physical in origin, and that at the level of the central nervous system, a nearly perfect summation of the stimuli heard by the two ears takes place. These authors found the average difference between the monaural and binaural thresholds to be about 8 dB for pure tones and for speech (Hirsh, 1948, however, found a 3 dB difference for speech intelligibility). However, Sivian and White (1933) deny that there is any differences between monaural and binaural minimum audible fields which are not due to the greater sensitivity of the better ear. But, suitable methods show a substantial additive effect of the two ears at threshold (Shaw, Newman and Hirsh, 1947).

According to Keys (1947), the amount of binaural gain is dependent upon the amount of binaural stimulation, which in turn, is dependent up to a certain limit upon the size of the disparity in the intensity and frequency of the auditory stimuli presented to the two ears. When there is a discrepancy between the two ears, the general principle that arises is that sufficient correction must be made for the discrepancy, so that both ears are actually stimulated. Otherwise, the maximal increment in acuity will not be realized (Keys, 1947).

This criticism has been shown to be inconsistent by the research of Causeé and Chavasse (1942), and later by Hirsh (1948) by a preliminary equating of the sensitivity of the two ears, so that they should be functionally equal in binaural and monaural determinations. Complete agreement as to the presence, the site, and the amount of binaural summation has not yet been reached (Bocca, 1955).

One of the earliest observations on binaural summation at threshold was made by LeRoux in 1875 (Hirsh, 1948). He reported to his medical colleagues that the addition of a supraliminal sound to one ear would make a formerly subliminal sound in the opposite ear audible (Hirsh, 1948).

Tarchanow (1933) noted that supraliminal sounds heard with two ears sounded louder than the same sounds heard in only one ear. He noted further that the two sounds had to be of the same intensity and frequency in order to summate (Hirsh, 1948). In support of his generalization, he reported that persons with unilateral hearing loss do not show this summation but rather hear the sound always in their good ear (Tarchanow, 1933). This requirement of equated loudness or equal sensation level for binaural threshold summation has been shown to be correct, but the necessity for the two tones to have the same frequency does not seem to hold (Hirsh, 1948). Tarchanow (1933) was apparently the first to suggest that there must be some kind of central summating mechanism.

Binaural Summation with Masking Noise

The binaural summation principle has also been utilized under the conditions of masking noise. In this regard, binaural summation refers to the phenomenon in which the binaural threshold is better than the monaural threshold obtained for masked thresholds only when the phase angles between the two earphones are opposite for the tones and the noise

(Hirsh, 1948). This is true for filtered speech as well. It was found that the binaural summation was maximal in the quiet or in an anechoic chamber, and decreased as the level of masking noise increased (Hirsh, 1948). For lower frequencies and for speech not only does the binaural summation decrease to zero, but it also becomes negative (Hirsh, 1948). In other words, under the conditions of masking noise, the binaural threshold of a tone is poorer than the monaural threshold. In the quiet, however, the tone does sound louder binaurally than monaurally (Hirsh, 1948). Hirsh (1948) found that binaural threshold is shown to be poorer than monaural threshold indicating some kind of interaural inhibition. Interaural inhibition is thus exhibited when the binaural threshold of a tone is poorer than the monaural threshold (Hirsh, 1948). For listening to at least certain stimuli in the presence of loud thermal noise, two ears are not better than one (Hirsh, 1948). Interaural inhibition, as well as its antipode, interaural summation, increases as the intensity of the masking noise is increased (Hirsh, 1948).

The simple summative results which are obtained when thresholds are measured in quiet do not apply to thresholds of stimuli which are masked by noise (Hirsh, 1948). Interaural inhibition may be observed for certain interaural phase relations between the tone and the masking noise, and the binaural threshold is then poorer than the monaural threshold (Hirsh, 1948). For other phase relations, interaural summation may be observed (Hirsh, 1948). The adjective "interaural" has been introduced to modify both "summation" and "inhibition" (Hirsh, 1948). Interaural suggests an interaction between the ears rather than the independent action of two separate ears suggested by binaural (Hirsh, 1948). If masking were entirely a peripheral phenomenon, there should be no shift in the monaural threshold of a 200 Hz tone that is masked by noise in one ear when noise is added to the other ear, nor should there be further shifts when the interaural phase relation of the noise is changed; but, there are such shifts (Hirsh, 1948). It seems apparent that some central interaction must take place (Hirsh, 1948).

Binaural Summation with Filtered Speech

Factors in auditory perception have been identified and categorized as common auditory abilities and/or basic auditory factors (Karlin, 1942; Hanley, 1956; Solomon, Webster and Curtis, 1966). Resistance to distortion has been most intriguing (Flowers and Costello, 1963). The effects of low- and high-pass filtering and masking noise on speech reception abilities has been investigated by Hirsh, Reynolds and Joseph (1954). Peters (1953) investigated the effects of high- and low-pass filtering on speaker intelligibility and found that high-pass filtering differences were not significant; and, low-pass filtering was significant at the .05 level. Miller and Nicely (1955) followed the same procedures as Hirsh, et. al.

(1954) and found that in low-pass filtering systems, the confusions fall into consistent patterns which have been categorized in what the author called "confusion matrices." It was further observed that audibility was the problem for high-pass systems and confusibility was the major problem with low-pass filtering.

Binaural Summation with Filtered Speech in Patients with Central Nervous System Pathology

The distorted speech signal was further used with the binaural summation principle in order to aid the investigation of central nervous system pathology (Bocca, Calearo, Cassinari and Migliavacca, 1955; Bocca, 1955; Calearo, 1957; Jerger, Mier, Boshes and Canter, 1960; Flowers and Costello, 1963). The assessment of central auditory sound discrimination abilities may also be accomplished with the use of binaural summation techniques (Flowers and Costello, 1963).

Patients with Supratenrorial Cerebral Tumors.--Bocca, Calearo, Cassinari and Migliavacca (1955) tested patients with supratentorial cerebral tumors. A low-pass filtering system at about 1000 Hz was utilized in this study (Bocca, et. al., 1955). In nearly all cases observed, the articulation score for distorted voice of the two ears was evidently asymmetric; the score was definitely better in the ear contralateral to the lesion (Bocca, et. al, 1955). In all of these cases, the pathological findings confirmed the presence of an involvement of the temporal cortex (Bocca, et. al., 1955). Normal tone and speech audiometry failed to reveal any deviation from normal in both ears in nearly all of these cases (Bocca, et. al., 1955).

With normal subjects, Bocca (1955) developed a procedure which made use of filtered and subthreshold auditory stimuli to test for binaural summation. Words were spoken by an examiner, and delivered through two independent channels to the two ears of the subject (Bocca, 1955). Channel one provided attenuation, Channel two attenuation plus 500 Hz low-pass filtering (Bocca, 1955). The output intensity was adjusted each time at a level where no more than 40% discrimination score was attained in repeated tests (Bocca, 1955). The filter in Channel two did not allow more than 50% discrimination score when the stimulus was presented at 45 dB above threshold (Bocca, 1955). When the two stimuli were presented simultaneously, one to each ear of the subject, discrimination scores became much better, and reached a per cent value which was approximately equal to the addition of the two monaural discrimination scores (Bocca, 1955). This experiment provided evidence for binaural summation and binaural summation.

