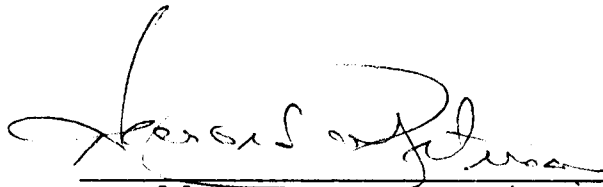


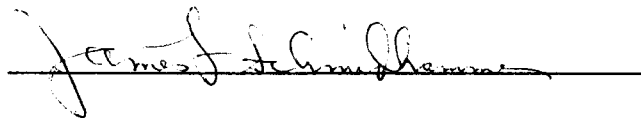
To the Graduate Council:

I am submitting herewith a dissertation written by Richard A. Neeley entitled "Performance of Children with Normal Articulation on Two Tests of Central Auditory Processing." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Speech and Hearing Science.



Harold A. Peterson, Major Professor

We have read this dissertation
and recommend its acceptance:



Accepted for the Council:



Vice Chancellor
Graduate Studies and Research

PERFORMANCE OF CHILDREN WITH NORMAL ARTICULATION
ON TWO TESTS OF CENTRAL AUDITORY PROCESSING

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Richard A. Neeley
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ABSTRACT

The purpose of this study was to explore the performance of children with non-normal articulation skill on two tests of central auditory processing. The two test paradigms used in this study were dichotic listening with CV syllables as stimuli and a variety of tone patterns using combinations of 500 Hz and 1000 Hz tones as stimuli. Six subject groups were used with 10 subjects assigned to each group on the basis of age and previous articulation skill. This method of assignment resulted in three experimental groups and three control groups.

No significant differences were found to exist between experimental groups and their matched controls regarding performance on either of the central auditory tests. However, significant differences were discovered to exist between the subjects in the youngest age category and the subjects in the older age categories. Regardless of experimental or control group assignment, the subjects less than 12 years of age consistently scored more poorly than those subjects older than 12 years. This finding appears to indicate that language facility is a maturational skill and that this linguistic maturation appears to be complete by the age of 12 years.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
Purpose of the Study	5
II. REVIEW OF THE LITERATURE	6
Central Auditory Processing Defined	7
Central Auditory Processing Skills	8
Assessment of Central Auditory Processing	10
Central Auditory Tests	11
Experimental Task I	13
Use of the Ear Advantage in Dichotic Listening as an Index of Hemispheric Lateralization.	13
Variables Which Influence Dichotic Ear Preference	15
Laterality Effects in Children	20
Experimental Task II	23
Variables Which Influence Temporal Sequencing	24
Experimental Task I Summary	29
Experimental Task II Summary	30
Experimental Questions	31
III. PROCEDURES	33
Description of the Subjects	34
Materials and Equipment: Experimental Task I	41
Diotic and Dichotic Listening Tasks	44
Treatment of Data from Experimental Task I	45
Materials and Equipment: Experimental Task II.	45
Experimental Task for Pattern Recognition Tests	47
Treatment of Data from Experimental Task II.	49
IV. RESULTS AND DISCUSSION	50
Experimental Task I	50
Diotic Listening Task Performance	51
Dichotic Listening Task Performance	53
Experimental Task II	61
Pattern Recognition Task Performance	65
Discussion	77
V. SUMMARY AND CONCLUSIONS	83
Experimental Task I	84
Experimental Task II	85

Suggestions for Future Research	86
REFERENCES	88
APPENDICES	95
A. Subjects' Ages and Group Mean Ages	96
B. Experimental Subjects' Performance on the Arizona Articulation Proficiency Scale	97
C. Subjects' Scores on the PPVT-R and T-D	98
D. Diotic and Dichotic Response Sheet	100
E. Diotic and Dichotic Stimuli in Order of Presentation	102
F. TI Basic Programs used to Generate Tone Pattern Recognition Tests	104
G. Response Sheets for the Six Pattern Recognition Tests	116
VITA	123

LIST OF TABLES

TABLE	PAGE
I. Summary of the six pattern recognition tests	48
II. Diotic listening task performance for all subjects in all participating groups	52
III. Dominant ear scores as measured by a dichotic listening task for all subjects in all subjects groups	55
IV. Summary table for the two way analysis of variance procedure performed on the dominant ear data of the six subject groups	55
V. Non-dominant ear performance, as measured by a dichotic listening task, for all subjects in all participating groups	58
VI. Summary table for the two way analysis of variance procedure performed on the non-dominant ear data	59
VII. Percentage of error responses given by each subject on a 90 item dichotic listening task	62
VIII. Summary table for the two way analysis of variance procedure performed on the error data obtained from the dichotic listening task	62
IX. Pattern recognition test scores for all subjects on each of the six tests	66
X. Summary of the two way analysis of variance procedure performed on the amended data sets for each of the six pattern recognition tests	72
XI. Test-retest reliability data for subject # 5 of each subject group for the six pattern recognition tests	75

LIST OF FIGURES

FIGURE		PAGE
I.	Graphic display of the relationships among the mean dominant ear scores of the subject groups segregated according to age	57
II.	Graphic illustration of the relationships among the group means for non-dominant ear performance during the dichotic listening task	60
III.	Graphic illustration of the relationships among the group means of error responses obtained during the dichotic listening task	63
IV.	Illustration of the mean scores of subject groups separated only by the age factor for each of the six pattern recognition tests	69

CHAPTER 1

INTRODUCTION

The relationship between central auditory processing and language skill has received much attention in the recent literature though that relationship has not been specifically defined. Young (1983) hypothesized that the relationship between central auditory processing and language development may be based on the neuromaturation of the central auditory nervous system. In developing such an argument, she presents evidence that language acquisition mirrors the maturation of the auditory system. She concluded from this evidence that speech and language disorders could be the result of immaturity of the neural mechanisms responsible for central auditory processing.

Tallal (1980) observed that some children with speech and language disorders had difficulty in processing rapid auditory signals associated with formant transitions for speech and nonspeech stimuli. She theorized that sound discrimination and identification were dependent upon the subject's ability to perform temporal analysis of acoustic rather than linguistic information. Musiek and Pinheiro (1985, pg. 230) stated that the "general function of the left hemisphere has been described as analytical and, therefore, important to serial ordering of temporal

information." Berlin and McNeil (1976) stated that temporal sequencing was a left hemisphere function and that speech was a special type of temporal sequence. Based on these studies, Young (1983) concluded that speech and language disorders may be the result of an auditory processing deficit in temporal analysis in the language dominant hemisphere.

The dichotic listening paradigm has long been used as a method for determining laterality of language functioning (Berlin and McNeil, 1976; Kimura, 1963). Ear preference scores have typically been interpreted as indices of the magnitude of laterality. From an ear preference score a determination could be made concerning which hemisphere was dominant for language or other functions being tested. More recently, dichotic listening tasks have been included in a number of central auditory processing test batteries (Katz, 1977; Willeford, 1977; Flowers and Costello, 1970). These tests were initially included due to their sensitivity in determining anatomic site of lesion. In addition, Dempsey (1983) reported that dichotic listening tasks were sensitive to neurologic development in children.

Ear preference scores have been used to categorically separate normal and disordered communicative performance. The research and review of the literature by Johnson, Sommer, and Wiedner (1977) revealed that a significant

percentage of aphasic patients with left temporal lobe damage, stutterers, children with severe articulation disorders, and children with language disorders exhibit either less of a right ear advantage than normal controls, a lack of ear preference, or a left ear advantage.

Since ear preference scores have been used to differentiate normal and disordered communicative performance, the assumption could be made that ear preference scores would improve to match those of normal communicators if the disordered communication was remediated. Neeley (1986) reported that this trend was not evident for children who had been released from articulation therapy for a time period ranging from three months to two years. In that study, children identified as having articulation disorders and subsequent normal articulation obtained significantly lower ear preference scores than children who had never been identified as having articulation disorders. However, the ear preference scores of the "now-normal" articulation group were consistently higher than those of children who were receiving articulation therapy.

In view of Young's (1983) hypothesis that speech and language disorders could be the result of immaturity of the neural mechanisms responsible for central auditory processing, Neeley proposed that one possible explanation or interpretation of the "now-normal" articulation group's

ear preference scores was that their performance was indicative of the developmental lag concerning the relative ease or facility with which the children processed competitive auditory stimuli. This interpretation implied that sufficient practice of the newly acquired articulation skills in the form of routine communicative interactions would result in an increase in facility. Alternatively, those data could be interpreted as indicative of a central auditory processing disorder rather than just reduced facility.

Another paradigm used in the assessment of central auditory processing involves tone patterns as stimuli in an attempt to control any possible bias resulting from the assessment of language skill using speech stimuli. Mazziotta and Phelps (1985) reported that the subjects who reported that they used a strategy for analysis of tone patterns revealed more left hemisphere metabolic activity than subjects who reported no use of strategies. Reivich, Alavi, Gur, and Greenberg (1985) asked subjects to determine if two tone patterns were alike or different. These researchers reported that subjects who reported having a system or analytic approach on which to base their judgements demonstrated greater left hemisphere activity while subjects with less musical sophistication or less stereotyped strategies had diffuse right hemisphere asymmetries.

PURPOSE OF THE STUDY

The present study was designed to further explore the central auditory processing skills of this quondam articulatory deficient population with regard to the relative ease with which they process auditory input. Specifically, this investigation had three purposes. The first was to determine if ear preference scores of children who were once identified as having articulation disorders but now have normal articulation improve to match those of normally articulating peers as the length of time since being dismissed from therapy increases. The second purpose was to examine the performance of these same subject groups on a series of pattern recognition tasks. The third purpose was to determine if a predictive relationship existed between the subjects' performance on the two tests of central auditory processing.

CHAPTER II

REVIEW OF THE LITERATURE

This study has been conducted as an attempt to determine if certain central auditory processing skills of quondam articulatory deficient children are equivalent to those of students who have never been diagnosed as having articulation problems. The review of the literature has included a variety of topics felt to be germane to central auditory processing. Specifically, the topics addressed in the review are as follows:

- 1) a description of the phenomenon called central auditory processing,
- 2) a brief account of the research regarding central auditory processing including information such as the development of assessment tools and the purposes for which assessment has been completed,
- 3) the populations with whom central auditory processing assessment has been conducted.

In addition to these general topics, specific emphasis was placed on the review of two topics which were of particular importance in the methodology of this study.

First, competing-signal testing or a dichotic listening task has been included in a number of central auditory test batteries which are currently available such as Competing Environmental Sounds (Katz, 1977), Competing Sentence Test

(Willeford, 1977), the Competing Message Subtest of the Flowers-Costello Test of Auditory Abilities (Flowers and Costello, 1970) and the Staggered Spondaic Word Test (Katz, 1968). Review of the dichotic listening task literature has focused primarily on 1) the use of dichotic ear effects as an index of cerebral dominance, 2) the variables which influence dichotic ear preference scores, and 3) the demonstration of dichotic ear preferences in children.

The second major focus of this review centered on the use of pattern recognition tasks as an integral component of a central auditory processing test battery. The Pitch Patterns developed by Pinheiro (1977) provided the impetus for the construction and use of the six subtests found in the present study. Therefore, the review of the literature was concerned with research pertinent to the development of a set of pattern recognition tests, the use of these patterns in the assessment of central auditory processing disorders, and the interpretation of the results of pattern recognition testing.

Central Auditory Processing Defined

Though there has been considerable interest and research devoted to central auditory processing in the recent past, there appears to be a great deal of confusion

among the related professionals regarding what central auditory processing entails and how it should be operationally defined. Lasky and Katz (1983) stated that these conflicting points of view among professionals who work with children with central auditory processing disorders probably reflect the fact that there is much about the phenomenon that we do not yet know. Rees (1981) reinforced this idea by stating that the assessment of central auditory functioning is "in a state of experimental exploration" since it has failed to yield an explanatory model of how central auditory processing works and in what ways it can become dysfunctional. In spite of these confusions and conflicting points of view, Lasky and Katz (1983, pg 4) offer the following definition:

"We, therefore, consider central auditory processing to be the manipulation and utilization of sound signals by the central nervous system - what we do with what we hear. Central auditory processing involves a range of activities from awareness of the presence of sound to the analysis of linguistic information."

Central Auditory Processing Skills

The confusion regarding how central auditory processing is operationally defined is also reflected in the lack of standardized terminology for the auditory skills considered to be central in nature. The following list of terms and their definitions was compiled by Keith (1988, pg 1218) to represent those central auditory abilities which are most frequently assessed by central auditory tests:

"Localization. The ability to locate auditorily the source of sound. This ability requires binaural hearing."

"Binaural Synthesis. The ability to centrally integrate incomplete stimulus patterns presented simultaneously or alternately to opposite ears."

"Figure Ground. The ability to identify a primary signal or message in the presence of competing sounds. This term was initially used in relation to vision. Auditorily, the task may be more difficult, because both the primary and competing sounds change their acoustic features continually over time. Auditory figure ground can be a monaural or a binaural task."

"Binaural Separation. The ability to listen with one ear while ignoring stimulation of the opposite ear. Dichotic listening, as a binaural separation task, requires the listener to attend to, and report back, different signals presented simultaneously to two ears."

"Memory. The ability to store and to recall auditory stimuli, including the ability to recall the length or number of auditory stimuli; and sequential memory, or the ability to recall the exact order of auditory stimuli presented."

"Blending. The ability to form words out of separately articulated phonemes."

"Discrimination. The ability to determine whether two acoustic stimuli are the same or different. In speech, auditory discrimination is the ability to recognize fine differences that exist among phonemes."

"Closure. The ability to perceive the whole (word or message) when parts are omitted."

"Attention. The ability to persist in listening over a reasonable period."

"Association. The ability to establish correspondence between a nonlinguistic sound and source."

"Cognition. The ability to establish a corres-

pondence between a linguistic sound and its meaning. Cognition is the highest level of auditory perception and results from a summation of all auditory (and all sensory) tasks."

Keith (1988) did stress that the above list was not to be considered complete since other authors had included other skills as being central auditory abilities. For example, Zigmond (1968) defined two other skills as auditory processes. These were analysis and sequentializing. She defined analysis as the process of reducing connected speech into its component parts while sequentializing was described as differentiating between two sound patterns or sequences.

Assessment of Central Auditory Processing

Assessment of central auditory processing has been undertaken using a myriad of tests, procedures, and assessment batteries. Though the number and type of central auditory tests continues to increase, the purposes for performing the assessment have remained relatively stagnant. Dempsey (1983) offered several reasons for assessing central auditory processes. She reported that audiologists routinely choose tests which are designed to determine the site of lesion in the auditory pathway or tests that describe a person's understanding of speech in a social situation. She further indicated that speech pathologists and other educational professionals might assess auditory abilities in order to explain a student's

classroom difficulties or in preparation for speech or language therapy.

Central Auditory Tests

A number of central auditory tests have been developed for the purpose of identifying site of lesion associated with deficits in central auditory processing. Musiek (1985, pg 325) provided a synopsis of the various types of these tests along with his interpretation of the sites of lesion for which each type of test is most sensitive. Musiek reported that dichotic tasks such as competing CV syllables or staggered spondee words may indicate lesions at various levels of the auditory pathway depending on the type of responses given by the subject. He also reported that severe bilateral deficits on pattern tasks such as frequency and intensity patterns may indicate lesions at the hemispheric or interhemispheric level.

Central auditory tests have also been used in recent years in the assessment of neuromaturational functioning of children with language learning problems. Keith (1981) proposed that many of the central auditory processing tests can be used to assess the maturation of the auditory system if they are properly interpreted. Keith stated that the immaturity of the auditory system or disordered functioning of the system could be indicated by a person's failure to develop normal cerebral assymetry, a person's inability to localize sounds, poor sound integration or sound synthesis

skills, and a reduced ability to deal with competitive auditory input. In order for a test to qualify as an auditory neuromaturational test, Keith (1981, pg 63 and 64) proposed that it must possess certain qualities. The following list represents Keith's proposed criteria:

- 1) It cannot be loaded with language comprehension items.
- 2) It cannot require linguistic manipulation of the signal.
- 3) It should utilize (but when necessary minimize) cross sensory input (auditory-visual) or response modality (e.g., auditory - motor).
- 4) It should utilize nonlinguistic signals.
- 5) It must be primarily a speech imitative task using nonmeaningful material or speech stimuli so familiar to the person being tested that comprehension plays no role in the response.

Neuromaturational assessment of the auditory system has received much criticism and continues to be a controversial issue. Musiek (1985, pg 329) stated that "if central tests are used in the evaluation of learning disabled children they should be cautiously administered and interpreted with the examiner being keenly aware of their limitations." Some of these limitations have been specified by other authors. For example, educational and language factors as well as social and maturational factors may influence the validity of central auditory tests (Rees, 1981; Butler, 1981).