<u>Patients with Lesions of the Temporal Lobe</u>.--Bocca (1955), and then Calearo (1957) tested subjects with lesions of the temporal lobe and found that the summation ability was absent in cases where there was impairment of the cortical auditory area. Calearo (1957) concluded that the binaural summation

test offered evidence for the assumption that a normal binaural summation can be obtained only when both central auditory areas are intact. Calearo (1957) further stated that his experimental results offered some cue to the localization of the lesion even though he admitted that it was still difficult to interpret such a finding. This author (Calearo, 1957) also believed that these tests could be used to evaluate the central mechanism of hearing.

Patients with Parkinson's Disease.--Jerger, Mier, Boshes and Canter (1960) evaluated auditory integration with the "SWAMI" test--speech with altering masking index. This was used to investigate the behavior of patients with Parkinson's disease (Jerger, et. al., 1960). The tasks involved listening to low-pass filtered phonetically balanced words in each ear separately, and then listening to phonetically balanced words while .05 second bursts of thermal noise at a level 20 dB higher than the speech were alternated between the ears (Jerger, et. al., 1960). In effect, the words are virtually unintelligible through either earphone singly. The noise bursts mask out all or part of most of the words (Jerger, et. al., 1960). While listening through both earphones, the listener experiences an illusion in which bursts of noise are localized in the ears, but the words are heard in the center of the head (Newby, 1964, p. 182). As a result, the words are understood easily, and the discrimination score is usually between 90-100% (Newby, 1964, p. 183). The summation phenomenon took place in the "SWAMI" test as well.

Binaural Summation with Filtered Speech in Articulation Defective Children

Flowers and Costello (1963) attempted to assess and compare the responses to distorted speech and binaural summation techniques of children with severe and multiple articulation problems, and normal speaking children in the second, third, and fourth grades. They (Flowers and Costello, 1963) examined children who were suspected of having subtle abberations of central hearing (reasons unstated in the article). Their methodologies were based on Bocca's (1955) techniques. Each subject was given tests of filtered speech and binaural summation with the use of a picture-word test. The results indicated that the control group responded significantly better than the experimental group on the talk-back test in both the filter and binaural summation conditions (Flowers and Costello, 1963). The children with severe articulation problems had more difficulty with the distorted speech signal than did the normal speaking children (Flowers and Costello, 1963). Flowers and Costello (1963) concluded that the filtered speech and binaural summation tests could be used as diagnostic aids in the assessment of the central mechanism of hearing as related to speech-articulation deficiency.

No studies have been done on the effects of filtered speech and binaural summation techniques on fifth and sixth grade children with severe articulation problems who have not responded to speech therapy after at least one year, and normal speaking children of the same age. The writer speculates that these children who have not responded to therapy may have subtle abberations of central hearing. The need for further investigation in this area follows logically from the review of literature. The present study will generally follow the methodologies of Flowers and Costello (1963) based on Bocca's (1955) research.

CHAPTER III

SUBJECTS, PROCEDURE, EQUIPMENT

Preliminary Study

The purpose of this preliminary study was to determine the optimal filtering and unadulterated speech discrimination levels to be presented to the 60 subjects in the major part of this investigation.

Subjects.--A total of six normal speaking public elementary school children in the fifth and sixth grades (3 males and 3 females), whose chronological ages ranged from 10 years, 2 months, to 11 years, 10 months, served as subjects in this preliminary investigation.

Method of Selection and Assignment.--These six children were selected from the fifth and sixth grade children known by a Department of Speech Pathology and Audiology member. The children were from the East Central Illinois elementary school normal speaking population. They were children with no known hearing losses, and were selected for their availability. No student was studied who had a speech reception threshold (SRT) poorer than 10 dB in either ear.

<u>Equipment</u>.--An IAC 160 3A audiometric suite equipped with a Beltone 15-C two-channel audiometer (ISO) with TDH-39 earphones was utilized in this investigation. An Allison Model 25 filter was also used in conjunction with Channel two of the audiometer in order to present filtered speech to the subjects.

In order to establish SRT's for each subject, the recorded version of the C.I.D. Auditory Test W-1, List A, was presented to each child. Recorded version of the C.I.D. Auditory Test W-22, List 1A was employed to determine unadulterated speech discrimination scores at threshold level (0 dB re SRT) in the right ear. The right ear was chosen arbitrarily as the ear to receive the unadulterated speech discrimination task. Recorded versions of the C.I.D. Auditory Test, Lists 2A, 3A, and 4A were utilized in order to determine the optimal filtering levels. The left ear was chosen arbitrarily as the one to receive the filtered speech. These five recordings had never been used prior to this investigation.

<u>Procedure</u>.--Each of these six children was examined individually. Each subject was seated in a chair against the east wall of the audiometric suite in order to minimize extraneous noises, and to insure uniform testing conditions. The suite was lighted adequately. Amplifier output was adjusted so that zero reference on the audiometer attenuators corresponded to 18.2 S.P.L. The Allison filter was connected

to Channel two so that filtered speech could be presented in the left ear.

Earphones were placed on the subject and the recorded version of the C.I.D. Auditory Test W-1, List A, was used to obtain monaural speech reception thresholds. Oral responses were transmitted to the examiner in the control room of the suite.

SRT was then determined as follows: At approximately 20 dB above the examiner's estimate of the subject's threshold, testing began. The stimuli were then attenuated in 5 dB steps to inaudibility, increased again to audibility, and ultimately the level at which the subject could repeat three out of six spondee words was determined as his SRT (1 dB level). If the subject did not repeat 50% of the words--that is, if he repeated four out of six and two out of six at succeeding levels, the level at which he repeated two out of six was considered his SRT.

For the following discrimination tasks, the C.I.D. Auditory Test W-22 lists were used. These phonetically balanced words are reliable with inter-test reliability established at .91 or better and have been shown to be equivalent in their inter-changeability of lists (Ross and Huntington, 1962). The W-22 lists were chosen because of their availability, ease of administration, and known performance with normal hearing subjects under undistorted conditions. For each of the following tasks, 50 of the W-22 words were administered.

Each subject was instructed that he would hear the various auditory conditions and that the discrimination words would be preceded by the carrier phrase, "You will say," and that he should say the word that he heard. Each subject was also oriented to each of the test conditions by permitting him to hear an example of the type of auditory stimulus that he was to receive. The examiner said, "How are you today?" in each of the test conditions. These four C.I.D. W-22 lists were chosen and presented in a random order to control for ordering effects.

To find the optimal unadulterated discrimination score, List 1A was presented to the subject through Channel one of the audiometer at 0 dB re his right SRT. This level was chosen in order to find the frequency cut-off that permitted a maximum unadulterated discrimination score of approximately 50% in the right ear (Bocca, 1955). Bocca (1955) used a -5 dB level re the subject's right ear SRT in order to obtain less than a 40% discrimination score. For the purposes of this study, a 0 dB level re the subject's right SRT was employed since these were young children with SRT's of less than 5 dB. For this reason, it was virtually impracticable to use a -5 dB level re the subject's right ear SRT. This limitation can be attributed to the inability of the audiometer used in this study to obtain thresholds that are below 0 dB.

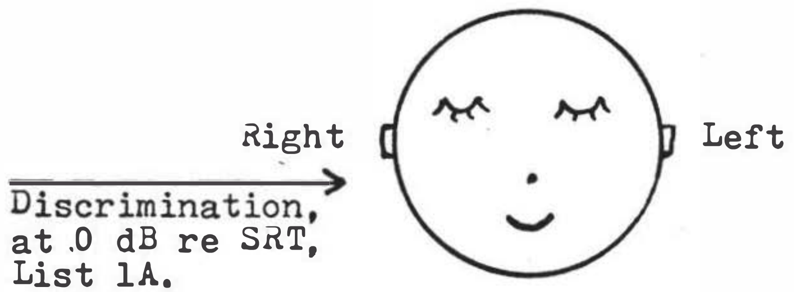
To determine the optimal low-pass filtering cut-off, and hence, the filtered speech scores, the methods similar to Bocca's (1955) were used. One of the C.I.D. Auditory Test W-22 lists, either 2A, 3A, or 4A, was then presented to the subject through Channel two of the audiometer on a random basis at various low-pass cut-off filtering levels at 40 dB re his left ear SRT. These low-pass filtering levels only permitted the frequencies below the specified cut-off range to pass through to the subject's left ear. The three low-pass cut-off levels chosen for this study were 780 Hz (List 2A), 720 Hz (List 3A), and 660 Hz (List 4A), respectively. These levels were chosen to identify the frequency cut-off that permitted a maximum discrimination score under filtered conditions of approximately 50% in the left ear (Bocca, 1955). The filtered speech score was obtained in this way. According to Bocca's (1955) investigation with adults, the optimal unadulterated discrimination score and the optimal filtered speech score should yield an additive binaural summation score of approximately 90%. For further clarification of the discrimination tasks in this preliminary study, see p. 33.

<u>Results</u>.--The results of this preliminary study are presented in Table 1 on p. 34. The unadulterated discrimination scores were above 50% in four out of six cases. Bocca (1955) utilized a -5 dB level re the subject's right ear

PRELIMINARY STUDY

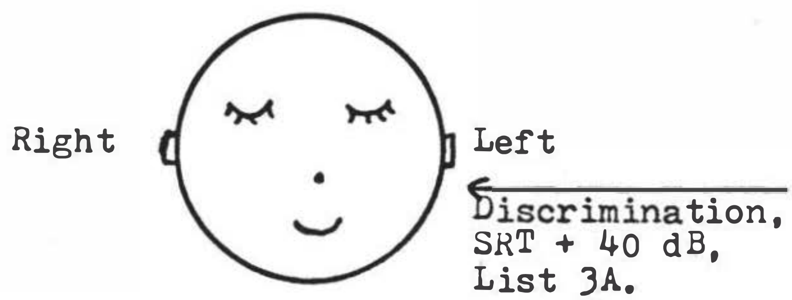
Discrimination Tasks

Unadulterated Discrimination at Threshold Level



Filtered Speech at 780 Hz Low-Pass Cut-Off

Filtered Speech at 720 Hz Low-Pass Cut-Off



Filtered Speech at 660 Hz Low-Pass Cut-Off

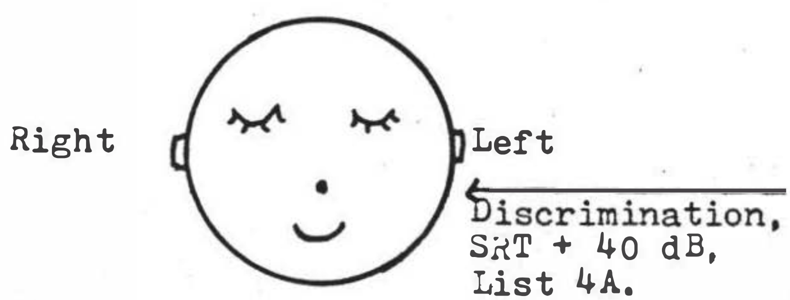


TABLE 1

DISCRIMINATION SCORES

Subject		Age	Grade	SRT R	SRT L	Unadulterated Discrimination Scores re Right Ear SRT (List 1A)	Filtered Speech Scores re Left Ear SRT + 40 dB at 780 Hz Low-Pass Filtering (List 2A)	Filtered Speech Scores re Left Ear SRT + 40 dB at 720 Hz Low-Pass Filtering (List 3A)	Filtered Speech Scores re Left Ear SRT + 40 dB at 660 Hz Low-Pass Filtering (List 4A)
1.	M	10-2	5	8	8	48%	52%	50%	40%
2.	M	10-9	5	9	4	54%	74%	72%	46%
3.	M	11-10	6	2	9	48%	68%	64%	48%
4.	F	10-10	5	9	9	54%	68%	54%	44%
5.	M	10-11	5	8	9	58%	54%	50%	36%
6.	M	11-5	6	8	6	58%	64%	62%	48%

SRT in order to obtain values of less than 40% on adult subjects. Since the present study involved fifth and sixth grade children with SRT's of less than 5 dB, the -5 dB level could not be utilized due to the limits of the audiometer. For this reason, this preliminary study did not yield additive effects of approximately 90% of the unadulterated discrimination scores and the filtered speech scores. Additive effects were obtained, however, but were greater than approximately 90%.

The 780 Hz and the 720 Hz low-pass cut-off filtering levels did not permit filtered speech scores of less than 50%. Therefore, these two levels were not optimal for this study (Bocca, 1955). The 660 Hz low-pass cut-off filtering level permitted all of the six filtered speech scores to be below 50%. This low-pass cut-off level was, therefore, the optimal level sought for the major part of this study (Bocca, 1955).

For the purposes of the major study, the binaural summation scores are most important to assess the discrimination abilities of normal speaking children and articulation defective children. The additive effects that Bocca (1955) found with the unadulterated discrimination scores and the filtered speech scores are not of great concern in the main investigation.

The subjects and their data obtained in the preliminary study were not used in the major study.

Major Study

Subjects.--A total of 60 public elementary school children in the fifth and sixth grades (33 make and 27 female), whose chronological ages ranged from 9 years, 11 months, to 12 years, 0 months, served as subjects in the major study.