The remainder of this literature review has as its focus two tests which are considered to be tests of central

auditory processing by authorities in the field (e.g. Keith, 1988; Musiek, 1985). Experimental task I was a dichotic listening task which employed CV syllables as stimuli while experimental task II was made up of six tone-pattern recognition tests.

EXPERIMENTAL TASK I

Use of the Ear Advantage in Dichotic Listening Tasks as an Index of Hemispheric Lateralization

Verbal Dichotic Listening Tasks - The Right Ear Effect

Kimura (1961) explored the effects of unilateral temporal lobe damage on auditory perception. In this study, spoken digits were presented dichotically to subjects grouped according to the location of temporal lobe lesions. The subjects were tested before and after surgery to remove the impaired cortical tissue. For all groups tested, the preoperative score was higher for the right ear than for the left ear. Left temporal lobe damage impaired test performance regardless of the ear to which stimuli were presented. Unilateral temporal lobectomy on either side reduced the ability to recognize stimuli presented to the ear contralateral to the removal. This effect was independent of damage to Heschel's gyrus which is the primary auditory receiving area. From these results, Kimura (1961) concluded that "the left temporal lobe is particularly

important in the perception of verbal material, at least in the auditory modality."

The left hemisphere of most human brains appears to be specifically organized for speech and language functions (Penfield and Roberts, 1959). Geschwind and Levitsky (1968) examined 100 adult human brains. Their results indicated that the auditory association cortex located behind Heschel's gyrus (planum temporale) was significantly larger in the left hemisphere than in the homologous area of the right hemisphere. These findings confirmed the coexistence of left hemisphere structural asymmetries with demonstrated functional asymmetries.

Shankweiler (1971) proposed that dichotically presented stimuli were necessary for lateral differences in perception to occur. If the stimuli were presented monaurally, neither ear showed an advantage. He concluded that dichotic ear preferences were jointly dependent on differences in function of the two cerebral hemispheres and a system designed to favor contralateral transmission during simultaneous stimulation of the two ears. The dichotic presentation may result in a marked advantage to the input channel which has even slightly stronger representation in the hemisphere specialized for processing the type of stimuli presented.

Rosenzweig (1951) suggested that the auditory system is arranged so that some "central units" in each half of

the brain fire in response to stimulation of the ipsilateral ear, some to the contralateral ear, and some to both. He concluded that more units are activated by contralateral stimulation than by ipsilateral stimulation. According to Rosenzweig, the primary difference between competing pathways is the number of areas activated in each auditory cortex.

Variables Which Influence Dichotic Ear Preference

Effects of Stimulus Onset Time Alignment in Dichotic Identification

Berlin et al. (1973) conducted a series of studies concerning the effect of onset time for dichotically presented stimuli and right ear advantage. As stimuli, the six stop consonants were paired with the vowel /a/. In the first experiment, the stimuli were presented simultaneously and yielded a right ear advantage of 14 percent. These data are similar to the magnitude of right ear advantage reported by Studdert-Kennedy and Shankweiler (1970). In a subsequent study, Berlin et al. (1973) separated the stimuli by varying the time of onset. The results of these studies further confirmed the right ear superiority, however, three important observations were made:

- 1) Intelligibility in the lagging ear improved as the stimuli were separated in time. This was called the "lag effect".
- 2) Between 15 and 30 msec lag time, the intelligibility of the leading ear dropped.

- 3) Intelligibility in both ears improved beyond 30 msec of time separation.

Lowe et al. (1970), as well as Gerber and Goldman (1971), reported that voiceless consonants were more intelligible than voiced consonants when presented simultaneously in a dichotic listening task regardless of which ear was administered the voiceless consonant. Berlin et al. (1972) explained that this phenomenon occurs as a result of the voiceless consonant being perceived as lagging by his proposed "time limited processor." This left hemisphere speech processor would interpret the voiceless CV as having been presented after the voiced CV because of its long burst duration. The processor then would be interrupted in its analysis of the voiced CV and would suppress this information in order to analyze the newly arrived voiceless CV. This proposed processor's functional existence was supported when Berlin et al. (1973) shifted the onset of the voiced CV to coincide with the vocalic onset of the voiceless CV. This shift resulted in the voiced CV's gaining equal intelligibility without suppressing the voiceless CV's.

Effects of Varying Intensity in Dichotic Identification

Varying the intensity of syllables presented to one ear while the intensity of syllables presented to the other ear remained constant resulted in a right ear advantage even when the CV's presented to the right ear were 10 dB

less intense than those presented to the left ear (Berlin et al., 1977). This finding is supported by the research of Brady-Wood and Shankweiler (1976). Thompson et al. (1972) reported a study in which CV syllables were presented dichotically at equal intensity levels from 30 to 80 dB SPL. The intensity of the signals presented to the reference ear remained at 50 dB SPL while the variable ear was presented the competing signals in five dB increments from 30 dB to 80 dB SPL. A right ear advantage was shown for all but the most extreme intensity differences. From these results, the authors concluded that plus or minus 10 dB represents adequate intensity control necessary to reveal reliable ear effect results at intensity levels between 50 dB SPL and 80 dB SPL.

Effects of Selective Attention on Ear Preference Scores

Kinsbourne (1978) hypothesized the existence of primitive right-attending mechanisms which dominate human behavior from infancy through early childhood. The author used this right attentional bias to account for the left hemisphere dominance of speech and language skill in most right handed persons. He suggested that right ear advantages were a direct consequence of this right attentional bias when preparing to receive verbal stimuli. Kinsbourne also proposed that the location of the active processor and the complexity of the signal being processed regulate the degree to which attention shifts contralaterally to the

active hemisphere. This can be used to explain the differences in laterality effects observed for different tasks.

Kinsbourne (1974) proposed that one task of the selective attention mechanism is to provide a sorting system for excess information. Therefore, attentional processes might be presumed to be more active during dichotic stimulation. Shadden (1979) used both reaction time and accuracy measures of processing tasks under dichotic stimulation conditions to support this hypothesis. Shadden (1979) emphasized, however, that her results could be explained equally well by Kimura's (1967) model of central nervous system lateralization for auditory stimuli. Kimura (1967) proposed that right ear input is less subject to suppression since it follows the shortest route to the hemisphere containing the processor.

Using dichotic stimulation, the selective attention model would predict that the size of the observed laterality effects would be altered by manipulation of subject attention. The magnitude of the right ear advantage should be reduced when subjects are specifically instructed to attend to the left ear. Hiscock and Kinsbourne (1977) suggest that the ability to shift the focus of attention increases with age and central nervous system development. Laterality effects would not, however, be expected to be eliminated under conditions of directed attention during

dichotic stimulation since interference with left ear performance might be expected from their unattended but verbally pre-emptive right ear channel (Kinsbourne, 1970; Treisman and Geffen, 1968). These authors failed to consider the language skill of their subjects.

Effects of Sex and Handedness on Hemispheric Lateralization

Gur et al. (1982) investigated sex and handedness differences in cerebral blood flow during rest and cognitive activity. Subjects were grouped according to sex and handedness yielding the following four groups:

1. left handed females
2. right handed females
3. left handed males
4. right handed males

All subjects were between the ages of 18 years and 26 years. Cerebral blood flow was measured using a Xenon inhalation technique during periods of rest, solving verbal analogies, and solving a spatial line orientation task.

Cognitive activity yielded increased blood flow in all groups. However, both groups of right handed subjects showed greater increases in left hemisphere flow than right hemisphere flow for the verbal task. The laterality effect was weaker in the left handed subjects. Left handed males showed an equivalent increase in blood flow for both hemispheres during the verbal task and a greater rate of flow in the right hemisphere for the spatial task. Blood flow rates in females were found to be higher for all tasks than

those of males regardless of handedness. Since the rate of hemispheric blood flow was greater for females and left handed males, the authors concluded that brain organization in these groups differs from that of right handed males.

Laterality Effects in Children

Kimura (1963) investigated ear superiority in children four to nine years of age in a study which employed spoken digits that were dichotically presented. She attempted to ascertain at which age speech was lateralized in the left hemisphere. Her data revealed that left cerebral dominance for speech as evidenced by right ear preference is established in children by four years of age regardless of sex. Though no significant sex difference was noted, four year old boys demonstrated significantly greater perception for material presented to the right than to the left ear.

Kimura (1963) reported a difference between boys and girls in overall task efficiency, which was evident at age four and was statistically significant at ages five and six. She suggested that boys lag behind girls in the perception of speech sound stimuli as well as in production and that this developmental lag difference disappears in normal children at seven years of age. She did not, however, describe her subjects in relation to their language skills.

Berlin et al. (1973) demonstrated that five of six children exhibit a right ear advantage for verbal dichotic

stimuli by age five. This right ear advantage was presumed to be independent of the total number of dichotically presented CV syllables that children can identify correctly. The authors concluded that the speech processors' ability to correctly identify two simultaneous stimuli increase with age, and phonetic confusions made by nine, eleven, and thirteen year olds are similar to those made by adults. In children younger than seven, the authors concluded that this adult pattern was not established.

Relationship Between Ear Preference and Language Skill

Johnson et al. (1977) stated that a significant percentage of aphasic patients with left temporal lobe damage, stutterers, children with severe articulation defects, and children with language disorders manifest either less of a right ear advantage than normal controls, a lack of ear preference, or a left ear advantage. Johnson drew these conclusions from his research and his review of the research of others.

McDuffie (1975) investigated the relationship between dichotic listening task performance and the level of language development in five and six year old boys using syllables presented dichotically. The subjects were grouped according to their language skill into good and poor language groups. The results revealed a statistically

significant right ear preference for the good language group. The poor language group also demonstrated a statistically significant right ear advantage though the magnitude of the right ear preference was smaller than that of the good language group. Task efficiency was reported to be greater for the good language group than the poor language group. She concluded that response differences between the groups were due to the difference in their ability to deal with competitive auditory input.

Minor (1977) demonstrated that right ear preference scores in a group of children with poor articulation skills could be modified by training. However, these modifications proved to be temporary. She concluded that the ability to selectively attend was responsible for the changes in right ear preference scores rather than an increase in the subjects' ability to discriminate dichotically presented stimuli.

Neeley (1986) investigated differences in ear preference scores of subjects grouped according to articulation skill. Subjects were male elementary school students ranging in age from 8.5 years to 9.5 years. The normal group was composed of students who were never identified as having articulation disorders, the now-normal group was composed of students who had once been identified as having articulation disorders but at the time of testing had

normal articulation, and the poor articulation group was composed of students still enrolled in articulation therapy. The results of this investigation revealed that the ear preference scores of the now-normal articulation group were not significantly different from those of the poor articulation group while the performance of both groups was significantly poorer than that of the normal articulation group. Though the articulation performance of the now-normal articulation group was age-appropriate, these results suggested that their facility to deal with competitive linguistic input was inferior to that of their normally articulating peers.

EXPERIMENTAL TASK II

Musiek and Pinheiro (1985, pg. 230) stated that the "general function of the left hemisphere has been described as analytical and, therefore, important to serial ordering of temporal information. It may compare or analyze the interrelationships among the components of a sequence." Berlin and McNeil (1976) stated even more specifically that "temporal sequencing is a left hemisphere function and speech is a special case of a temporal sequence." Mazziota and Phelps (1985) reported that the use of specific strategies for making judgements of temporal ordering for tone pattern recognition tasks resulted in higher levels of metabolic activity in the left hemisphere than the right

hemisphere. These researchers reported, however, that these metabolic activity levels were reversed when the judgements concerning tone patterns were made without the use of a strategy for analysis. With this information in mind, the remainder of this literature review will focus on the previous research using temporal sequencing or pattern recognition tasks and the variables which influence their construction and use.

Variables That Influence Temporal Sequencing

Subject Training

Both trained and untrained subjects have been used in a variety of pattern recognition tasks with varied results depending on the complexity of the stimuli and the difficulty of the task. Efron (1963) indicated that untrained subjects performed significantly more poorly than trained normal subjects on some temporal ordering tasks. Warren (1974), however, reported that subject training was unnecessary for patterns in which the duration of components was at least 200 msec. Musiek and Pinheiro (1985) suggested that the need for subject training may depend on the type of data being collected. For example, psychophysical data to be used for descriptions and measurements of basic auditory functions and the capacity of the central auditory nervous system to process certain

information could most accurately be acquired using well trained subjects. However, normative data to be used as a basis for clinical procedures might best be established on a naive population.

Stimuli for Pattern Recognition Tasks

Stimulus Type. Many different types of stimuli have been used in temporal ordering studies. These include noise, tones, clicks, speech or speech-like sounds, or a combination of these different types with the most common stimulus type being tones. Musiek and Pinheiro (1985) specified that regardless of the stimuli used, the auditory signals in the sequence should not require discrimination between or among acoustic cues not under study. They explained that if any differences existed among the signals in frequency, intensity, or duration, the subject should be able to distinguish between them easily.

Since tone patterns are the most widely used type of stimuli in temporal ordering tasks, several factors have been determined to influence their construction and use. These factors include frequency, intensity, duration, number of components in a sequence, rate and manner of presentation, and the response task.

The importance of the frequency relationship or separation between tones in a sequence has been demonstrated by Divenyi and Hirsh (1974). These researchers reported that a frequency separation of less than one-third to two-thirds

of an octave decreased the accuracy of subjects responses. They also stated that a simple harmonic relationship among components of a sequence facilitated temporal order judgments. Pinheiro et al. (as cited by Musiek and Pinheiro, 1985) used tone patterns composed of three tones and systematically varied the frequency, intensity, and duration of the component tones. From the results of their investigation, they concluded that pitch pattern sequences were temporally ordered more easily than sequences in which either intensity or duration was the variable.

Tone Duration. Musiek and Pinheiro (1985) stated that the duration of the individual components in a sequence influences the perception of the sequence and the task of ordering it. Duration requirements for the four components of a contiguous sequence necessary for accurate judgements of temporal order were reported to be 125 to 700 msec duration if the sequence was repeated (Divenyi and Hirsh, 1974). Slightly longer durations were required if the sequence was presented only once. Contiguous sequences with a smaller number of components required shorter durations for accurate temporal ordering (Peters and Wood, 1973; Hirsh, 1959).

A number of researchers have investigated the variable of duration on tone pattern tasks by inserting intervals of silence between successive tonal components of a sequence

and between sequences. Peters and Wood (1973) used three different temporally segmented pulsed tones as stimuli. Their subjects were required to judge the order of the tones or identify the position of a specific component within a sequence. These researchers concluded that performance on these temporally segmented patterns was significantly improved over that of contiguous stimuli. Pinheiro and Andrews (as reported by Musiek and Pinheiro, 1985) employed temporally spaced tone triplets to determine the effects of tone duration and silent interval duration on the performance of pattern recognition tasks. Component durations were systematically varied within the range of 150 to 500 msec while silent interval durations were varied within the range of 50 to 300 msec. These authors reported that the adult subjects could accurately order these tone patterns with approximately 100 percent success when pitch pattern components and silent intervals had durations of 150 to 200 msec with a total pattern duration of about 900 msec. They also reported that normal nine year old children could perform as well as adults on patterns with these durations. However, younger children required longer durations of pattern components.

Response Modes. A variety of response modes have been used in temporal sequencing research and have been found to significantly influence results. Musiek and Pinheiro (1985) stated that some responses to pattern recognition

tasks require higher levels of cognitive processing than others. Hirsh (1959) asked his subjects to judge which of two overlapping tones began first. Other researchers required subjects to judge whether two sequences were the same or different (Efron, 1973; as reported by Musiek and Pinheiro, 1985). In their review of previous research in temporal sequencing, Musiek and Pinheiro (1985) concluded that the most difficult type of judgement of temporal order appeared to be a description of the sequence or actual ordering of the sequence components by labeling them verbally, manually, or repeating the actual order of the components in some other form of response. These authors also concluded that the actual ordering of components in a sequence involved language processing when either verbal or manual responses were required. These conclusions concerning verbal responses did not include hummed responses. Hummed responses for tonal sequences or pitch patterns were found to be an imitative type of response requiring less cognitive processing than a verbal or manual response (Musiek and Pinheiro, 1985).

Pinheiro (1977) developed the Pitch Pattern Sequence Test for the assessment of central auditory processing disorders in children and adults. This test is made up of 120 test pattern sequences with each sequence consisting of three tones, two of which are matched with regard to fre-

quency, arranged in six possible combinations. The frequencies for the high and low tones are 1430 Hz and 880 Hz respectively. Tone durations were set at 200 msec with 150 msec of silence between tones yielding a total sequence duration of 900 msec.

Using these six sequences, presented randomly, the test administration can be "tailored" to fit the subjects' specific needs. For example, the stimuli can be presented monaurally or binaurally under earphones or in a sound field. Pinheiro (1977) reported that normal adults obtained similar test results from each of these methods of presentation. Response modes can also be varied. Pinheiro reported similar results for normal adults using either verbal or manual responses.

EXPERIMENTAL TASK I: SUMMARY

A review of the literature concerning the use of the dichotic listening procedure revealed the following:

1. The left cerebral hemisphere is dominant for speech and language functions in most individuals (Penfield and Roberts, 1959), and the ear contralateral to the dominant hemisphere performs more efficiently in a dichotic listening task, regardless of handedness (Kimura, 1961; Shankweiler, 1971).

2. Children typically demonstrate ear preference, as measured by a dichotic listening task, by age four

(Kimura, 1963; Berlin et al., 1973). Berlin and McNeil (1976) reported that five of six individuals show a right ear advantage regardless of handedness.

3. Ear preference appears to be related to the level of language competence in children (McDuffie, 1975).

4. The temporal relationship between the onsets of dichotic stimulus pairs can influence laterality effects. When the onset times of dichotic stimulus pairs are separated between 15 and 30 msec the lagging stimulus becomes more intelligible while the leading stimulus becomes less intelligible. As onset times are separated beyond 30 msec, the intelligibility of both stimuli increases (Berlin et al., 1973).

5. Plus or minus 10 dB is considered adequate intensity control necessary to reveal reliable ear effect results for dichotically presented CV syllables at intensity levels between 50 dB SPL and 80 dB SPL (Thompson et al., 1972).

EXPERIMENTAL TASK II: SUMMARY

A review of the literature concerning temporal sequencing or pattern recognition tasks revealed the following:

1. Pitch pattern sequences were temporally ordered more easily than sequences in which either intensity or duration was the variable (Pinheiro et al. as reported by

Musiek and Pinheiro, 1985).

2. Normal subjects, at least nine years old, could accurately order pitch patterns when the components and silent intervals of the sequences had durations of 150 to 200 msec (Pinheiro and Andrews as reported by Musiek and Pinheiro, 1985).

3. The actual ordering of sequence components requires language processing when manual or verbal response modes are employed (Musiek and Pinheiro, 1985).

4. When specific strategies are used by subjects to make judgements concerning the ordering of tone patterns, left hemisphere activity increases (Mazziota and Phelps, 1985).

EXPERIMENTAL QUESTIONS

This project involved two experimental tasks to be completed using the same subject groups. Three experimental questions were posed. They are as follows:

1. Do the ear preference scores of students who were once identified as having articulation disorders but now have normal articulation improve to match those of normally articulating peers as the length of time since being dismissed from therapy increases?

2. Do differences exist between students who have never had articulation disorders and students who were once identified as having articulation disorders but now have

normal articulation regarding their performance on a series of tone pattern recognition tasks?

3. Since both experimental tasks are considered to be tests of central auditory processing, does a predictive relationship exist between subject performance on the two tasks?

CHAPTER III

PROCEDURES

This study was designed to compare the performance of quondam articulatory deficient children with that of children who have always been considered as having normal articulation skill on two tests considered to be tests of central auditory processing. The first test was a dichotic listening task which used CV syllables as stimuli. The second test was comprised of a series of tone pattern recognition tasks developed using the Pinheiro Pitch Pattern Test (1977) as a model. As was reported in the previous review of the literature, both of these test paradigms have been used in the assessment of central auditory processing disorders.

This investigation had three purposes. The first objective was to determine if ear preference scores, as measured by a dichotic listening task, of students who were once identified as having articulation disorders but now have normal articulation improve to match those of children who have never been identified as having articulation disorders as the length of time since being dismissed from therapy increases. The second objective was to determine if differences existed between subject groups concerning their performance on a series of tone pattern recognition tasks. The third and final aim was to determine if a

relationship existed between the subjects' performance on the two test batteries.

This chapter contains a discussion of the criteria used for subject selection, the construction of the two experimental tasks, the procedures and equipment used for data collection for both experimental tasks, and the statistical procedures used for data analysis.

Description of the Subjects

The subjects for this study were obtained from the Sloan-Hendrix and Black Rock School Districts in Arkansas. These schools were selected because this investigator was employed as a speech/language pathologist by both districts between the years of 1977 and 1983. As a result, this investigator was responsible for the evaluation, placement, treatment, and dismissal from therapy of those students selected for inclusion as experimental group subjects in this study. Though the control group subjects were never a part of this investigator's case load since they had no speech or language disorders, this investigator had had contact with each of these students through the routine speech/language screening process and social interaction. Subjects were selected for inclusion in this study on the basis of the following criteria:

- 1) male sex
- 2) hearing acuity within normal limits bilaterally
- 3) normal intelligence
- 4) normal articulation

Ten subjects were assigned to each of the three experimental groups based on their age and the time elapsed since being dismissed from therapy. Experimental group I was composed of subjects between the ages of nine and eleven years who had been dismissed from therapy for three years. The mean age of the subjects assigned to this group was 118.0 months with the group having a standard deviation of 7.19 months. Experimental group II was composed of subjects between the ages of 11 and 14 years with a mean age of 148.1 months and a standard deviation of 11.28 months. Experimental group II subjects had been dismissed from articulation therapy for five years. Experimental group III was composed of subjects between the ages of 14 and 17 years who had been dismissed from therapy for seven years. This group had a mean age of 180.7 months with a standard deviation of 12.45 months. Appendix A provides a listing of each subject's age in months, group age means, and standard deviations.

All students included in these three groups were initially diagnosed as having functional articulation disorders. None of these students were observed as having

concomitant disorders that could have negatively influenced articulation skill such as craniofacial abnormalities, language disorders, mental retardation, cerebral palsy, or learning disabilities. In addition, no subtle neuromuscular disorders were apparent in any of the subjects. Sommers and Kane (1974, pg. 107) stated that the term "functional is appropriately applied to inadequate performance of the articulatory forms within a language, irrespective of etiology, when there are no obvious signs of structural and neurological deviations."

All students comprising experimental groups I, II, and III were evaluated and placed in articulation therapy based on the results of the same assessment battery following the guidelines specified in Public Law 94-142 and Arkansas Act 102. Articulation skill was initially evaluated using the Arizona Articulation Proficiency Scale (Fudala, 1974). This test provides a systematic method for determining severity based on the number of correctly articulated stimulus items and the student's age. While the students selected for inclusion in the experimental groups of this study did vary according to the severity of the articulation disorder each exhibited, all students presented at least a moderate articulation disorder. Appendix B provides a listing of each experimental subject's score on the Arizona Articulation Proficiency Scale and the subsequent severity rating when initially placed in

articulation therapy.

All students in the three experimental groups received articulation therapy based on Van Riper's traditional approach which involves the remediation of one target sound at a time. Therapy progressed through auditory discrimination and production of the targeted phoneme in stages which included isolation, syllables, words, phrases, sentences, and conversation. Students were dismissed from therapy when they had demonstrated the ability to correctly articulate all error phonemes with 90 percent accuracy for three consecutive therapy sessions in the sentence exercises and when they demonstrated the ability to self-correct their articulation errors at the conversational level of practice. All experimental subjects exhibited normal articulation skill at the time of this experimental testing. Appendix C provides a listing of all subjects' articulation test scores obtained at the time of experimental testing.

Subjects for the three control groups were selected on the basis of the same criteria as the experimental groups which included the following:

- 1) male sex
- 2) hearing acuity within normal limits bilaterally
- 3) normal intelligence
- 4) normal articulation

Ten subjects were assigned to each control group and were matched to the corresponding experimental group on the basis of age. Control group I subjects were between the ages of nine and eleven years with a mean age of 123.2 months and a standard deviation of 7.79 months. Control group II was composed of subjects between the ages of 11 and 14 years with a mean age of 151.7 months and a standard deviation of 8.97 months. The subjects comprising control group III were between the ages of 14 and 17 years with a mean age of 183.3 months and a standard deviation of 12.41 months. A one-way analysis of variance procedure was used to compare the mean ages of corresponding subject groups. No significant differences were found to exist between corresponding subject groups on the basis of age. Appendix A provides a listing of each subject's age, group age means and standard deviations, and the results of each one-way analysis of variance procedure used to compare these means.

No conscious attempt was made to control subjects with regard for socio-economic status or cultural background but all experimental and control subjects were enrolled in one of two relatively rural school districts in Northeast Arkansas.

Measure of Hearing Acuity

Pure tone audiometric thresholds were obtained for each prospective subject for the frequencies 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. This was done for two reasons.

The first reason involved the subject selection criterion regarding normal hearing acuity. All subjects were required to demonstrate hearing thresholds at or below 20 dB for the frequencies tested to be included in this study. The second reason thresholds were obtained was to insure that no differences between left and right ear acuities for any subject exceeded 10 dB for any of the frequencies listed above.

Measure of Intelligence

For the purpose of this study, the Peabody Picture Vocabulary Test - Revised was considered to be a screening test of verbal intelligence. Students who failed to demonstrate standard scores in the range of 85 to 115 (stanine scores of 3 to 7), according to the published norms for this test (Dunn and Dunn, 1981), were not included in this study. In addition, classroom teachers were consulted to verify that each subject's academic performance in the areas of mathematics and English was at least average. Average academic performance in these subject areas was also indicated by the use of report card letter grades for the previous semester's work. A grade of at least "C" was required for each student in both subject areas. Appendix C provides a listing of each subject's score on the Peabody Picture Vocabulary Test - Revised.

Measure of Preferred Handedness

Each subject's preferred handedness was determined by parental and teacher reports and was verified by this examiner's observing each student perform a writing task. The writing task involved each subject's copying from the chalkboard a paragraph composed by this investigator.

This investigator realizes that other phenomena can be used as indices of laterality in addition to ear preference scores and handedness which are addressed in this study. These phenomena include eyedness and leggedness (Corballis and Beale, 1971). Since many of the dichotic listening studies in the literature use only handedness and ear preference scores as subject control measures, this investigator did not control for subject's eyedness and leggedness.

Measure of Articulation Skill

Each prospective subject was administered the Templin-Darley Test of Articulation (Screening Portion) to determine current levels of articulatory performance. Students who failed to obtain a mean articulation score for their age (47 correct of 50 items) on the articulation screening were excluded from this study. All subjects in both control and experimental groups exhibited normal articulation by making no errors on the screening portion of the Templin-Darley Test of Articulation (See Appendix C). In addition, this investigator observed no

articulation errors in any of the subjects' conversational utterances.

Materials and Equipment for Task I

Stimuli

Six CV combinations, composed of one of the six stop consonants /p,b,t,d,k,g/ and the vowel /a/, were used as stimuli for the diotic and dichotic tasks. For the dichotic task, these six CV combinations were grouped into 15 minimal pair contrasts with each pair being contrasted by voicing and/or place of articulation. The stimulus pairs, grouped according to their distinctive feature contrasts, are as follows:

<u>voicing</u>		<u>place</u>		<u>voicing and place</u>	
pa	ba	pa	ta	pa	da
ta	da	pa	ka	pa	ga
ka	ga	ta	ka	ba	ta
		ba	da	ba	ka
		ba	ga	ta	ga
		da	ga	da	ka

The CV syllables in each left column were designated A while the CV syllables in each right column were designated B. Each stimulus pair was dichotically presented three times with pair member A channeled to the right ear and pair member B channeled to the left ear, and presented three times with the order of presentation reversed. This yielded a total of six presentations of each of the 15

dichotic stimulus pairs, or a total of 90 dichotic stimulus items presented randomly.

For the diotic task, each of six CV combinations were presented diotically 15 times in random order. This represented a total of 90 diotic stimuli. Therefore, the complete task for this portion of the study consisted of 90 randomly presented diotic items followed by 90 randomly presented dichotic items.

Response Paradigm

A six choice selection task was used to elicit the responses to the stimulus presentations. Each of the CV combinations was represented by a typewritten letter combination. This group of six choices was displayed for each stimulus item during both the diotic and dichotic tasks. The subjects responded by circling the written symbol which represented the CV syllable they heard best. A complete response form for the diotic and dichotic tasks is provided in Appendix D.

Experimental Tape

One two-track stimulus tape containing computer generated synthetic speech stimulus pairs (described above) was obtained from the Kresge Hearing Research Laboratory at the Louisiana State University Medical Center. The stimuli were randomly recorded in groups of 30 pairs with an interstimulus interval of seven seconds. The duration of the tape was approximately 12 minutes. For the diotic

task, the stimuli from the left channel of the dichotic tape were presented simultaneously to both ears of the subject being tested. Both diotic and dichotic stimuli are listed in order of presentation in Appendix E.

Validation checks of stimulus onset synchronization for the dichotic tape were conducted using a Teac A40 Playback Recorder and a Tektronix Type 5103N Dual Trace Cathode Ray Oscilloscope with storage capability. Stimulus onsets were determined to be aligned within 10 msec.

A graphic display of intensity levels between and within stimulus pairs on the dichotic tape was obtained using a Teac A40 Tape Recorder, Bruel and Kjaer Type 2307 Level Recorder with a 50 dB potentiometer, and a Bruel and Kjaer Type 2603 Microphone Amplifier. Stimulus intensity levels between and within the stimuli recorded on both channels of the tape were found to be within 2 dB. The signal to noise ratio was determined to be 24 dB for the stimulus tape.

This tape was used in a previous study by this investigator (Neeley, 1986). The procedures listed were used to check the quality of the audio signals on the tape both prior to and subsequent to data collection for the previous investigation as well as the current study.

Diotic and Dichotic Listening Tasks

Testing Procedure

Stimuli were presented using a stereophonic tape recorder with a stereophonic junction box which would accommodate three sets of earphones. Three subjects were tested at a time. Stimuli were presented through the three sets of earphones simultaneously at a level equivalent to a 1000 Hz calibration tone at 78 dB SPL. This calibration was completed before and after data collection.

Subjects were tested in groups of three. In an attempt to acquaint the subjects with the type of stimuli being presented, the rate of stimulus presentation, and the response procedure, a test sample consisting of ten items was played prior to the administration of each test. Each subject was supplied with a response sheet and pencil prior to testing and was instructed to circle the written syllable that represented the syllable he heard best. To discourage the possibility of subjects copying, each of the three subjects being tested were asked to sit facing different directions. In an attempt to prevent subject fatigue, all subjects were given brief (approximately two minutes) rest periods following the presentation of each group of 30 stimuli. Though no specific reinforcement was given regarding the accuracy of subject responses, all subjects were verbally praised during the rest periods for

their attention and encouraged to continue cooperating.

Treatment of the Data from Task I

Data were collected which represented subject performance in the following areas:

- 1) correct identification of diotically presented signals.
- 2) identification of right ear responses, left ear responses, and error responses for the dichotically presented signals. Of the six possible choices for each stimulus pair presented dichotically, one was a correct identification for the right ear, one was correct for the left ear, and the remaining choices were scored as error responses.

The data were reported in terms of each group's performance which yielded mean scores. The differences among these means which represented each groups' performance were analyzed using a two way analysis of variance (Neter, Wasserman, and Kutner, 1985).

Materials and Equipment for Task II

Pattern Recognition Tasks

The second experimental task of this study was comprised of six pattern recognition tests. Each test was composed of 60 stimulus items with the initial 10 items of each test used as familiarization items. Each of the six

pattern recognition tests presented a different configuration of tone patterns. For convenience, the individual tests have been named and are listed below in order of their administration:

- 1) oddball paradigm
- 2) four tone sequence in pairs
- 3) four tone sequence (singles)
- 4) three tone sequence
- 5) two tone sequence
- 6) Pinheiro (fast)

Stimuli

The tonal components used in each of these tests were computer generated 500 Hz and 1000 Hz tones. The tone durations and time intervals between tone presentations within individual patterns were consistent for each of the six tests. The tone durations were 100 msec while the interstimulus intervals were 200 msec. The time interval between individual tone patterns varied with the test. These intervals of silence between patterns ranged from 500 msec in duration to five seconds in duration depending on the difficulty of the response task or the expected length of time needed to respond to the task. The computer programs, written in TI BASIC, used to generate the various tone pattern tasks and screen print instructions are

provided in Appendix F.

Table I provides a summary of each of the pattern recognition tests including such information as the number of tonal components in each stimulus sequence, the type of judgements to be made by the subjects for each test, and descriptions of the stimuli used.

The six tone pattern tests were recorded on video tape (VHS format) by connecting the video cassette recorder to the television which was used as the video monitor for the TI99/4a computer. As the computer executed the BASIC programs, the video cassette recorder was engaged to record the audio signals generated and the "print" instructions. The video monitor was used to display item numbers and stimulus descriptions for familiarization purposes and item numbers only for test purposes.