Method of Selection and Assignment.--The 30 subjects in the control group (Group I) were selected from the fifth and sixth grade children enrolled in various elementary schools in the East Central Illinois area. Elementary school teachers were asked to prepare a list of the normal speaking children with no known hearing losses from their classes. These children were then selected for their availability. This group consisted of 15 fifth and 15 sixth grade children.

The 30 subjects in the experimental group (Group II) had two other considerations for selection. These children had been diagnosed by various speech clinicians in the East Central Illinois area as having a severe unresponsive articulation disorder. These children were then selected from speech correction classes. For the purposes of this study, a severe unresponsive articulation disorder was operationally defined as one consisting of at least one distortion in the following group of phonemes: /s, ʃ, tʃ, dʒ, r, l/. These were children who were not able to correct their error sound(s) in spontaneous speech after at least one year of speech therapy even though they might have been able to produce the sound(s) correctly in isolation, words, or nonsense syllables. All of these subjects were not dismissed from speech therapy at the time this study took place. These 30 children were then chosen for their availability. Hence, 15 fifth graders and 15 sixth graders who met this added criterion of a "severe unresponsive articulation disorder" were used in this investigation. It was felt that these 60 students represented an adequate sampling of the student population. No child had any previous experience with the test materials that were used. No attempt was made to match the groups in terms of sex, type of articulation error, or clinician.

Examiners.--The writer was the only examiner in the major part of this study. A team of two examiners were used to determine the inter-examiner reliability of the children's responses to the auditory stimuli. Each of these examiners was a graduate student in the area of Speech Pathology and Audiology at Eastern Illinois University, and was trained in these areas for at least two years. To establish inter-examiner reliability for the two groups, two subjects were randomly selected from a table of random numbers for four different lists in each group. The two examiners then obtained four percentage of agreement scores for each group. In this manner, reliability was established twice of all four of the C.I.D. Auditory Test Lists, 1A, 2A, 3A, and 4A, with the control and the experimental groups.

Reliability was established at 100% and 98% with subject 11 (Lists 2A and 4A), and 98% and 100% with subject 30 (Lists 3A and 1A) of the control group (Group I). The reliability of the two examiners was then established at 98% and 100% with subject 14 (Lists 4A and 3A), and at 96% and 96% with subject 21 (Lists 1A and 2A) of the experimental group (Group II). All these values were interpreted to show high levels of inter-examiner reliability.

Equipment.--The same audiological equipment was used in the major study as in the preliminary study (c.f., preliminary study, pp. 22-23).

To establish SRT's for each of the subjects, the same C.I.D. Auditory Test W-1, List A, and procedure was used as in the preliminary study.

The C.I.D. Auditory Test W-22 lists were also employed in the major study. However, Lists 1A, 2A, 3A, and 4A were here used to determine: 1) baseline speech discrimination scores at threshold level (List 1A); 2) new speech discrimination scores at threshold level (List 2A); 3) filtered speech scores (List 3A), and 4) binaural summation scores (List 4A).

A fill-in sheet was devised in order to record the monaural SRT's and the four discrimination score percentages. The percentages recorded represented the number of correct auditory responses given by each of the 60 children. The responses obtained from the first five control subjects are presented in Appendix I on p. 68.

Procedure.--The 60 subjects in Groups I and II were then examined on an individual basis. Monaural SRT's were obtained as in the preliminary study.

To establish baseline discrimination behavior at threshold level, C.I.D. Auditory Test W-22, List 1A was given to each subject first. This method is the same as in the preliminary study (c.f., preliminary study, pp. 24-25). The first unadulterated discrimination score was then obtained. The next three lists, 2A, 3A, and 4A, were then given in random order to once again prevent ordering effects.

List 2A consisted of a new speech discrimination task at threshold level, and was presented in the same manner as List 1A. The second unadulterated discrimination score was then obtained.

List 3A consisted of a filtered speech task as in the preliminary study. The 660 Hz low-pass cut-off filtering level was the only one used in this part of the study, since it was shown to be the optimal level. The filtered speech score was then obtained. Both the filtered speech scores and the unadulterated discrimination scores at threshold were determined in this study to show that the binaural summation effect described below was obtained, and that it was approximately additive.

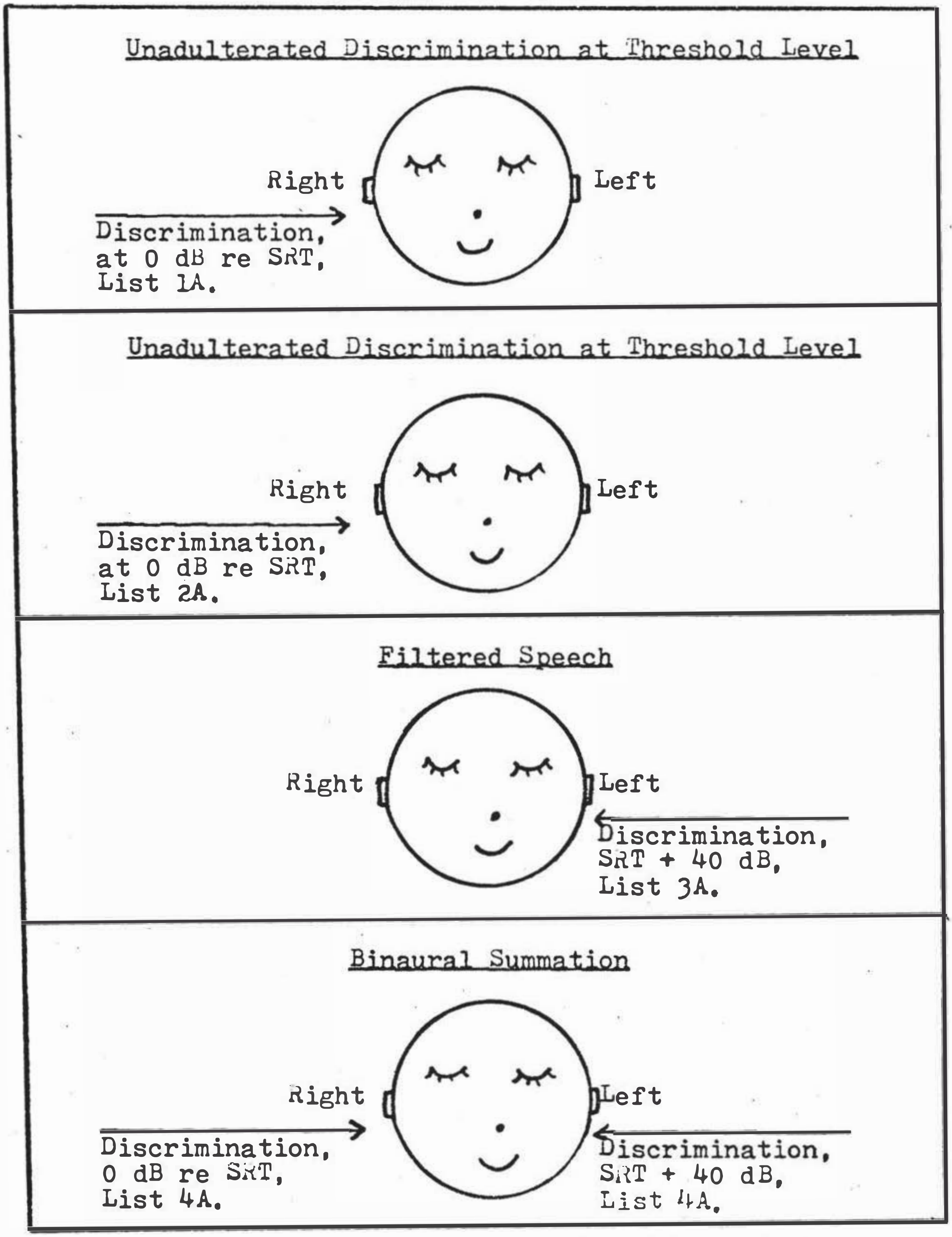
In this major study, a new discrimination task was involved. List 4A from the C.I.D. Auditory Test W-22 was then presented in the left ear at the same presentation level as the filtered speech task, under the same low-pass filtering system. At this point, the same words were simultaneously introduced into the right ear at the same sensation level as the unadulterated discrimination task. The left ear stimulus was filtered and the right ear stimulus was unfiltered. The subject was then receiving a suprathreshold distorted signal (quantity) in one ear, and a threshold undistorted signal (quality) in the other ear. These results were the subject's binaural summation scores.