Experimental Task for Pattern Recognition Tests

Method of Presentation

Each pattern recognition test was presented using a video cassette recorder (VHS format) and a television monitor. The video signals consisted of stimulus item numbers and the frequency of the tones generated (in Hertz) which corresponded to the tone patterns emitted by the television's speaker for familiarization purposes. Item numbers only were presented in an effort to keep subjects from "losing their place" during test administration.

Table I. Summary of the six pattern recognition tests.
500 and 1000 Hz tones were used for each test.
Tone durations were 100msec with interstimulus
interval of 200 msec for tones within each
pattern.

Name	Description	Subjects' Task
oddball	Tones are presented in random order with a high-low ratio of 70/30.	Count the oddball tone (500 Hz)
four tones (pairs)	2 pairs of tones are presented in each pattern with 200 msec of silence separating pair members, 500 msec separating pairs, and 2 seconds between patterns.	Circle the pair that is different
four tones (singles)	4 tones are presented in sequence with 200 msec between tones and 2 seconds between patterns.	Circle the tone that is different
three tones	3 tones are presented in sequence with 200 msec between tones and 2 seconds between patterns.	Which tone is different or are all the same?
two tones	2 tones are presented in sequence with 200 msec between tones and 2 seconds between patterns.	Is the second tone higher, lower, or same as the first?
Pinheiro	3 tones are presented in sequence with 200 msec between tones and 5 seconds between patterns.	Duplicate the tone pattern

Testing Procedures

Subjects were tested in groups of ten. As an attempt to acquaint subjects with the type of stimuli being used and the type of response required for each pattern recognition test, a familiarization period preceded the administration of each test. This test sample period consisted of ten stimulus items. Subjects were supplied with response sheets and pencils as well as oral and written instructions for completing each test. Copies of each of the six response sheets are provided in Appendix G.

Treatment of Data from Experimental Task II

The data collected represent each subject's accuracy on each of the six pattern recognition tasks and are reported as percentages. Mean percentage scores were calculated for each subject group for each of the experimental tasks. Differences between and within group mean scores were analyzed for significance using a two way analysis of variance (Neter, Wasserman, and Kutner, 1985). Correlation of each subject's performance on the two experimental tasks were completed using a multiple regression process.

CHAPTER IV

RESULTS AND DISCUSSION

This study was comprised of two experimental tasks both of which are considered to be tests of central auditory processing. The purpose of the first task was to determine if ear preference scores of children who were once identified as having articulation disorders but now have normal articulation improve to match those of children who have never been identified as having articulation disorders as the length of time since being dismissed from therapy increases. The purpose of the second task was to investigate the performance of these same subject groups on a series of pattern recognition tasks. The third purpose of this investigation was to determine if a relationship existed between subject performance on the two experimental tasks.

Experimental Task I

The test stimuli for the diotic/dichotic listening tasks consisted of computer generated CV syllables made up of the six stop consonants, /p,t,k,b,d,g/, and the vowel /a/. The diotic task involved the random presentation of each of the syllables 15 times. This resulted in a total of 90 diotic stimulus items. The dichotic task was comprised of presentation of the six CV syllables in 15

contrasting pairs. Each pair was contrasted by voicing or place or both. Each set of these competing pairs was randomly presented six times for a total of 90 dichotic stimulus items.

The data analyzed for experimental task one included a diotic discrimination score, a dominant ear score, non-dominant ear score, and an error score. The diotic discrimination score represented the number of stimuli the subject correctly identified in response to the 90 diotic items. The dominant ear score reflected the number of dichotically presented stimulus items correctly identified when presented to the dominant (usually right) ear. The non-dominant ear score represented the number of correctly identified stimulus items presented to the non-dominant ear. The error score reflected the number of incorrect responses to the dichotic task. Raw scores were converted to percentage scores. From these percentage scores, group means and ear preference calculations were made.

Diotic Listening Task Performance

The diotic listening task performance for each subject is listed in Table II as the percentage of correct responses to the 90 item diotic task. Subject group means are also reported in Table II. Control group 1 (ages 9 to 11 years) obtained diotic scores ranging from 91 to 100 percent with a mean of 97.3 percent. Control group 2 (ages

Table II: Diotic listening task performance for all subjects in all participating groups. All values represent percentage scores based on the number of correct responses to the 90 item diotic task.

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
1	100	100	100	98	100	100
2	94	100	98	100	100	100
3	100	98	100	98	100	100
4	91	100	100	100	98	100
5	94	100	100	100	100	100
6	96	100	100	95	100	100
7	100	100	98	100	100	100
8	100	100	100	100	100	100
9	98	98	100	100	100	100
10	100	100	100	100	100	100
MEAN	97.3	99.6	99.6	99.1	99.8	100

12 to 14 years) obtained diotic scores ranging from 98 to 100 percent with a mean of 99.6 percent. Control group 3 (ages 15 to 17 years) obtained diotic scores also ranging from 98 to 100 percent with a mean of 99.6 percent.

Experimental group 1 with ages matching those of control group 1 obtained diotic scores ranging from 95 to 100 percent with a mean score of 99.1 percent. Experimental group 2 (ages 12 to 14 years) obtained diotic scores ranging from 98 to 100 percent with a mean of 99.8 percent. Each member of experimental group 3 (ages 15 to 17 years) obtained perfect diotic scores of 100 percent with a mean of 100 percent.

These group scores were analyzed statistically using a one way analysis of variance procedure. The results of this analysis indicated that statistically significant differences existed among the means ($F = 3.77$, $p = .005$, df 5, 54). Further analysis revealed that the mean score obtained by control group 1 was significantly different from the means of the remaining groups. Though this difference exists statistically, this researcher attached no practical importance to it. Since the diotic scores of each subject included in this study exceeded the 90 percent level of accuracy, this researcher concluded that all subjects exhibited an ability to correctly identify diotically presented CV syllables with an acceptable level of proficiency so as not to jeopardize their dichotic task performance.

The diotic scores for control group 1 were visually analyzed in an effort to determine a possible explanation for the group's performance. No obvious error patterns were discernible that would explain the errors in terms of student familiarity with the task or temporary equipment failure. Since the errors did occur in a random fashion one possible explanation could be that the students were having slight difficulty attending to the stimuli.

Dichotic Listening Task Performance

Percentage scores for each subject reflecting the

number of stimuli correctly identified when dichotically presented to the dominant (usually right) ear are listed in Table III as well as the means for each group. Control group 1 obtained dominant ear scores ranging from 38 to 62 percent with a mean dominant ear score of 49.2 percent. Control group 2 obtained dominant ear scores ranging from 42 to 74 percent with a mean dominant ear score of 64.1 percent. Control group 3 obtained dominant ear scores ranging from 49 to 76 percent with a mean dominant ear score of 62.1 percent. Experimental group 1 obtained dominant ear scores ranging from 42 to 60 percent with a mean dominant ear score of 49.8 percent. Experimental group 2 obtained dominant ear scores ranging from 44 to 76 percent with a mean dominant ear score of 60.3 percent. Experimental group 3 obtained dominant ear scores ranging from 48 to 66 percent with a mean dominant ear score of 61.5 percent.

A two way analysis of variance procedure was used to analyze these data sets in terms of main effects, defined as subjects grouping according to age and subject grouping based on the existence or non-existence of previous articulation disorders, and interactions between these main effects. A summary of this statistical analysis is provided in Table IV which illustrates that statistically significant differences are present among the dominant ear score means for the groups of subjects included in this

Table III: Dominant ear scores as measured by a dichotic listening task for all subjects in all subject groups. All values are percentage scores based on a total of 90 items.

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
1	55	66	66	42	56	66
2	46	71	60	52	44	48
3	48	42	56	46	66	74
4	38	62	76	60	60	60
5	40	71	62	52	71	56
6	43	68	49	42	76	66
7	62	74	68	55	50	52
8	44	66	60	49	66	71
9	56	62	66	52	54	60
10	60	59	58	48	60	62
MEAN	49.2	64.1	62.1	49.8	60.3	61.5

Table IV: Summary table for the two way analysis of variance procedure performed on the dominant ear data of the six subject groups.

Source	DF	Sum of Squares	F	P
CE	1	24.06	0.36	0.5513
Age	2	2084.93	15.57	0.0001
CE*Age	2	51.73	0.39	0.6814
Error	54	3615.6		
Total	59	5776.3		

study. Further inspection revealed that the existing differences were the result of the age factor rather than group membership based on previous articulation disorders or an interaction between the two factors.

These findings are graphically illustrated in Figure I. Notice that even though the line representing the performance of the "middle" age subjects intersects that of the oldest subjects, the slopes of these lines were considered to be so nearly parallel that no interactions were judged to exist.

Since age was the only factor along which differences in dominant ear performance were determined to exist, post hoc analysis was used to specify these differences. Using the Scheffe procedure, the mean dominant ear scores for the nine to 11 year old subjects, both experimental and control groups, were determined to be significantly lower than those of the 12 to 14 year old subjects and the 15 to 17 year old subjects. No statistically significant differences were found to exist between the mean dominant ear scores of the latter subject groups.

Age was also determined to be the primary factor in segregating the subject groups with respect to mean non-dominant ear scores and mean error scores obtained during the dichotic testing procedure. Using the Scheffe procedure, it was determined that the nine to 11 year old age

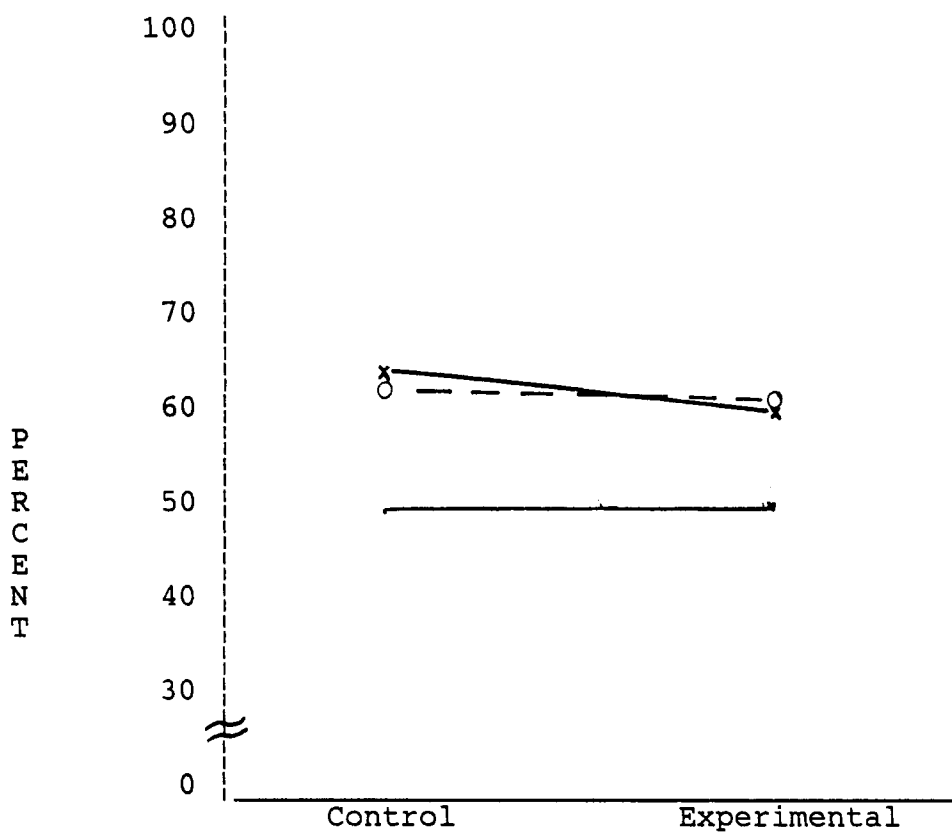


Figure I: Graphic display of the relationships among the mean dominant ear scores of the subject groups segregated according to age. The nine to 11 year old groups' performances are represented by the solid black line. The 12 to 14 year old groups' performances are represented by the x's connected by the solid line. The 15 to 17 year old groups' performances are represented by the o's connected by the dashed line.

groups, both experimental and control, responded significantly more often to stimuli presented dichotically to the non-dominant ear than either of the older age groups while no significant difference was found to exist between the mean non-dominant ear scores of these older groups. A listing of non-dominant ear scores and group means are

presented in Table V which is followed by the results of the two way analysis of variance listed in Table VI. The relationship between the mean non-dominant ear scores for each of the groups with respect to the age factor is illustrated in Figure II.

Statistically significant differences among the error responses of the subject groups concerning the dichotic listening task were also revealed by the two way analysis of variance procedure beyond the .01 level of confidence.

Table V: Non-dominant ear performance, as measured by a dichotic listening task, for all subjects in all participating groups. All values represent percentages based on a total of 90 items.

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
1	20	12	14	32	24	12
2	30	18	20	35	28	18
3	34	39	18	30	12	10
4	24	24	10	12	15	22
5	22	20	14	24	18	16
6	24	20	20	35	08	22
7	16	12	16	22	26	26
8	32	27	18	30	15	14
9	22	14	08	16	22	12
10	24	20	24	28	12	16
MEAN	24.8	20.6	16.2	26.4	18.0	16.8

Table VI: Summary table for the two way analysis of variance procedure performed on the non-dominant ear data.

Source	DF	Sum of Squares	F	P
CE	1	0.26	0.01	0.9369
Age	2	868.93	10.29	0.0002
CE*Age	2	48.13	0.57	0.5688
Error	54	2279.60		
Total	59	3196.9		

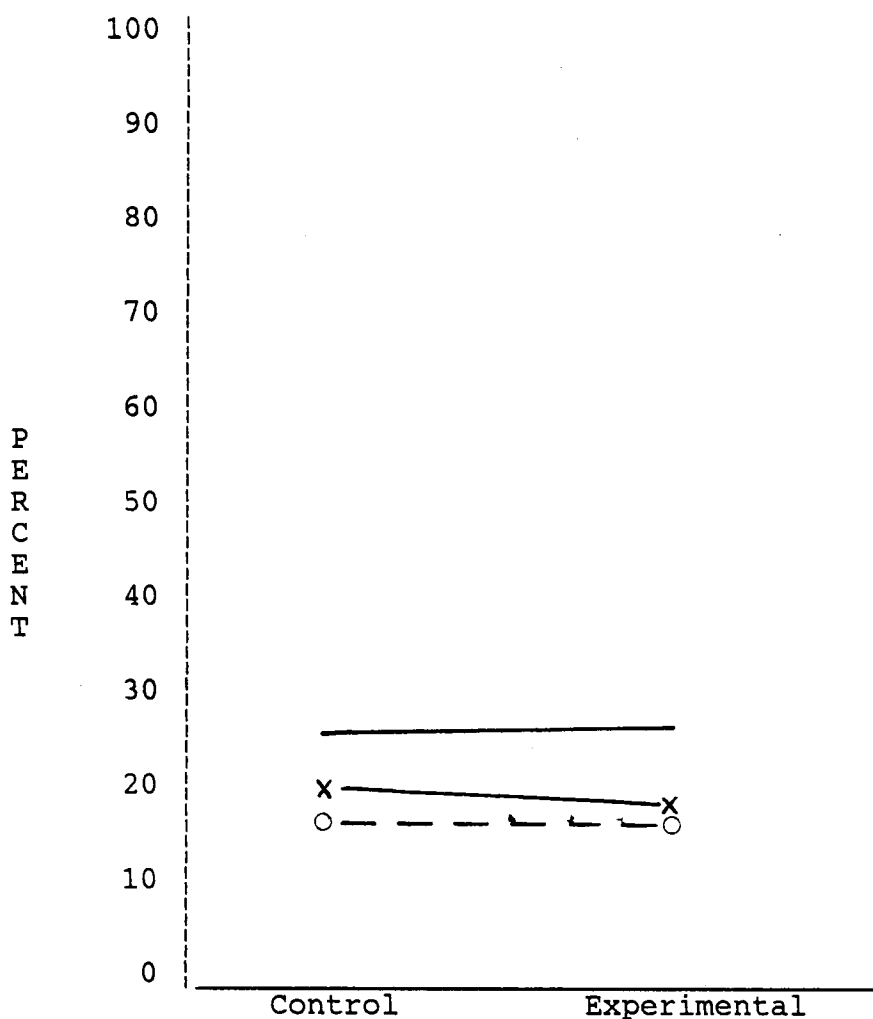


Figure II: Graphic illustration of the relationships among the group means for non-dominant ear performance during the dichotic listening task. The mean non-dominant ear scores for the nine to 11 year old subjects are represented by the solid black line. The mean non-dominant ear scores for the 12 to 14 year olds are represented by the x's connected by the solid line. Mean non-dominant ear scores for the 15 to 17 year olds are represented by the o's connected by the dashed line.