To clarify these four discrimination tasks, refer to the illustration on p. 41.

All 60 subjects were examined over a period of 14 days, and were all treated in an equal manner during the testing situation.

MAJOR STUDY

Discrimination Tasks



CHAPTER IV

RESULTS AND DISCUSSION

Results

The purpose of this chapter is to report the statistical computations and interpret the results of the present study.

A two by three factorial analysis of variance was computed in order to determine if significant differences existed between and within the two groups of children. A summary of this analysis is presented in Table 2 on p. 43. In this analysis of variance, the two factors present were groups, and types of discrimination tests. Within these two factors, levels existed. In group, the two levels were the control, and the experimental; in types of discrimination tests, the three levels were the unadulterated discrimination test, the filtered speech test, and the binaural summation test. Both main factors and their resulting interactions yielded statistically significant F-ratios which were significant beyond the .05 level. The null hypothesis was then rejected. Therefore, in an effort to identify specific sources of variance, 15 *t*-tests were computed.

Each *t*-test was computed and interpreted for one-tailed tests (Guilford, 1965, p. 581). Since there was good

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	df	MS	F
Group	4929.78	1	4929.78	76.47*
Type of Discrimination Test	19322.73	2	9661.37	149.87*
Interaction	3542.56	2	1771.28	27.48*
Within Sets	11216.93	174	64.47	
Total	39012.00	179		

*Significance beyond the .05 level ($P_{.05}$=3.91)

TABLE 3

MEANS OF GROUP I AND GROUP II
IN THE DISCRIMINATION TESTS

	$\bar{M}$ Unadulterated Discrimination Scores (A)	Filtered Speech Scores (B)	Binaural Summation Scores (C)
Group I	61.4	46.8	82.1
Group II	55.9	43.8	59.2

*Significance beyond the .05 level ($P_{.05}$=1.70)

TABLE 4

MEANS OF GROUP I AND GROUP II
IN THE DISCRIMINATION TESTS

	df	t
I A vs. II A	29	2.37*
I B vs. II B	29	1.82*
I C vs. II C	29	8.39*
I A vs. I B	29	8.59*
I B vs. I C	29	17.29*
I A vs. I C	29	10.72*
II A vs. II B	29	6.26*
II B vs. II C	29	9.72*
II A vs. II C	29	1.72*

*Significance beyond the ;05 level ($P_{.05}$=1.70) reason to make a directional prediction based on Flowers and Costello's (1963) research, a one-tailed test was chosen for interpretation of the statistical analyses. This was based upon the confidence that an outcome in the opposite direction would not be obtained (Williams, 1968, p. 66). The *t*-value required to reach the .05 level with 29 degrees of freedom was 1.70. The following comparisons were made to test the hypotheses for the three test conditions which were lettered as follows for clarification of the analyses: A--unadulterated discrimination scores; B--filtered speech scores, and C--binaural summation scores. Group I comprised the control group or the normal speaking children; and Group II comprised the experimental group or the articulation defective children.

Between Comparisons

Group I A vs. Group II A.--The resulting *t*-value of 2.37 reached significance at the .05 level. This was interpreted to mean that there was a statistically significant difference between normal speaking children and articulation defective children in their unadulterated speech discrimination scores. In this task, the normal speaking children correctly discriminated more speech sounds than the articulation defective children. This task, therefore, did differentiate the discrimination abilities of the normal speaking children and the articulation defective children under unadulterated speech conditions. The null hypothesis was then rejected. The mean scores of the two groups and the discrimination scores is presented in Table 3 on p. 44.

Group I B vs. Group II B.--The resulting *t*-value of 1.82 was statistically significant at the .05 level. This was interpreted to mean that there was a statistically significant difference between normal speaking children and articulation defective children in their filtered speech scores. In this task, the normal speaking children experienced less difficulty with the distorted speech signal than the articulation defective children. In Flowers and Costello's (1963) study, the normal speaking children did do significantly better than the articulation defective children on the filtered speech task. In the present study, the filtered speech task did differentiate the normal speaking children from the articulation defective children in their abilities to discriminate speech sounds under filtered speech conditions. The inability of the articulation defective children to deal with the filtered speech task substantiates the work of Flowers and Costello (1963), and extends the generality of these findings to articulation defective children in the fifth and sixth grades as well. The null hypothesis was, therefore, rejected.

Group I C vs. Group II C.--The resulting *t*-value of

8.39 was significant beyond the .05 level. This was interpreted to mean that there was a statistically significant difference between the normal speaking children and the articulation defective children in their binaural summation scores. In this task, the normal speaking children correctly discriminated more speech sounds than the articulation defective children. The normal speaking children demonstrated much more facility than the articulation defective children with this task that apparently involves central processing of two different auditory signals. The articulation defective children did not summate the two separate stimuli as well as the normal speaking children thereby forming a total message. Instead, the binaural summation scores were considerably less than 90% for the articulation defective children. This poorer ability to summate substantiates the Flowers and Costello (1963) study, and extends the generality to a new age range. Flowers and Costello (1963) found that children in the second, third, and fourth grades with severe and multiple articulation errors obtained poorer binaural summation scores than the normal speaking children. The discrimination abilities of the normal speaking children was far superior to those of the articulation defective children. This task, therefore, differentiated between the discrimination abilities of the normal speaking children and the articulation defective children in the binaural summation task. The null hypothesis was then rejected.