Using a Scheffe procedure to specify these differences as a result of the age factor, the nine to 11 year old subjects, both experimental and control, were found to respond incorrectly to dichotically presented CV's significantly more often than the 15 to 17 year old subjects. However, no significant differences in error responses were noted between the nine to 11 year olds and the 12 to 14 year olds or the 12 to 14 year olds and the 15 to 17 year old subjects. Each subject's error data are listed in Table VII as well as group means. This is followed by Table VIII which provides a summary of the two way analysis of variance results for the error data obtained from the dichotic listening task. Figure III provides a graphic representation of the relationship between the group mean error scores with respect to the age factor. The essence of these data is that although there were some differences in diotic and dichotic performances as a function of age, there were no apparent differences related to previous articulation skill.

Experimental Task II

The second experimental task of this study was comprised of six pattern recognition tests. Each test was composed of 60 stimulus items with the initial 10 items of each test used to familiarize the subjects with the stimuli and response task. Each of the six pattern recognition

Table VII: Percentage of error responses given by each subject on a 90 item dichotic listening task.

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
1	25	22	20	26	20	22
2	24	11	20	13	28	34
3	12	19	26	24	22	16
4	38	14	14	28	25	18
5	38	09	24	24	11	28
6	33	12	31	23	16	12
7	22	14	16	23	24	22
8	24	07	22	21	19	15
9	22	24	26	32	24	28
10	16	21	18	24	28	22
MEAN	25.4	15.3	21.7	23.8	21.7	21.7

Table VIII: Summary table for the two way analysis of variance procedure performed on the error data obtained from the dichotic listening task.

Source	DF	Sum of Squares	F	P
CE	1	38.4	0.98	0.3258
Age	2	372.4	4.77	0.0124
CE*Age	2	179.2	2.29	0.1105
Error	54	2108.4		
Total	59	2698.4		

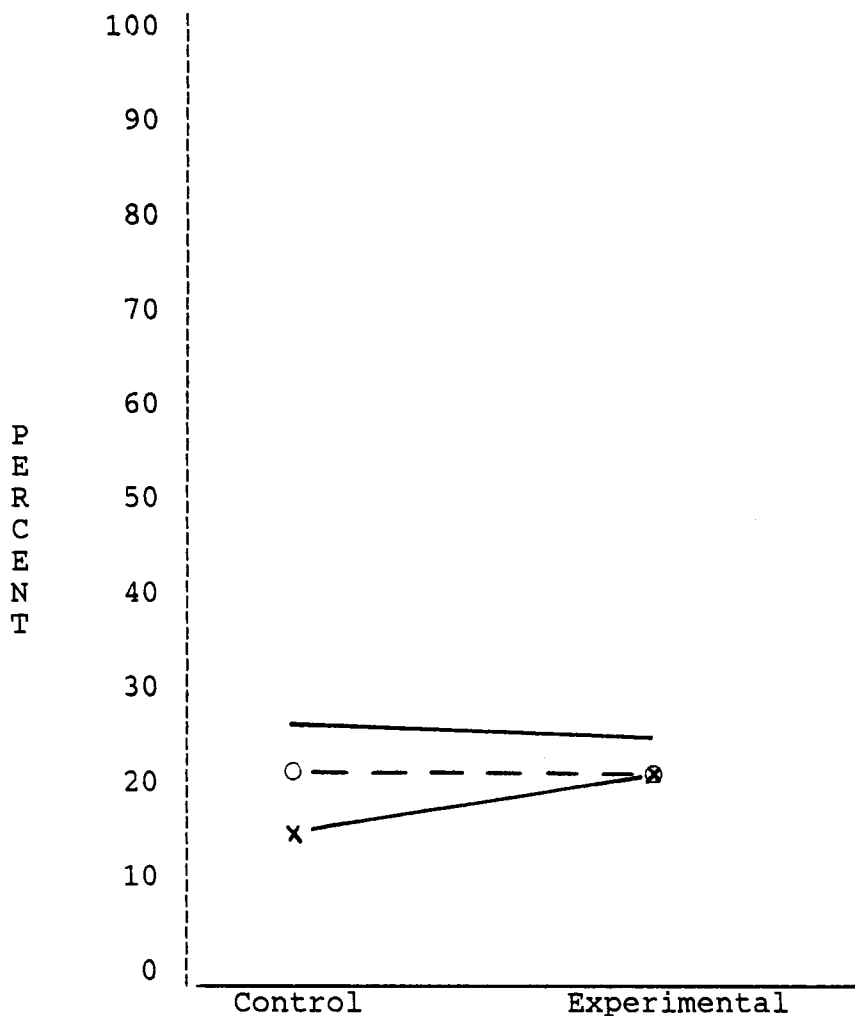


Figure III: Graphic illustration of the relationships among the group means of error responses obtained during the dichotic listening task. The mean error scores for the nine to 11 year old subjects, both control and experimental, are represented by the solid line. The mean error scores for the 12 to 14 year olds are represented by the x's connected by the solid line. Mean error scores for the 15 to 17 year olds are represented by the o's connected by a dashed line.

tests presented a different configuration of tone patterns. The tonal components used in each of the tests were computer generated 500 Hz and 1000 Hz tones. The tone durations were 100 msec while the silent intervals between tones within a pattern were 200 msec. The time interval between individual tone patterns within a test varies with the test. These intervals between patterns range from 500 msec in duration to five seconds in duration depending on the difficulty of the response task or the expected length of time needed to respond to the task.

The pattern recognition tests were audio and video taped directly from the computer monitor. This video tape was then used for the administration of the test stimuli to all subjects. As described earlier, ten sample items were displayed on the video screen as examples with tone sequences identified as high or low. After a pause for questions or other preparation, the 50 test items were presented with only the item number displayed on the screen. The item numbers of each of the tone patterns were visible on the screen as an aid to help subjects coordinate their responses with the correct item numbers on the response sheet.

Table I (pg. 48) provided a listing of the six pattern recognition tests as well as a brief description of the tonal stimuli and the response task.

Pattern Recognition Task Performance

The pattern recognition task performance for each subject is reported as the percentage of correct responses to each of the 50 item tests. A complete listing of each subject's scores as well as group means for each pattern recognition test is provided in Table IX.

A two way analysis of variance procedure was used to analyze these pattern data sets for each pattern recognition test in terms of main effects, defined as subject grouping according to age and subject grouping based on the existence or non-existence of a previous handicapping condition, and interactions between the main effects. From these analyses, statistically significant differences among group means were found to exist for all six pattern recognition tests using a .01 level of confidence. The primary factor from which these differences precipitated was age. No statistically significant differences among subject performances were found to exist as a result of subject grouping based on previous articulation disorders or the interaction of factors.

Post hoc analysis was conducted using a Scheffe procedure to specify the differences in group performance for the various pattern recognition tests. For each test the mean scores of the nine to 11 year old subjects were significantly lower than those of the 15 to 17 year old subjects. For the oddball, four tone pairs, two tone, and

Table IX: Pattern recognition test scores for all subjects on each of the six tests. All values represent percentages of correct responses based on a total of 50 stimulus items in each test. Group means are also listed for each test.

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
<u>Oddball Test</u>						
1	100	100	100	98	100	100
2	100	100	100	98	100	100
3	100	100	100	98	100	100
4	100	100	100	100	100	100
5	100	98	100	98	100	100
6	100	100	100	100	100	100
7	100	100	100	100	100	100
8	100	100	100	100	100	100
9	100	100	100	98	100	100
10	98	100	100	100	100	100
MEAN	99.8	99.8	100	99.0	100	100

Four Tone Pairs

1	100	100	100	96	100	100
2	100	100	100	98	100	100
3	98	100	100	94	96	100
4	68	100	100	94	96	98
5	84	100	100	98	100	98
6	98	100	100	100	100	100
7	100	100	100	100	100	100
8	100	100	100	92	100	100
9	100	100	100	90	96	94
10	100	100	100	96	100	100
MEAN	94.8	100	100	95.8	98.8	99.0

Table IX: (cont.)

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
<u>Four tone Singles</u>						
1	98	96	100	84	94	100
2	84	98	100	96	100	88
3	98	98	94	88	92	100
4	74	92	100	92	66	86
5	84	96	94	98	96	96
6	84	94	94	88	96	98
7	100	100	100	100	98	96
8	82	94	100	86	98	94
9	94	100	100	88	98	90
10	96	96	100	92	94	100
MEAN	89.4	96.4	98.2	91.2	93.2	94.8

Three tone

1	100	100	100	82	96	100
2	96	98	100	98	100	98
3	98	100	98	96	94	100
4	94	100	100	98	78	96
5	86	100	100	98	100	100
6	96	100	98	100	100	100
7	100	100	100	88	100	100
8	98	100	100	96	100	96
9	92	100	100	90	98	98
10	98	96	100	98	96	100
MEAN	95.8	99.4	99.6	94.4	96.2	98.8

Table IX: (cont.)

Subject #	Group C1	Group C2	Group C3	Group E1	Group E2	Group E3
<u>Two tone</u>						
1	98	98	100	92	100	92
2	100	100	100	100	100	80
3	98	96	100	72	72	100
4	100	100	100	56	80	94
5	90	100	100	98	98	100
6	80	98	98	90	100	100
7	100	100	94	74	100	94
8	100	100	100	82	100	98
9	88	98	100	88	90	92
10	96	100	96	90	94	92
Mean	95.0	99.0	98.8	84.2	93.4	94.2
<u>Pinheiro</u>						
1	98	96	100	60	98	96
2	100	94	100	90	100	76
3	98	100	82	90	52	94
4	84	100	100	38	54	92
5	66	96	100	96	76	100
6	80	76	98	70	98	96
7	94	100	100	82	100	88
8	84	100	100	74	100	96
9	92	96	100	86	86	90
10	36	96	100	90	98	94
MEAN	83.2	95.4	98.0	77.6	86.2	92.2

pinheiro pattern tests, the group mean scores of the nine to 11 year old subjects were again found to be significantly lower than those of the 12 to 14 year old subjects. However, no significant differences were found to exist between the group mean scores of the 12 to 14 year old subjects and the 15 to 17 year old subjects for any of the pattern recognition tests. These findings are illustrated in Figure IV.

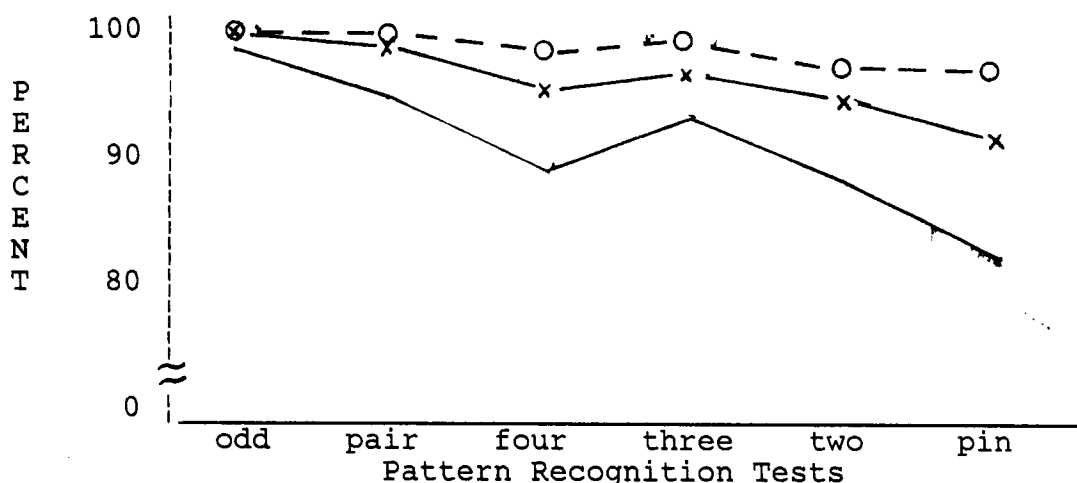


Figure IV: Illustration of the mean scores of subject groups separated only by the age factor for each of the six pattern recognition tests. Nine to 11 year old subject group performance is represented by the solid black line, 12 to 14 year old subject group performance is represented by x's connected by a solid line, and 15 to 17 year old subject group performance is represented by o's and a dashed line.

In an effort to locate other possible trends, the raw data sets obtained by all subjects on the pattern recognition tests were carefully scrutinized. One obser-

vation made by this researcher was that occasionally some subjects scores appeared inconsistent across the six tests. For example, subject # 10 of control group one scored at or above the 90 percent level of accuracy for five of the six subtests then obtained a score of 36 percent on the remaining test. After singling out nine incidents of this type, an effort was made to determine the cause of the poor performance. A review of each of these subjects' response sheets was conducted to ensure that no errors were made in scoring the tests and no scoring errors were noted. Also an attempt was made to determine if the subjects had inadvertently responded to the test stimuli out of proper sequence. However, no such explanations could be determined. The only plausible explanations of these occasional poor scores were concluded to be that either the subjects legitimately were unable to perform the task for that specific test, or that the subjects were consciously or unconsciously not cooperating.

Individual data cells which fell below three standard deviations of the group mean score were considered outlying scores and were eliminated from the statistical analysis. This effectively eliminated any individual score that fell below the 70 percent level of accuracy which resulted in the elimination of nine data points.

A two way analysis of variance procedure was used to analyze the amended data sets. Again the main effect of

age was the primary determinant of statistically significant differences in group means for the oddball, four tone pairs, four tone singles, and three tone pattern recognition tests at the .01 level of confidence. However, for the two tone test and the Pinheiro test, group membership based on the^e existence or non-existence of previous articulation disorders also resulted in statistically significant differences in group mean scores at the .01 level of confidence. Table X provides a summary of the two way analysis of variance results for the six pattern recognition tests.

Analysis of these data sets was also conducted using a multiple regression with forward selection process for the purpose of determining if subjects' performance on the pattern recognition tests could be correlated with their dominant ear scores as measured by the dichotic listening task. The results of this analysis revealed the only significant correlation to exist between dominant ear scores and subject performance on the four tone singles pattern recognition test. This relationship yielded correlation coefficient of .59245 indicating a moderate, positive correlation between subject performance on the dichotic listening task and the four tone pattern recognition test.

Table X: Summary of the two way analysis of variance procedure performed on the amended data sets for each of the six pattern recognition tests. The .01 level of confidence was used to determine statistically significant differences among group means.

Group	Mean	F	P	Main Effects	F	P
<u>Oddball Test</u>						
C1	99.8	4.73	.0012	CE	1.88	0.1756
C2	99.8			AGE	6.49	0.0030
C3	100.0			CE*AGE	4.40	0.0170
E1	99.0					
E2	100.0					
E3	100.0					
<u>Four tone pairs</u>						
C1	97.7	3.44	.0091	CE	3.91	0.0531
C2	100.0			AGE	6.25	0.0037
C3	100.0			CE*AGE	0.18	0.6387
E1	95.8					
E2	98.8					
E3	99.0					
<u>Four tone singles</u>						
C1	89.4	4.32	.0023	CE	0.20	0.6592
C2	96.4			AGE	9.38	0.0003
C3	98.2			CE*AGE	1.31	0.2785
E1	91.2					
E2	96.2					
E3	94.8					
<u>Three tones</u>						
C1	95.8	2.78	.0265	CE	2.83	0.0981
C2	99.4			AGE	5.07	0.0096
C3	99.6			CE*AGE	0.45	0.6369
E1	94.4					
E2	96.2					
E3	98.8					

Table X: (cont.)

Group	Mean	F	P	Main Effects	F	P
<u>Two tones</u>						
C1	95.0	3.91	.0043	CE	12.53	0.0008
C2	99.0			AGE	3.65	0.0327
C3	98.8			CE*AGE	0.18	0.8394
E1	87.3					
E2	93.4					
E3	94.2					
<u>Pinheiro</u>						
C1	91.3	4.68	.0015	CE	8.57	0.0052
C2	95.4			AGE	6.80	0.0025
C3	98.0			CE*AGE	0.34	0.7141
E1	84.8					
E2	94.5					
E3	92.2					

Reliability of the Tone Pattern Tests

Each of the tone pattern tests were administered a second time to a selected group of subjects for the purpose of determining test-retest reliability. Subject number five of each of the experimental and control groups was chosen to participate in the second administration of the tone patterns. The retest was conducted in the same room using the same audio/video equipment and response procedures as were used in the initial test conditions. The percent of agreement was calculated for each subject's scores on the initial and final administrations of each of the six tone pattern tests. Initial and final test scores and the calculated percent of agreement are located in Table XI. Of the 36 comparisons, 34 had percents of agreement of 84 or greater. The other two comparisons yielded 70 percent agreement. Both of these subjects earned the lowest scores for their subject group on the initial administration of the Pinheiro (fast) subtest. The performance of these two subjects on the second administration of the Pinheiro (fast) subtest exceeded the 90 percent accuracy level.

Table XI: Test-retest reliability data for subject #5 in each of the subject groups for the six pattern recognition tests.

Subject #	Group	Pretest	Posttest	% agreement
<u>Oddball Test</u>				
5	C1	100	100	100
5	C2	98	100	98
5	C3	100	100	100
5	E1	98	100	98
5	E2	100	100	100
5	E3	100	100	100
<u>Four Tone Pairs</u>				
5	C1	84	88	80
5	C2	100	98	98
5	C3	100	100	100
5	E1	98	100	98
5	E2	100	100	100
5	E3	98	100	98
<u>Four Tone Singles</u>				
5	C1	84	98	84
5	C2	96	92	88
5	C3	94	100	94
5	E1	98	100	98
5	E2	96	86	84
5	E3	96	100	96
<u>Three tones</u>				
5	C1	86	92	84
5	C2	100	100	100
5	C3	100	100	100
5	E1	98	94	92
5	E2	100	100	100
5	E3	100	100	100

Table XI: (cont.)

Subject #	Group	Pretest	Posttest	% agreement
<u>Two tones</u>				
5	C1	90	96	86
5	C2	100	98	98
5	C3	100	100	100
5	E1	98	92	92
5	E2	98	94	92
5	E3	100	92	92
<u>Pinheiro (fast)</u>				
5	C1	66	92	70
5	C2	96	98	94
5	C3	100	96	96
5	E1	96	90	88
5	E2	76	94	70
5	E3	100	100	100

DISCUSSION

Experimental Task I

In a previous study concerning the ear preference scores of children with articulation disorders, Neeley (1986) reported that children who had once been identified as having articulation disorders but now have normal articulation obtained significantly lower dominant ear scores than children who had never been identified as having articulation problems. This finding was consistent for subjects who had been out of articulation therapy for periods of up to two years. All subjects assigned to the experimental groups in the current study exhibited normal articulation but were previously diagnosed as having articulation disorders and were enrolled in articulation therapy. Subjects assigned to experimental group one had been released from therapy for three years, subjects assigned to experimental group two had been released from therapy for five years, and subjects assigned to experimental group three had been released from therapy for seven years at the time this testing was conducted. From the current study, it was noted that no significant differences existed between the dominant ear scores of experimental and control subjects at specific release time intervals. Significant differences in dominant ear scores were found to exist however, between the younger subjects and the

subjects in the two older age brackets.

The first experimental question of the study asked if ear preference scores of quondam articulatory deficient children improve to match those of normally articulating peers as the length of time since being released from therapy increases. Since the current study found no significant differences between the ear preference scores of experimental and control subjects at three years, five years, or seven years post-therapy, then this investigator cannot definitively answer the question. The data do, however, suggest a number of possible explanations. First, since the previous study found a significant difference between the ear preference scores of similar subject groups at two years post-therapy while the current study found no difference at three years post-therapy and beyond, then one could tentatively conclude that quondam articulatory deficient children do improve in their ability to deal with competitive linguistic input between two and three years post-therapy. This improved facility could be the result of the maturation of the neural mechanisms controlling speech and language functioning. Alternatively, the improvement could be the product of the students' continued practice of appropriate articulatory targets in routine communicative interactions. It is also conceivable that some combination of maturation and practice were

responsible for the improved ear preference scores of the experimental groups. A second possible explanation could be that the tests used in these studies were not sensitive to the differences between the experimental and controls groups.

In spite of the absence of a conclusive answer to the first experimental question, one significant trend was noted concerning ear preference scores. The ear preference scores of the experimental and control groups below the age of 12 years were significantly lower than those of their older counterparts. This finding appears to indicate that the ability to deal with competitive linguistic input is a maturational skill and that this linguistic maturation is complete by the age of 12 years.

Experimental Task II

The second experimental question posed by this study concerned the tone pattern tests' ability to separate subjects based on previous articulation skill. Two tone pattern tests, the two tone test and the Pinheiro (fast) test, were able to differentiate between subject groups based on the existence or non-existence of previous articulation disorders across all the ages of the subjects included in this study. The two tone test required subjects to determine if the second tone presented in each stimulus item was higher, lower, or the same as the first.

The pinheiro test required subjects to duplicate each pattern of three tones by circling the appropriate answers on the response sheet. These two tests were considered to be the most complex of the six pattern recognition tests and were, therefore, the last to be administered during each testing session. If these two tests are truly sensitive enough to differentiate between handicapped and nonhandicapped subject groups, then their use as screening tools may be valuable in identifying language disordered children.

The most consistent factor influencing subject performance on the six pattern recognition tests was age. Though other factors such as attention, motivation, and memory cannot be completely ruled out as having influenced subject performance, the stimuli used in the pattern recognition tests were designed to minimize that influence. The tonal components, their durations, and interstimulus intervals were constructed to eliminate the effects of masking and to make the subjects' response tasks as easy as possible. Subject performance improved on each test as age increased. The nine to 11 year old subjects obtained significantly lower scores than the 15 to 17 year old subjects on all tests. The 13 to 14 year old subjects' performance was more like that of the 15 to 17 year olds for five of the six pattern recognition tests. For the three tone test,

the scores of the 12 to 14 year olds were not significantly different from those of the younger or older subjects.

These results appear to indicate that temporal sequencing ability is also a maturational skill. This maturation may be reflected in the older subjects' speed and accuracy in devising appropriate strategies for decoding temporally sequenced stimuli. Musiek and Pinheiro (1985) reported that the analytical capabilities of the left hemisphere were important in the comparison or analysis of the interrelationships among the components of a sequence. Mazziota and Phelps (1985) reported that subjects who used analytic strategies to determine if two tonal sequences were identical exhibited higher levels of metabolic activity in the left cortical hemisphere than subjects who reported no use of strategies.

The third experimental question of this study asked if a predictive relationship existed between subject performance on the dichotic listening task and the tone pattern tests. Only one significant relationship was found to exist in this study as was indicated by the positive correlation between the four tone singles test and ear preference scores.

This author's equating of language facility and the ability to employ analytic strategies could be supported by the correlation between subjects' dominant ear scores and their performance on the four tone singles test. The four

tone singles test required the subjects to determine which of the four tones was different. One possible strategy for responding to each of these test items would require the subject to retain three of the four tones in memory. If the first three tones of the sequence were the same, the subject would know the fourth was different without listening to it. By the same reasoning, if one of the first three tones was different the subject could respond to the item without listening to the fourth tone. This strategy was considered by this researcher to be the most complex for responding to any of the pattern recognition tests due to the memory requirements. Since performance on the four tone singles test correlated significantly with the dominant ear scores, the use of strategies for analyzing temporal information may be a part of language facility.

Though these findings should be viewed with healthy skepticism until they can be replicated, they should provide some impetus for further research concerning the practical applications of these tests.

CHAPTER V

SUMMARY AND CONCLUSIONS

Sixty subjects, grouped according to age and the existence or nonexistence of previous articulation disorders, participated in the two experimental tasks of this study. The first experimental task involved diotic and dichotic listening exercises while the second experiment focused on the subjects' abilities to perform a series of pattern recognition tests.

The 90 item diotic task consisted of the random diotic presentation of six CV syllables which were composed of the six stop consonants and the vowel /a/. The 90 item dichotic task was comprised of the random dichotic presentation of 15 CV syllable pairs. The CV syllables for the dichotic task were also composed of the six stop consonants and the vowel /a/. Each of the 15 syllable pairs were contrasted by voicing, place of articulation, or both. The subjects' task for the diotic exercise was to select the printed syllable from six choices which represented the stimulus item which he perceived. The subjects' task for the dichotic exercise also required the selection of a printed syllable from six choices which represented the stimulus syllable that he perceived best.

The six pattern recognition tests are listed and

described in Table I (pg. 48). Each computer generated test was designed in such a way that different configurations of 500 Hz and 1000 Hz tones would be emitted with consistent intensities and durations. The subjects' task varied with the pattern recognition test. These tasks are also listed in Table I (pg. 48).

For experimental task one, the data obtained by each subject consisted of a diotic discrimination score for the diotic task and a dominant ear score, a nondominant ear score, and an error score for the dichotic task. For experimental task two each subject obtained a raw score that was converted to a percentage score which reflected the level of accuracy with which the test was completed. Each subject obtained six percentage scores which represented the level of performance for the six pattern recognition tests.

Experimental Task I

The purpose of this investigation was to determine if ear preference scores of children who were once identified as having articulation disorders improve to match those of normally articulating children as the length of time since being dismissed from therapy increases. The following conclusions were drawn as a result of data analysis:

- 1) Ear preference scores of quondam articulatory deficient children do improve to match those of normally

articulating peers. This conclusion resulted from the finding that no significant differences in dominant ear scores existed between experimental and control groups at intervals of three, five, and seven years post-therapy.

2) Language facility, the relative ease with which linguistic information is processed, continues to develop until at least the age of 12 years. This conclusion was based on the finding that dominant ear scores for the nine to 11 year old subjects were significantly lower than those of the subjects in the older age ranges.

Experiment Task II

The purpose of the second experimental task was to investigate the performance of these same subject groups on a series of pattern recognition tests. The following conclusions resulted from the analysis of the data obtained by the subjects on the six tests:

1) Performance on each of the six pattern recognition tests was influenced by the age of the subjects. Group mean scores for the nine to 11 year old subjects were found to be significantly lower than those of the subjects in the 15 to 17 year old groups for all six tests and significantly lower than those of the 12 to 14 year old subjects for five of the six tests. No significant differences were found to exist between the scores of the

12 to 14 year olds and the 15 to 17 year olds.

2) Performance on the two tone test and the pinheiro test may have been related to the existence or nonexistence of previous articulation disorders. Experimental subjects, regardless of age category, routinely obtained significantly lower scores on these two tests than control subjects.

3) The positive, moderate correlation between the dominant ear scores and the four tone singles test ($r = .59245$) lends some credence to the argument that the use of analytic strategies for processing temporal information is some part of language facility.

SUGGESTIONS FOR FUTURE RESEARCH

The present study has provided some basic information concerning the use of pattern recognition tests in speech and language research. However, many avenues of investigation remain to be explored. For example, the finding that the two tone test and the pinheiro test were sufficiently sensitive to differentiate between subject groups on the basis of previous handicapping condition offers several opportunities for future research with a variety of disordered populations. However, the first step toward these projects would need to include a replication of the present study, at least with these two tests, to validate the current findings.

Another possible avenue of research could involve using the pattern recognition tests as stimuli in studies monitoring event related potentials. For example, Molfese and Molfese (1985), using CV syllables as stimuli, reported that accuracy and latency of response of infants as young as 36 hours were predictors of language skill at three years of age. Infants with longer latencies and poorer accuracy at 36 hours of age tended to show less language skill at three years of age. Using this same rationale, pattern recognition tasks could be used as stimuli with children old enough to properly execute the tasks. Measures of latency and accuracy of response could then be correlated with language skill.

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APPENDICES

APPENDIX A

This appendix provides a listing of all subjects age in months, the mean ages for each group, and group standard deviations.

subject number	group e1	group e2	group e3	group c1	group c2	group c3
1	110	136	171	109	142	183
2	117	132	180	121	136	169
3	121	143	185	111	164	203
4	112	161	173	131	151	201
5	126	153	201	123	146	172
6	111	134	169	130	155	189
7	129	156	173	126	149	172
8	109	147	182	123	159	172
9	123	159	203	127	152	181
10	122	160	170	131	163	191
Mean ages	118.0	148.1	180.7	123.2	151.7	183.3
Sdev	7.16	11.28	12.45	7.76	8.97	12.41

One-way analysis of variance procedure was used to compare the mean ages of group e1 and group c1. This analysis indicated that no significant difference existed between these mean ages ($F = 2.41$, $p = .138$, $df\ 1, 18$).

One-way analysis of variance procedure was used to compare the mean ages of group e2 and group c2. No significant difference was found between these mean ages ($F = .624$, $p = .440$, $df\ 1, 18$).

One way analysis of variance procedure was employed to compare the mean ages of group e3 and group c3. Again, no significant difference was found to exist between these age means ($F = .220$, $p = .645$, $df\ 1, 18$).

APPENDIX B

Experimental subjects' performance on the Arizona Articulation Proficiency Scale when initially placed in articulation therapy.

EXPERIMENTAL GROUP I

Subject number	AAPS Score	Severity Rating
1	74	moderate
2	72.5	moderate
3	61	severe
4	58	severe
5	80	moderate
6	71.5	moderate
7	68	severe
8	64	severe
9	67	severe
10	80	moderate

EXPERIMENTAL GROUP II

subject number	AAPS Score	severity rating
1	62.5	severe
2	67	severe
3	75	moderate
4	68.5	severe
5	81	moderate
6	74	moderate
7	70	moderate
8	63.5	severe
9	69	severe
10	57	severe

EXPERIMENTAL GROUP III

subject number	AAPS Score	severity rating
1	76	moderate
2	76.5	moderate
3	82.5	moderate
4	74	moderate
5	63	severe
6	69	severe
7	72	moderate
8	65.5	severe
9	60	severe
10	73	moderate

APPENDIX C

Scores of experimental and control group subjects on the Peabody Picture Vocabulary Test - Revised and the Templin Darley Test of Articulation (Screening Portion) at the time of testing.

EXPERIMENTAL GROUP I

Subject Number	T-D	PPVT
1	50	93
2	50	99
3	50	105
4	50	96
5	50	89
6	50	99
7	50	93
8	50	106
9	50	101
10	50	97

EXPERIMENTAL GROUP II

Subject Number	T-D	PPVT
1	50	119
2	50	108
3	50	127
4	50	118
5	50	120
6	50	105
7	50	118
8	50	106
9	50	121
10	50	120

EXPERIMENTAL GROUP III

Subject Number	T-D	PPVT
1	50	129
2	50	120
3	50	133
4	50	132
5	50	117
6	50	127
7	50	136
8	50	126
9	50	130
10	50	128

APPENDIX C (cont.)

CONTROL GROUP I

Subject Number	T-D	PPVT
1	50	97
2	50	112
3	50	104
4	50	89
5	50	109
6	50	104
7	50	94
8	50	96
9	50	91
10	50	91

CONTROL GROUP II

Subject Number	T-D	PPVT
1	50	133
2	50	120
3	50	105
4	50	108
5	50	121
6	50	119
7	50	130
8	50	127
9	50	112
10	50	126

CONTROL GROUP III

Subject Number	T-D	PPVT
1	50	123
2	50	134
3	50	127
4	50	134
5	50	129
6	50	146
7	50	120
8	50	131
9	50	127
10	50	119

APPENDIX D

SUBJECT #: _____ GROUP: _____ DATE: _____

DIOTIC/DICHOTIC ANSWER SHEET

- | | |
|-----------------------|-----------------------|
| 1. pa ba ta da ka ga | 21. pa ba ta da ka ga |
| 2. pa ba ta da ka ga | 22. pa ba ta da ka ga |
| 3. pa ba ta da ka ga | 23. pa ba ta da ka ga |
| 4. pa ba ta da ka ga | 24. pa ba ta da ka ga |
| 5. pa ba ta da ka ga | 25. pa ba ta da ka ga |
| 6. pa ba ta da ka ga | 26. pa ba ta da ka ga |
| 7. pa ba ta da ka ga | 27. pa ba ta da ka ga |
| 8. pa ba ta da ka ga | 28. pa ba ta da ka ga |
| 9. pa ba ta da ka ga | 29. pa ba ta da ka ga |
| 10. pa ba ta da ka ga | 30. pa ba ta da ka ga |
| 11. pa ba ta da ka ga | 31. pa ba ta da ka ga |
| 12. pa ba ta da ka ga | 32. pa ba ta da ka ga |
| 13. pa ba ta da ka ga | 33. pa ba ta da ka ga |
| 14. pa ba ta da ka ga | 34. pa ba ta da ka ga |
| 15. pa ba ta da ka ga | 35. pa ba ta da ka ga |
| 16. pa ba ta da ka ga | 36. pa ba ta da ka ga |
| 17. pa ba ta da ka ga | 37. pa ba ta da ka ga |
| 18. pa ba ta da ka ga | 38. pa ba ta da ka ga |
| 19. pa ba ta da ka ga | 39. pa ba ta da ka ga |
| 20. pa ba ta da ka ga | 40. pa ba ta da ka ga |

DIOTIC/DICHOTIC ANSWER SHEET (cont.)