Within Comparisons

Group I A vs. Group I B.--The resulting *t*-value of 8.59 was significant beyond the .05 level. This was interpreted to mean that there was a statistically significant difference between the unadulterated discrimination and the filtered speech scores in normal speaking children. The normal speaking children obtained better unadulterated discrimination scores than filtered speech scores. In Bocca's (1955) study with adults, the unadulterated speech scores and the filtered speech scores yielded a 90% additive effect (c.f., preliminary study, p. 31). As explained in the preliminary study, the unadulterated discrimination scores were expected to be better than the filtered speech scores due to the limitations of the audiometer. The audiometer did not permit thresholds to be taken below 0 dB, since the Beltone 15-C two-channel model used in this study ranged in intensity from 0-110 dB. This significant difference, therefore, was anticipated and the obtained scores are thus explained. The null hypothesis was then rejected. The mean comparisons of the two groups and the discrimination scores is presented in Table 4 on p. 44.

Group I B vs. Group I C.--The resulting *t*-value of 17.29 was statistically significant far beyond the .05 level. This was interpreted to mean that there was a significant difference between the filtered speech scores and the binaural summation scores in the normal speaking children. The binaural summation scores were much better than the filtered speech scores. In normal speaking children, it has been shown that binaural summation scores of approximately 90% are obtained under binaural summation conditions (Flowers and Costello, 1963). The unadulterated discrimination scores obtained were expected to be less than approximately 40%, and the filtered speech scores were expected to be approximately 50% (Bocca, 1955). The binaural summation scores, therefore, should have yielded an additive effect of approximately 90% (Bocca, 1955). Since it was expected that the filtered speech scores should be approximately 50% (Bocca, 1955), it was not surprising that the *t*-value was of such a great magnitude. The null hypothesis was then rejected.

Group I A vs. Group I C.--The resulting *t*-value of 10.72 was significant beyond the .05 level. This was interpreted to mean that the unadulterated discrimination scores and the binaural summation scores were significantly different in normal speaking children. The binaural summation scores were much better than the unadulterated discrimination scores. This is explained by the approximate 50% unadulterated discrimination scores expected according to Bocca's (1955) study. The unadulterated discrimination scores and the filtered speech scores together were expected to yield an additive effect of approximately 90% (Bocca, 1955). A statistically significant *t*-value was, therefore, expected to be obtained from the normal speaking children. The null hypothesis was then rejected.

Group II A vs. Group II B.--The resulting t-value of 6.26 was statistically significant beyond the .05 level. This was interpreted to mean that there was a significant difference between the unadulterated discrimination scores and the filtered speech scores in articulation defective children. The unadulterated discrimination scores were better than the filtered speech scores. As explained in the preliminary study (c.f., preliminary study, p. 31), the unadulterated discrimination scores were expected to be better than the filtered speech scores due to the limitations of the audiometer. The Beltone 15-C two-channel audiometer used in this study covers the intensity range of 0-110 dB. As a result of this minimum intensity output of 0 dB, no thresholds below this level could be obtained. For this reason, the unadulterated discrimination scores were expected to be better than the filtered speech scores. This significant difference can thus be understood. The null hypothesis was then rejected.

Group II B vs. Group II C.--The resulting t-value of 9.72 was significant beyond the .05 level. This was interpreted to mean that there was a statistically significant difference between the filtered speech scores and the binaural summation scores in the articulation defective children. The binaural summation scores were better than the filtered speech scores. According to Bocca's (1955) study, significant differences were expected here since the unadulterated discrimination scores and the filtered speech scores should yield an additive effect of approximately 90%. The filtered speech scores were obtained from approximately one-half of the binaural summation scores. For this reason, the obtained difference was anticipated from prior research (Bocca, 1955; Flowers and Costello, 1963). The null hypothesis was, therefore, rejected.

Group II A vs. Group II C.--The resulting *t*-value of 1.72 was statistically significant at the .05 level. This was interpreted to mean that there was a significant difference between the unadulterated discrimination scores and the binaural summation scores in articulation defective children. The binaural summation scores were better than the unadulterated discrimination scores. The binaural summation scores, which were approximately 90% in normal speaking children (Flowers and Costello, 1963), were expected to be less than 90% in the articulation defective children. The summation that occurred in these children was considerably less than 90%. The unadulterated discrimination scores and the binaural summation scores in the articulation defective children were significantly different; but, the magnitude of the difference was not great as in the Group I comparison. Since the articulation defective children did not obtain summation scores of approximately 90% as the normal speaking children did, the statistically significant differences between the unadulterated discrimination scores and the binaural summation scores was of a smaller magnitude than Group I. The *t*-value, moreover, just reached significance at the .05 level. The binaural summation scores did not yield an additive effect of approximately 90% with the unadulterated discrimination scores and the filtered speech scores since the unadulterated discrimination scores exceeded 40% (c.f., preliminary study, p. 31), and the articulation defective children did not obtain summation scores of approximately 90% as the normal speaking children did. The null hypothesis was then rejected.

Interaction Effects

When interaction is present, columns are different in different ways within rows, and vice-versa (Hays, 1963, p. 390). In this study, the groups (columns), and the types of discrimination tests (rows) yielded statistically significant interaction effects. This was interpreted to mean that the groups (control and experimental), and the types of discrimination tests (unadulterated speech, filtered speech, and binaural summation) were differentially affected. The mean scores of the two groups and the discrimination scores with the resulting interaction effects is presented in Table 5 on p. 53.

Interaction effects lead to a qualification on the

TABLE 5

MEANS OF GROUP I AND GROUP II
IN THE DISCRIMINATION TESTS
(INTERACTION EFFECTS)

	df	t
I A vs. II B	29	9.56*
I A vs. II C	29	1.14
I B vs. II A	29	5.30*
I B vs. II C	29	6.15*
I C vs. II A	29	12.17*
I C vs. II B	29	16.53*

*Significance beyond the .05 level ($P_{.05}$=1.70) estimate that can be made of the difference attributable to one factor which depends on the particular level of the other factor (Hays, 1963, p. 390). For example, the control group's unadulterated discrimination scores and the experimental group's binaural summation scores yielded statistically significant interaction effects (Group I A vs. Group II C). This comparison, however, was not meaningful in respect to clinical management differences. It was not anticipated pre-experimentally that these two groups with these two discrimination tests should yield important comparisons.

"Significant interaction effects usually reflect a situation in which overall estimates of differences due to one factor are fine as predictors of average differences over all possible levels of the other factor" (Hays, 1963, p. 391). But, it will not necessarily be true that these are good estimates of the differences to be expected when information about the category of the other factor is given (Hays, 1963, p. 391). Significant interaction serves as a warning: treatment differences do exist, but to specify how the treatments differ, and especially to make good individual predictions, one must look within the discrimination tests of the other group to make good individual predictions. In other words, when interaction effects are present, the best forecast can be made only if the individual's status on both factors is known (Hays, 1963, p. 391).