- | | |
|-----------------------|-----------------------|
| 41. pa ba ta da ka ga | 66. pa ba ta da ka ga |
| 42. pa ba ta da ka ga | 67. pa ba ta da ka ga |
| 43. pa ba ta da ka ga | 68. pa ba ta da ka ga |
| 44. pa ba ta da ka ga | 69. pa ba ta da ka ga |
| 45. pa ba ta da ka ga | 70. pa ba ta da ka ga |
| 46. pa ba ta da ka ga | 71. pa ba ta da ka ga |
| 47. pa ba ta da ka ga | 72. pa ba ta da ka ga |
| 48. pa ba ta da ka ga | 73. pa ba ta da ka ga |
| 49. pa ba ta da ka ga | 74. pa ba ta da ka ga |
| 50. pa ba ta da ka ga | 75. pa ba ta da ka ga |
| 51. pa ba ta da ka ga | 76. pa ba ta da ka ga |
| 52. pa ba ta da ka ga | 77. pa ba ta da ka ga |
| 53. pa ba ta da ka ga | 78. pa ba ta da ka ga |
| 54. pa ba ta da ka ga | 79. pa ba ta da ka ga |
| 55. pa ba ta da ka ga | 80. pa ba ta da ka ga |
| 56. pa ba ta da ka ga | 81. pa ba ta da ka ga |
| 57. pa ba ta da ka ga | 82. pa ba ta da ka ga |
| 58. pa ba ta da ka ga | 83. pa ba ta da ka ga |
| 59. pa ba ta da ka ga | 84. pa ba ta da ka da |
| 60. pa ba ta da ka ga | 85. pa ba ta da ka ga |
| 61. pa ba ta da ka ga | 86. pa ba ta da ka ga |
| 62. pa ba ta da ka ga | 87. pa ba ta da ka ga |
| 63. pa ba ta da ka ga | 88. pa ba ta da ka ga |
| 64. pa ba ta da ka ga | 89. pa ba ta da ka ga |
| 65. pa ba ta da ka ga | 90. pa ba ta da ka ga |

APPENDIX E

DIOTIC AND DICHOTIC STIMULUS ITEMS IN ORDER OF EXPERIMENTAL PRESENTATION

I. DIOTIC STIMULUS ITEMS

1. ba	31. ka	61. pa
2. ba	32. ta	62. ga
3. ka	33. ka	63. ba
4. ta	34. ka	64. ta
5. ga	35. ta	65. ba
6. ga	36. da	66. pa
7. ba	37. da	67. ta
8. ka	38. pa	68. ta
9. pa	39. da	69. pa
10. ba	40. ba	70. da
11. ka	41. pa	71. ka
12. ga	42. ta	72. ga
13. ka	43. pa	73. ga
14. da	44. ka	74. ta
15. ga	45. pa	75. da
16. pa	46. ta	76. ta
17. ta	47. ga	77. ba
18. pa	48. da	78. ka
19. ta	49. ga	79. pa
20. da	50. ba	80. ka
21. pa	51. ka	81. da
22. ba	52. ga	82. ba
23. ga	53. ba	83. pa
24. ta	54. ba	84. ga
25. ka	55. da	85. ka
26. da	56. pa	86. da
27. da	57. ta	87. ba
28. da	58. ba	88. ka
29. pa	59. ga	89. da
30. ta	60. ga	90. ga

II. DICHOTIC STIMULUS ITEMS

left	right	left	right	left	right
1. pa	ka	31. pa	ba	61. ga	ka
2. da	ka	32. ka	pa	62. ta	pa
3. ka	ta	33. ga	ta	63. ta	ga
4. pa	ba	34. da	pa	64. da	ga
5. ka	da	35. ka	da	65. da	pa
6. ga	ka	36. ba	ta	66. pa	ba
7. ta	ka	37. ga	pa	67. ba	ta
8. ta	ga	38. da	ga	68. ba	ga
9. ba	da	39. ba	ka	69. pa	ka
10. ga	ta	40. pa	da	70. ka	ba
11. ta	ba	41. ba	ga	71. ba	pa
12. ka	ba	42. pa	ga	72. ga	pa
13. ga	pa	43. ta	ba	73. ga	ba
14. ga	ba	44. ka	ga	74. ga	ta
15. da	pa	45. ka	ta	75. da	ba
16. da	ga	46. ta	da	76. ga	da
17. ka	pa	47. ga	ka	77. ka	ta
18. pa	ta	48. ta	pa	78. ba	da
19. da	pa	49. ba	pa	79. ba	ka
20. ba	pa	50. da	ka	80. ka	da
21. ba	ga	51. ta	ga	81. da	ka
22. da	ba	52. ga	ba	82. ka	pa
23. ga	da	53. da	ta	83. pa	ga
24. ta	da	54. ka	ba	84. ta	ba
25. ka	ga	55. ga	da	85. ta	da
26. ba	ta	56. da	ba	86. ta	ka
27. pa	ga	57. pa	ka	87. ka	ga
28. pa	da	58. ta	ka	88. pa	da
29. ba	ka	59. ba	da	89. pa	ta
30. ta	pa	60. pa	ta	90. da	ta

APPENDIX F

TI BASIC PROGRAMS USED TO GENERATE TONE PATTERN RECOGNITION TESTS

Test 1: Oddball Paradigm

```
1  Rem  Oddball paradigm 70/30
2  Rem  1000 and 500 Hz tones
3  Rem  Tone duration = 100 msec
4  Rem  ISI = 500 msec
5  Rem  HAP 1/14/85  RAN 8/86
10 Randomize
15  For loop = 1 to 6
20  let note = int(100*rnd)
25  let t = t+1
26  IF T = 11 THEN 350
27  IF T = 21 THEN 350
28  IF T = 31 THEN 350
30  IF T = 41 THEN 350
31  IF T = 51 THEN 350
32  IF T = 61 THEN 330
33  PRINT T
35  PRINT ,NOTE
40  IF NOTE < 30 THEN 200
50  IF NOTE > 30 THEN 300
200 CALL SOUND (100, 500, 5)
201 LET C = C + 1
205 PRINT , "500";C
210 FOR DELAY = 1 TO 500
220 NEXT DELAY
225 NEXT LOOP
300 CALL SOUND (100, 1000, 5)
305 PRINT , "1000"
310 FOR DELAY = 1 TO 500
320 NEXT DELAY
325 GOTO 15
330 END
350 FOR DELAY = 1 TO 1250
360 NEXT DELAY
370 GOTO 32
```

Test 2: Four Tones (Pairs)

```
1  REM  WHICH PAIR IS ALIKE?
2  REM  4 TONE SEQUENCE
3  REM  500 AND 1000 HZ TONES
4  REM  100 MSEC TONE DURATION
5  REM  200 MSEC ISI
6  REM  500 MSEC BETWEEN PAIRS
7  REM  2 SECONDS BETWEEN QUARTETS
10 REM  HAP 1/17/86  RAN 8/86
25 LET N = N + 1
26 PRINT N
27 IF N = 11 THEN 1100
28 IF N = 21 THEN 1100
29 IF N = 31 THEN 1100
30 IF N = 41 THEN 1100
31 IF N = 51 THEN 1100
32 IF N = 61 THEN 1000
34 FOR LOOP = 1 TO 6
35 LET C = C + 1
38 IF C = 5 THEN 400
39 IF C = 6 THEN 700
40 IF C = 7 THEN 400
50 LET NOTE = INT(2*RND)
80 IF NOTE = 0 THEN 200
90 IF NOTE = 1 THEN 300
200 CALL SOUND (100, 500, 5)
210 PRINT "500 TONE 1"
220 PRINT
230 FOR DELAY = 1 TO 50
240 NEXT DELAY
250 LET C = C + 1
260 NEXT LOOP
300 CALL SOUND (100, 1000, 5)
310 PRINT "1000 TONE 2"
320 PRINT
330 FOR DELAY = 1 TO 50
340 NEXT DELAY
350 LET C = C + 2
360 GOTO 30
400 FOR DELAY = 1 TO 250
405 NEXT DELAY
406 PRINT
407 PRINT
410 LET NOTE = INT (2*RND)
420 IF NOTE = 0 THEN 500
430 IF NOTE = 2 THEN 600
500 CALL SOUND (100, 1000, 5)
505 PRINT "1000 TONE 2"
506 PRINT
```

```

510 FOR DELAY = 1 TO 50
520 NEXT DELAY
530 CALL SOUND (100, 500, 5)
540 PRINT "500 TONE 1"
550 PRINT
560 FOR DELAY = 1 TO 1000
570 NEXT DELAY
575 LET C = 0
576 PRINT
577 PRINT
580 GOTO 25
600 CALL SOUND (100, 500, 5)
605 PRINT "500 TONE 1"
606 PRINT
610 FOR DELAY = 1 TO 50
620 NEXT DELAY
630 CALL SOUND (100, 1000, 5)
640 PRINT "1000 TONE 2"
650 PRINT
660 FOR DELAY = 1 TO 1000
670 NEXT DELAY
671 PRINT
672 PRINT
675 LET C = 0
680 GOTO 25
700 FOR DELAY = 1 TO 250
710 NEXT DELAY
715 PRINT
716 PRINT
720 LET NOTE = INT (2 * RND)
730 IF NOTE = 0 THEN 800
740 IF NOTE = 1 THEN 900
800 CALL SOUND (100, 500, 5)
805 PRINT "500 TONE 1"
810 PRINT
815 FOR DELAY = 1 TO 50
820 NEXT DELAY
830 CALL SOUND (100, 500, 5)
835 PRINT "500 TONE 1"
840 PRINT
850 FOR DELAY = 1 TO 1000
860 NEXT DELAY
870 LET C = 0
871 PRINT
872 PRINT
880 GOTO 25
900 CALL SOUND (100, 1000, 5)
905 PRINT "1000 TONE 2"
910 PRINT
920 FOR DELAY = 1 TO 50

```

```
930 NEXT DELAY
940 CALL SOUND (100, 1000, 5)
945 PRINT "1000 TONE 2"
950 PRINT
960 FOR DELAY = 1 TO 1000
965 NEXT DELAY
970 LET C = 0
975 PRINT
976 PRINT
980 GOTO 25
1000 END
1100 FOR DELAY = 1 TO 1000
1110 NEXT DELAY
1120 GOTO 34
```

Test 3: Four Tones (Singles)

```
1  REM  WHICH TONE IS ODD?
2  REM  4 TONE SEQUENCES (SINGLES)
3  REM  500 AND 1000 HZ TONES
4  REM  TONE DURATION = 100 MSEC
5  REM  ISI = 200 MSEC
6  REM  2 SECONDS BETWEEN QUARTETS
7  REM  HAP 1/17/86  RAN 8/86
25 LET N = N + 1
26 PRINT N
27 IF N = 11 THEN 1100
28 IF N = 21 THEN 1100
29 IF N = 31 THEN 1100
30 IF N = 41 THEN 1100
31 IF N = 51 THEN 1100
32 IF N = 61 THEN 1000
34 FOR LOOP = 1 TO 6
35 LET C = C + 1
38 IF C = 5 THEN 400
39 IF C = 6 THEN 700
40 IF C = 7 THEN 400
50 LET NOTE = INT ( 2 * RND)
60 IF NOTE = 0 THEN 200
70 IF NOTE = 1 THEN 300
200 CALL SOUND (100, 500, 5)
210 PRINT , "500 TONE 1"
220 PRINT
230 FOR DELAY = 1 TO 50
240 NEXT DELAY
250 LET C = C + 1
260 NEXT LOOP
300 CALL SOUND (100, 1000, 5)
310 PRINT , "1000 TONE 2"
320 PRINT
330 FOR DELAY = 1 TO 50
340 NEXT DELAY
350 LET C = C + 2
360 GOTO 34
400 LET NOTE = INT ( 2 * RND)
410 IF NOTE = 0 THEN 500
420 IF NOTE = 1 THEN 600
500 CALL SOUND (100, 1000, 5)
505 PRINT , "1000 TONE 2"
506 PRINT
510 FOR DELAY = 1 TO 50
520 NEXT DELAY
530 CALL SOUND (100, 500, 5)
540 PRINT , "500 TONE 1"
550 PRINT
```

```

560 FOR DELAY = 1 TO 1000
570 NEXT DELAY
575 LET C = 0
576 PRINT
577 PRINT
580 GOTO 25
600 CALL SOUND (100, 500, 5)
605 PRINT , "500 TONE 1"
606 PRINT
610 FOR DELAY = 1 TO 50
620 NEXT DELAY
630 CALL SOUND (100, 1000, 5)
640 PRINT , "1000 TONE 2"
650 PRINT
660 FOR DELAY = 1 TO 1000
670 NEXT DELAY
671 PRINT
671 PRINT
680 GOTO 25
700 LET NOTE = INT (2 * RND)
710 IF NOTE = 0 THEN 800
720 IF NOTE = 1 THEN 900
800 CALL SOUND (100, 500, 5)
805 PRINT , "500 TONE 1"
810 PRINT
820 FOR DELAY = 1 TO 50
825 NEXT DELAY
830 CALL SOUND (100, 500, 5)
835 PRINT , "500 TONE 1"
840 PRINT
850 FOR DELAY = 1 TO 1000
860 NEXT DELAY
870 LET C = 0
871 PRINT
872 PRINT
880 GOTO 25
900 CALL SOUND (100, 1000, 5)
905 PRINT , "1000 TONE 2"
910 PRINT
920 FOR DELAY = 1 TO 50
930 NEXT DELAY
940 CALL SOUND (100, 1000, 5)
945 PRINT , "1000 TONE 2"
950 PRINT
960 FOR DELAY = 1 TO 1000
970 NEXT DELAY
975 LET C = 0
976 PRINT
977 PRINT
980 GOTO 25
1000 END

```

```
1100 FOR DELAY = 1 TO 1500
1110 NEXT DELAY
1120 GOTO 34
```

Test 4: Three Tone Sequences

```
1  REM  WHICH TONE IS DIFFERENT?
2  REM  500 AND 1000 HZ TONES
3  REM  TONE DURATION = 100 MSEC
4  REM  200 MSEC BETWEEN TONES
5  REM  2 SECONDS BETWEEN PATTERNS
10 REM  HAP 2/28/86  RAN 9/86
25 LET C = C + 1
30 FOR LOOP = 1 TO 5
35 IF T = 3 THEN 400
40 IF T = 0 THEN 500
60 LET NOTE = INT (100 * RND)
70 PRINT C,NOTE
75 IF C = 61 THEN 150
80 IF NOTE < 50 THEN 200
90 IF NOTE > 50 THEN 300
150 END
200 CALL SOUND (100, 500, 5)
205 PRINT , "500 TONE 1"
210 PRINT
220 FOR DELAY = 1 TO 50
230 NEXT DELAY
240 LET T = T + 1
250 NEXT LOOP
300 CALL SOUND (100, 1000, 5)
310 PRINT , "1000 TONE 2"
315 PRINT
320 FOR DELAY = 1 TO 50
330 NEXT DELAY
340 LET T = T + 1
350 GOTO 30
400 FOR DELAY = 1 TO 1000
410 NEXT DELAY
411 LET T = 0
415 LET C = C + 1
416 PRINT
417 PRINT
420 GOTO 30
430 LET C = C + 1
500 IF C = 11 THEN 600
510 IF C = 21 THEN 600
520 IF C = 31 THEN 600
530 IF C = 41 THEN 600
540 IF C = 51 THEN 600
550 GOTO 60
600 FOR DELAY = 1 TO 1000
610 NEXT DELAY
620 GOTO 60
```

Test 5: Two Tone Sequences

```
1  REM  IS SECOND TONE HIGHER, LOWER, OR SAME AS FIRST?
2  REM  500 AND 1000 HZ TONES
3  REM  100 MSEC TONE DURATION
4  REM  200 MSEC ISI -- 2 SECONDS BETWEEN PATTERNS
5  REM  FOR CNV HAP 2/7/85  RAN 9/86
25 FOR LOOP = 1 TO 5
30 IF T = 2 THEN 400
35 LET NOTE = INT (100 * RND)
36 LET C = C + 1
37 IF C = 61 THEN 100
40 PRINT C, NOTE
41 IF T = 0 THEN 500
45 IF NOTE < 50 THEN 200
50 IF NOTE > 50 THEN 300
100 END
200 CALL SOUND (100, 500, 5)
205 PRINT , "500"
206 PRINT
210 FOR DELAY = 1 TO 50
220 NEXT DELAY
225 LET T = T + 1
230 LET C = C - 1
240 NEXT LOOP
300 CALL SOUND (100, 1000, 5)
305 PRINT , "1000"
306 PRINT
310 FOR DELAY = 1 TO 50
320 NEXT DELAY
330 LET T = T + 1
340 LET C = C - 1
350 GOTO 25
400 FOR DELAY = 1 TO 500
405 NEXT DELAY
410 LET T = 0
415 LET C = C + 1
420 PRINT
430 PRINT
440 GOTO 25
500 IF C = 11 THEN 600
510 IF C = 21 THEN 600
520 IF C = 31 THEN 600
530 IF C = 41 THEN 600
540 IF C = 51 THEN 600
550 GOTO 45
600 FOR DELAY = 1 TO 1000
610 NEXT DELAY
620 GOTO 45
```