Interaction effects can be studied separately only in a two-way (or higher) analysis of variance with crossed factors, where the experimental group is carried out with replication (Hays, 1963, p. 392). In this manner, an error sum of squares would be available, permitting the study of tests, both for treatment effects and for interaction (Hays, 1963, p. 392). For the purposes of this study, the resulting statistically significant interactions were not meaningful comparisons in that they did not yield practical clinical management decisions. In order to further explore the exact significance of these effects, replication would be necessary (Hays, 1963, p. 392).

Discussion

The major finding in this experiment was that normal speaking children and articulation defective children differ significantly in their abilities to discriminate speech sounds under unadulterated speech, filtered speech, and binaural summation conditions. This finding substantiated Bocca's (1955) study, and Flower and Costello's (1963) findings that normal subjects (without central nervous system pathology) and normal speaking subjects can summate effectively while patients with certain central nervous system pathologies and children with severe and multiple articulation problems cannot. The normal speaking children performed significantly better under all three test conditions. Generality was then extended from the filtered speech and binaural summation phenomena to fifth and sixth graders as well as second, third, and fourth grade children in the population.

At this time, it can only be inferred that these children may have subtle abberations in the central mechanism of hearing. More research is needed in the area of the central mechanism of hearing in relation to the binaural summation task in order to determine how it might differ in normal speaking and in articulation defective children. The filtered speech task and the binaural summation task could be used as diagnostic aids in the assessment of the central mechanism of hearing as related to speech articulation deficiency. More research is needed, however, in order to establish a causal relationship between central mechanism of hearing deficits and speech articulation deficiency.

It would be worthwhile knowing if the filtered speech and the binaural summation tasks were affected by maturation and/or learning. If it was established that the discrimination abilities of articulation defective subjects were not affected by maturation, and also could not be learned, then these findings would lend support to the hypothesis that the filtered speech and the binaural summation tasks may be related to a central deficit.

Further experimentation with patients with central nervous system pathologies and with normal subjects is needed in order to assess the discrimination abilities of subjects under the filtered speech and binaural summation conditions.

Localization of the sites of lesion causing the poor ability to summate may be obtained from this type of research.

Penfield and Roberts (1959) discovered many speech phenomena that resulted from extensive cortical brain mappings on patients with epilepsy. Distortion of words and syllables was noted when an electrode was placed in various areas of the brain such as the junction of the fissures of Rolando and Sylvius (Penfield and Roberts, 1959, p. 125). The distorted sound was defined by Penfield and Roberts (1959, p. 59) as a sound which is not a word but an unintelligible sound.

Lesions which have produced difficulty in understanding speech have also involved both temporal regions, usually the first and second temporal, and Heschl's convolutions (Penfield and Roberts, 1959, p. 75). This type of problem is referred to as auditory agnosia wherein a patient may retain the ability to hear sounds but lose the ability to recognize that he had heard them before (Penfield and Roberts, 1959, p. 74). The temporal lobe, and more specifically, Wernicke's area, is believed to be the center of auditory recognition (Penfield and Roberts, 1959, p. 74).

Schuknecht and Woellner have shown that essentially normal, pure-tone thresholds for speech frequencies (512, 1024, and 2048 Hz) may exist with a speech discrimination score of only 16% in a patient who had an acoustic neurinoma (Penfield and Roberts, 1959, p. 75). In other words, a lesion which has incompletely destroyed the auditory nerve may result in the patient's being able to appreciate pure tones but not being able to reproduce speech sounds (Penfield and Roberts, 1959, p. 75). The exact location areas for speech sound discrimination are not known as yet. It is hypothesized, however, that the temporal cortex, and more specifically, the junction of the fissures of Rolando and Sylvius, the first and second temporal regions, and Heschl's convolutions may be the cortical regions that govern speech sound discrimination.

With the assistance from speech scientists and neuroanatomists, more information can be obtained from more extensive research in the area of the central mechanism of hearing in relation to speech-articulation deficiency.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Three questions were considered in this study:

1. Are there significant between group differences in the three conditions of unadulterated discrimination scores, filtered speech scores, and binaural summation scores?

2. Are there significant within group differences in the three conditions of unadulterated discrimination scores, filtered speech scores, and binaural summation scores?

3. Can the filtered speech and the binaural summation tests be utilized as diagnostic aids in the assessment of the central mechanims of hearing as related to speech-articulation deficiency?

To provide answers to questions one and two, the following hypotheses were stated in null form:

Between Comparisons.--

1. There is no significant difference between normal speaking children and articulation defective children in their unadulterated speech discrimination scores.

2. There is no significant difference between normal speaking children and articulation defective children in their filtered speech scores.

3. There is no significant difference between normal speaking children and articulation defective children in their binaural summation scores.

Within Comparisons.--

1. There is no significant difference between the unadulterated discrimination scores and the filtered speech scores in normal speaking

children.

2. There is no significant difference between the filtered speech scores and the binaural summation scores in normal speaking children.

3. There is no significant difference between the unadulterated discrimination scores and the binaural summation scores in normal speaking children.

4. There is no significant difference between the unadulterated discrimination scores and the filtered speech scores in articulation defective children.

5. There is no significant difference between the filtered speech scores and the binaural summation scores in articulation defective children.

6. There is no significant difference between the filtered speech scores and the binaural summation scores in articulation defective children.

The third question was answered on the basis of inference derived from interpretation of the statistical analyses.

A review of the literature on binaural summation indicated the importance of assessing the speech sound discrimination abilities of normal speaking and articulation defective children. The only study in this area was done by Flowers and Costello (1963) on second, third, and fourth grade children. They (Flowers and Costello, 1963) found that articulation defective children with severe and multiple articulation problems could not summate whereas normal speaking children could summate. These articulation defective children obtained summation scores that were considerably less than 90% in comparison to the normal speaking children who obtained summation scores of approximately 90%. No study had been done on the discrimination abilities of severe articulation defective children and normal speaking children in the fourth and fifth grades. These children used in the present study were operationally defined as those children who had not improved in speech therapy after at least one year on one or more of their error sound(s) consisting of: /s, ʃ, tʃ, dʒ, r, l/. The present study was undertaken in order to assess the speech sound discrimination abilities of severe articulation defective children and normal speaking children in the fifth and sixth grades under the three conditions of unadulterated speech, filtered speech, and binaural summation conditions. Four discrimination tasks were given to each of the 30 children in Group I (control), and 30 children in Group II (experimental). The first task given to each child was the baseline unadulterated discrimination task. A new unadulterated discrimination task, a filtered speech task, and a binaural summation task were then presented to each child randomly in order to control for ordering effects.

In order to ascertain the presence or absence of a statistically significant difference between and within the two groups of children, a two by three factorial analysis of variance was computed. The between and within group analyses and the resulting interactions yielded statistically significant F-ratios which were significant beyond the .05 level. The null hypothesis was then rejected. To identify sources of variance, 15 *t*-tests were computed.

In answer to question one, are there between group differences in the three conditions of unadulterated discrimination scores, filtered speech scores, and binaural summation scores, the between group differences for Group I were all statistically significant. The null hypothesis was then rejected. The normal speaking children did significantly better than the articulation defective children on the unadulterated discrimination task, the filtered speech task, and the binaural summation task. The work of Flowers and Costello (1963) supports this data that articulation defective children have more trouble dealing with the filtered speech signal as well as the binaural summation task in comparison to normal speaking children. One hypothesis formulated to account for this is as follows: The filtered speech task and the binaural summation task involve the central mechanism of hearing; the articulation defective children have subtle abberations in this area and are, therefore, unable to deal with the filtered speech signal or the binaural summation task.

In answer to question two, are there significant within group differences in the three conditions of unadulterated discrimination scores, filtered speech scores, and binaural summation scores, the within group differences for Group I were all statistically significant. The null hypothesis was, therefore, rejected. According to Bocca's (1955) study, the unadulterated discrimination task should yield scores of approximately 40%; the filtered speech task should yield scores of approximately 50%. An additive effect of approximately 90% of the unadulterated discrimination score and the filtered speech score was found in Bocca's (1955) study; this was called the binaural summation score.

The unadulterated discrimination scores and the filtered speech scores were expected to be different as stated in the preliminary study (c.f., preliminary study, p. 31), due to the audiometer's limitations. This inability to obtain thresholds below 0 dB accounted for the unadulterated discrimination scores being greater than 40%. This is one hypothesis to account for the significant differences in these two tasks.

The filtered speech scores and the binaural summation scores were also expected to be different according to Flowers and Costello's (1963) study with articulation defective and normal speaking children. The null hypothesis was rejected here. Flowers and Costello (1963) obtained filtered speech scores of approximately 50% and binaural summation scores of approximately 90%. For this reason, significant differences may have been obtained.

The unadulterated discrimination scores and the binaural summation scores were anticipated to be significantly different in the normal speaking children. The null hypothesis was rejected here. The unadulterated discrimination scores were expected to be approximately 40% of the binaural summation scores of approximately 90%. Significant differences were expected for that reason.

The within group differences for Group II were statistically significant in all three comparisons. The null hypothesis was then rejected. It was expected that the unadulterated discrimination scores and the filtered speech scores would be different in the articulation defective children from the preliminary study (c.f., preliminary study, p. 31) due to the limitations of the audiometer to obtain thresholds of less than 0 dB. Statistical significance, therefore, was accounted for.

The differences between the filtered speech scores and the binaural summation scores were statistically significant. The null hypothesis was unsupported here. The significance was explained by Bocca's (1955) study wherein the binaural summation score is an approximate composite of both the filtered speech score and the unadulterated discrimination score.

Statistically significant results were obtained between the unadulterated discrimination scores and the binaural summation scores. From this result, the null hypothesis was rejected. The articulation defective children did not summate as well as the normal speaking children; therefore, the binaural summation scores did not yield an additive effect of approximately 90% (Bocca, 1955). In fact, the unadulterated discrimination scores and the binaural summation scores just reached significance at the .05 level. A hypothesis was formulated to account for this: The binaural summation task involves the central mechanism of hearing; the articulation defective children have subtle abberations in this area and are, therefore, unable to summate effectively.

The statistically significant interaction effects were the result of the interplay between the two groups and the three discrimination tests presented to the subjects. These interaction effects did not yield meaningful comparisons in respect to clinical management differences for the subjects. Furthermore, the meaningful interaction effects are the same as those revealed by direct comparisons of groups and types of discrimination tests in which significant differences were demonstrated.

In answer to question three, can the filtered speech and the binaural summation tasks be utilized as diagnostic aids in the assessment of the central mechanism of hearing as related to speech-articulation deficiency, only inferences can be drawn from the statistical analyses.

The filtered speech task did differentiate the normal speaking children from the articulation defective children in this study. For this reason, the filtered speech task would be recommended as an aid in the assessment of the central mechanism of hearing as related to speech-articulation deficiency. More research is needed to learn more about the filtered speech signal in relation to speech sound discrimination abilities.

The binaural summation task can be used in conjunction with other tests for assessing the central mechanism of hearing as related to speech-articulation deficiency. The results of this study substantiate the previous research of Flowers and Costello (1963) in differentiating the discrimination abilities of normal speaking children and articulation defective children in the binaural summation task. Generality was extended to fifth and sixth graders in the normal speaking and articulation defective population. These tasks seem to be useful aids in the assessment of the central mechanism of hearing.

Implications for Future Research

There are several implications for further studies which have been brought about as a result of the present study:

1. A study comparing the unadulterated discrimination scores, filtered speech scores, and binaural summation scores of subjects with articulation errors grouped according to their specific erred phoneme(s). i.e., Subjects with /s/ problems versus subjects with /ʃ/ problems, versus /tʃ/ problems, versus /dʒ/ problems, versus /r/ problems, versus /l/ problems, etc. In this manner, a specific phoneme may prove to be related to the subject's poor ability to summate.

2. A study comparing the unadulterated discrimination scores, filtered speech scores, and binaural summation scores of subjects with articulation errors grouped according to classification of error. i.e., Those subjects having omissions, versus those having distortions, versus those having substitutions. In this manner, a specific type of error

may prove to be related to the subject's poor ability to summate.

3. A longitudinal study comparing the unadulterated discrimination scores, filtered speech scores, and binaural summation scores of articulation defective and normal speaking subjects in order to see if the ability to summate is affected by maturation and/or learning. In this manner, more evidence may be obtained in support of the central mechanism of hearing governing speech sound discrimination.

4. A study comparing the unadulterated discrimination scores, filtered speech scores, and binaural summation scores of subjects with known central nervous system pathologies in comparison to subjects with no central nervous system pathologies in order to assess their discrimination abilities under these three conditions. In this manner, more information can be obtained in reference to site of lesion in relation to speech sound discrimination problems.

APPENDIX I

CONTROL GROUP DISCRIMINATION SCORES

Subject		Age	Grade	SRT		Unadulterated Discrimination Scores (List 1A)	Unadulterated Discrimination Scores (List 2A)	Filtered Speech Scores (List 3A)	Binaural Summation Scores (List 4A)
				R	L				
1.	M	10-5	5	10	7	60%	66%	42%	90%
2.	M	11-10	6	9	1	62%	76%	56%	88%
3.	M	9-11	5	9	6	60%	66%	46%	88%
4.	M	10-5	5	9	10	48%	50%	44%	92%
5.	F	10-2	5	7	6	56%	58%	48%	78%
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