Test 6: Pinheiro (fast)

```
10 REM 3 TONE PINHEIRO FAST
20 REM TASK = DUPLICATE THE PATTERN
30 REM 500 AND 1000 HZ TONES
40 REM 100 MSEC TONE DURATIONS -- 200 MSEC ISI
50 REM 5 SECONDS BETWEEN PATTERNS
60 CALL CLEAR
70 FOR I = 1 TO 12
80 IF I = 2 THEN 400
90 IF I = 3 THEN 200
100 IF I = 4 THEN 400
110 IF I = 5 THEN 200
120 IF I = 6 THEN 400
130 IF I = 7 THEN 200
140 IF I = 8 THEN 400
150 IF I = 9 THEN 200
160 IF I = 10 THEN 200
170 IF I = 11 THEN 600
180 IF I = 12 THEN 1400
200 LET C = C + 1
210 CALL SOUND (100, 1000, 5)
220 PRINT C
225 PRINT "1000"
230 FOR DELAY = 1 TO 50
240 NEXT DELAY
250 CALL SOUND (100, 500, 5)
260 PRINT "500"
270 FOR DELAY = 1 TO 50
280 NEXT DELAY
290 CALL SOUND (100, 1000, 5)
300 PRINT "1000"
310 FOR DELAY = 1 TO 1500
320 NEXT DELAY
330 PRINT
340 PRINT
400 LET C = C + 1
410 CALL SOUND (100, 500, 5)
420 PRINT C
430 PRINT "500"
435 FOR DELAY = 1 TO 50
440 NEXT DELAY
450 CALL SOUND (100, 1000, 5)
460 PRINT "1000"
470 FOR DELAY = 1 TO 50
480 NEXT DELAY
490 CALL SOUND (100, 500, 5)
500 PRINT "500"
510 FOR DELAY = 1 TO 1500
520 NEXT DELAY
```

```
530 PRINT
540 PRINT
600 LET C = C + 1
610 CALL SOUND (100, 1000, 5)
620 PRINT C
630 PRINT , "1000"
635 FOR DELAY = 1 TO 50
640 NEXT DELAY
650 CALL SOUND (100, 1000, 5)
660 PRINT , "1000"
670 FOR DELAY = 1 TO 50
680 NEXT DELAY
690 CALL SOUND (100, 500, 5)
700 PRINT , "500"
710 FOR DELAY = 1 TO 1500
720 NEXT DELAY
730 PRINT
740 PRINT
800 LET C = C + 1
810 CALL SOUND (100, 500, 5)
820 PRINT C
825 PRINT , "500"
830 FOR DELAY = 1 TO 50
840 NEXT DELAY
850 CALL SOUND (100, 500, 5)
860 PRINT , "500"
870 FOR DELAY = 1 TO 50
880 NEXT DELAY
890 CALL SOUND (100, 1000, 5)
900 PRINT , "1000"
910 FOR DELAY = 1 TO 1500
920 NEXT DELAY
930 PRINT
940 PRINT
1000 LET C = C + 1
1010 CALL SOUND (100, 1000, 5)
1020 PRINT C
1025 PRINT , "1000"
1030 FOR DELAY = 1 TO 50
1040 NEXT DELAY
1050 CALL SOUND (100, 500, 5)
1060 PRINT , "500"
1070 FOR DELAY = 1 TO 50
1080 NEXT DELAY
1090 CALL SOUND (100, 500, 5)
1100 PRINT , "500"
1110 FOR DELAY = 1 TO 1500
1120 NEXT DELAY
1130 PRINT
1140 PRINT
1200 LET C = C + 1
```

```
1210 CALL SOUND (100, 500, 5)
1220 PRINT C
1225 PRINT ,"500"
1230 FOR DELAY = 1 TO 50
1240 NEXT DELAY
1250 CALL SOUND (100, 1000, 5)
1260 PRINT ,"1000"
1270 FOR DELAY = 1 TO 50
1280 NEXT DELAY
1290 CALL SOUND (100, 1000, 5)
1300 PRINT ,"1000"
1310 FOR DELAY = 1 TO 1500
1320 NEXT DELAY
1330 PRINT
1340 PRINT
1350 NEXT I
1400 END
```

APPENDIX G

EXAM 1

ODDBALL PARADIGM

SUBJECT #: _____ GROUP: _____ DATE: _____

Your task is to count each low tone. Circle the number that corresponds to each low tone.

- | | | |
|-----|-----|-----|
| 1. | 21. | 41. |
| 2. | 22. | 42. |
| 3. | 23. | 43. |
| 4. | 24. | 44. |
| 5. | 25. | 45. |
| 6. | 26. | 46. |
| 7. | 27. | 47. |
| 8. | 28. | 48. |
| 9. | 29. | 49. |
| 10. | 30. | 50. |
| 11. | 31. | 51. |
| 12. | 32. | 52. |
| 13. | 33. | 53. |
| 14. | 34. | 54. |
| 15. | 35. | 55. |
| 16. | 36. | 56. |
| 17. | 37. | 57. |
| 18. | 38. | 58. |
| 19. | 39. | 59. |
| 20. | 40. | 60. |

Raw Score _____ Percent _____

EXAM 2

FOUR TONES - TWO PAIRS

SUBJECT #: _____ GROUP: _____ DATE: _____

Your task is to determine which of the pairs is the same.
Indicate your answer by circling the pair of numbers that
correspond to the pair that is the same.

- | | | |
|-------------|-------------|-------------|
| 1. 1-2 3-4 | 21. 1-2 3-4 | 41. 1-2 3-4 |
| 2. 1-2 3-4 | 22. 1-2 3-4 | 42. 1-2 3-4 |
| 3. 1-2 3-4 | 23. 1-2 3-4 | 43. 1-2 3-4 |
| 4. 1-2 3-4 | 24. 1-2 3-4 | 44. 1-2 3-4 |
| 5. 1-2 3-4 | 25. 1-2 3-4 | 45. 1-2 3-4 |
| 6. 1-2 3-4 | 26. 1-2 3-4 | 46. 1-2 3-4 |
| 7. 1-2 3-4 | 27. 1-2 3-4 | 47. 1-2 3-4 |
| 8. 1-2 3-4 | 28. 1-2 3-4 | 48. 1-2 3-4 |
| 9. 1-2 3-4 | 29. 1-2 3-4 | 49. 1-2 3-4 |
| 10. 1-2 3-4 | 30. 1-2 3-4 | 50. 1-2 3-4 |
| 11. 1-2 3-4 | 31. 1-2 3-4 | 51. 1-2 3-4 |
| 12. 1-2 3-4 | 32. 1-2 3-4 | 52. 1-2 3-4 |
| 13. 1-2 3-4 | 33. 1-2 3-4 | 53. 1-2 3-4 |
| 14. 1-2 3-4 | 34. 1-2 3-4 | 54. 1-2 3-4 |
| 15. 1-2 3-4 | 35. 1-2 3-4 | 55. 1-2 3-4 |
| 16. 1-2 3-4 | 36. 1-2 3-4 | 56. 1-2 3-4 |
| 17. 1-2 3-4 | 37. 1-2 3-4 | 57. 1-2 3-4 |
| 18. 1-2 3-4 | 38. 1-2 3-4 | 58. 1-2 3-4 |
| 19. 1-2 3-4 | 39. 1-2 3-4 | 59. 1-2 3-4 |
| 20. 1-2 3-4 | 40. 1-2 3-4 | 60. 1-2 3-4 |

Raw Score _____ Percent _____

EXAM 3

FOUR TONE SINGLES

SUBJECT #: _____ GROUP: _____ DATE: _____

Your task is to determine which of the four tones is different and indicate by circling the number which corresponds to the tone in the sequence.

- | | | |
|-------------|-------------|-------------|
| 1. 1 2 3 4 | 21. 1 2 3 4 | 41. 1 2 3 4 |
| 2. 1 2 3 4 | 22. 1 2 3 4 | 42. 1 2 3 4 |
| 3. 1 2 3 4 | 23. 1 2 3 4 | 43. 1 2 3 4 |
| 4. 1 2 3 4 | 24. 1 2 3 4 | 44. 1 2 3 4 |
| 5. 1 2 3 4 | 25. 1 2 3 4 | 45. 1 2 3 4 |
| 6. 1 2 3 4 | 26. 1 2 3 4 | 46. 1 2 3 4 |
| 7. 1 2 3 4 | 27. 1 2 3 4 | 47. 1 2 3 4 |
| 8. 1 2 3 4 | 28. 1 2 3 4 | 48. 1 2 3 4 |
| 9. 1 2 3 4 | 29. 1 2 3 4 | 49. 1 2 3 4 |
| 10. 1 2 3 4 | 30. 1 2 3 4 | 50. 1 2 3 4 |
| 11. 1 2 3 4 | 31. 1 2 3 4 | 51. 1 2 3 4 |
| 12. 1 2 3 4 | 32. 1 2 3 4 | 52. 1 2 3 4 |
| 13. 1 2 3 4 | 33. 1 2 3 4 | 53. 1 2 3 4 |
| 14. 1 2 3 4 | 34. 1 2 3 4 | 54. 1 2 3 4 |
| 15. 1 2 3 4 | 35. 1 2 3 4 | 55. 1 2 3 4 |
| 16. 1 2 3 4 | 36. 1 2 3 4 | 56. 1 2 3 4 |
| 17. 1 2 3 4 | 37. 1 2 3 4 | 57. 1 2 3 4 |
| 18. 1 2 3 4 | 38. 1 2 3 4 | 58. 1 2 3 4 |
| 19. 1 2 3 4 | 39. 1 2 3 4 | 59. 1 2 3 4 |
| 20. 1 2 3 4 | 40. 1 2 3 4 | 60. 1 2 3 4 |

Raw Score _____ Percent _____

EXAM 4

THREE TONES

SUBJECT #: _____ GROUP: _____ DATE: _____

Your task is to determine which tone is different or if all tones are the same.

- | | | |
|----------------|----------------|----------------|
| 1. 1 2 3 same | 21. 1 2 3 same | 41. 1 2 3 same |
| 2. 1 2 3 same | 22. 1 2 3 same | 42. 1 2 3 same |
| 3. 1 2 3 same | 23. 1 2 3 same | 43. 1 2 3 same |
| 4. 1 2 3 same | 24. 1 2 3 same | 44. 1 2 3 same |
| 5. 1 2 3 same | 25. 1 2 3 same | 45. 1 2 3 same |
| 6. 1 2 3 same | 26. 1 2 3 same | 46. 1 2 3 same |
| 7. 1 2 3 same | 27. 1 2 3 same | 47. 1 2 3 same |
| 8. 1 2 3 same | 28. 1 2 3 same | 48. 1 2 3 same |
| 9. 1 2 3 same | 29. 1 2 3 same | 49. 1 2 3 same |
| 10. 1 2 3 same | 30. 1 2 3 same | 50. 1 2 3 same |
| 11. 1 2 3 same | 31. 1 2 3 same | 51. 1 2 3 same |
| 12. 1 2 3 same | 32. 1 2 3 same | 52. 1 2 3 same |
| 13. 1 2 3 same | 33. 1 2 3 same | 53. 1 2 3 same |
| 14. 1 2 3 same | 34. 1 2 3 same | 54. 1 2 3 same |
| 15. 1 2 3 same | 35. 1 2 3 same | 55. 1 2 3 same |
| 16. 1 2 3 same | 36. 1 2 3 same | 56. 1 2 3 same |
| 17. 1 2 3 same | 37. 1 2 3 same | 57. 1 2 3 same |
| 18. 1 2 3 same | 38. 1 2 3 same | 58. 1 2 3 same |
| 19. 1 2 3 same | 39. 1 2 3 same | 59. 1 2 3 same |
| 20. 1 2 3 same | 40. 1 2 3 same | 60. 1 2 3 same |

Raw Score _____ Percent _____

EXAM 5

TWO TONES

SUBJECT #: _____ GROUP: _____ DATE: _____

Is the second tone higher, lower, or the same as the first?

- | | | |
|--------------|--------------|--------------|
| 1. H L SAME | 21. H L SAME | 41. H L SAME |
| 2. H L SAME | 22. H L SAME | 42. H L SAME |
| 3. H L SAME | 23. H L SAME | 43. H L SAME |
| 4. H L SAME | 24. H L SAME | 44. H L SAME |
| 5. H L SAME | 25. H L SAME | 45. H L SAME |
| 6. H L SAME | 26. H L SAME | 46. H L SAME |
| 7. H L SAME | 27. H L SAME | 47. H L SAME |
| 8. H L SAME | 28. H L SAME | 48. H L SAME |
| 9. H L SAME | 29. H L SAME | 49. H L SAME |
| 10. H L SAME | 30. H L SAME | 50. H L SAME |
| 11. H L SAME | 31. H L SAME | 51. H L SAME |
| 12. H L SAME | 32. H L SAME | 52. H L SAME |
| 13. H L SAME | 33. H L SAME | 53. H L SAME |
| 14. H L SAME | 34. H L SAME | 54. H L SAME |
| 15. H L SAME | 35. H L SAME | 55. H L SAME |
| 16. H L SAME | 36. H L SAME | 56. H L SAME |
| 17. H L SAME | 37. H L SAME | 57. H L SAME |
| 18. H L SAME | 38. H L SAME | 58. H L SAME |
| 19. H L SAME | 39. H L SAME | 59. H L SAME |
| 20. H L SAME | 40. H L SAME | 60. H L SAME |

Raw Score _____ Percent _____

EXAM 6

PINHEIRO FAST

SUBJECT #: _____ GROUP: _____ DATE: _____

Your task is to duplicate the patterns you hear by
circling the appropriate letter.

- | | | |
|--------------------|--------------------|--------------------|
| 1. H H H
L L L | 16. H H H
L L L | 31. H H H
L L L |
| 2. H H H
L L L | 17. H H H
L L L | 32. H H H
L L L |
| 3. H H H
L L L | 18. H H H
L L L | 33. H H H
L L L |
| 4. H H H
L L L | 19. H H H
L L L | 34. H H H
L L L |
| 5. H H H
L L L | 20. H H H
L L L | 35. H H H
L L L |
| 6. H H H
L L L | 21. H H H
L L L | 36. H H H
L L L |
| 7. H H H
L L L | 22. H H H
L L L | 37. H H H
L L L |
| 8. H H H
L L L | 23. H H H
L L L | 38. H H H
L L L |
| 9. H H H
L L L | 24. H H H
L L L | 39. H H H
L L L |
| 10. H H H
L L L | 25. H H H
L L L | 40. H H H
L L L |
| 11. H H H
L L L | 26. H H H
L L L | 41. H H H
L L L |
| 12. H H H
L L L | 27. H H H
L L L | 42. H H H
L L L |
| 13. H H H
L L L | 28. H H H
L L L | 43. H H H
L L L |
| 14. H H H
L L L | 29. H H H
L L L | 44. H H H
L L L |
| 15. H H H
L L L | 30. H H H
L L L | 45. H H H
L L L |

EXAM 6 (cont.)

46. H H H
 L L L

47. H H H
 L L L

48. H H H
 L L L

49. H H H
 L L L

50. H H H
 L L L

51. H H H
 L L L

52. H H H
 L L L

53. H H H
 L L L

54. H H H
 L L L

55. H H H
 L L L

56. H H H
 L L L

57. H H H
 L L L

58. H H H
 L L L

59. H H H
 L L L

60. H H H
 L L L

Raw Score _____ Percent _____

VITA

Richard Alan Neeley was born in McDougal, Arkansas, on May 21, 1954. He received his elementary and secondary education in Corning, Arkansas, and graduated from Corning High School in 1972. In 1976, he graduated from Arkansas State University with a Bachelor of Science in Education degree after majoring in Speech Pathology. He then enrolled in the graduate program at Arkansas State University and received the Master of Speech Pathology degree in 1977.

He served as a speech/language pathologist with Sloan-Hendrix and Black Rock Schools in Arkansas from 1977 to 1982. In 1983 he was employed by the Blytheville Public School as a speech/language pathologist.

In 1984 he enrolled in the doctoral program in Speech and Hearing Science at the University of Tennessee, Knoxville, Tennessee. He received the Doctor of Philosophy degree in Speech and Hearing Science in May, 1990.