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MAYO, WALTER STEPHEN

AN INVESTIGATION OF AUDITORY LATERALITY EFFECTS FOR SUNG STIMULI: INFLUENCE OF MUSICAL TRAINING AND COMPLEXITY OF STIMULUS PRESENTATION

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AN INVESTIGATION OF AUDITORY LATERALITY EFFECTS FOR SUNG STIMULI: INFLUENCE OF MUSICAL TRAINING AND COMPLEXITY OF STIMULUS PRESENTATION

by

Walter Stephen Mayo

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The purpose of this study was to examine the viability of theories that verbal and musical components when presented as singing (combination of verbal and musical components) are processed:

1. using bilateral hemisphere involvement--parallel processing of components by both hemispheres;

2. using single hemisphere involvement--processing of both components by one hemisphere.

Variables were considered that might affect the processing of sung stimuli: musical training of subjects and complexity of stimulus.

Two hypotheses served as a basis for investigation:

1. Subjects with vocal training will process sung stimuli differently than subjects with other musical training.

2. Subjects with formal musical training will process variations in complexity of sung stimuli differently than subjects with limited musical training.

Subjects participating in the study had vocal, instrumental, or limited musical training. All subjects were right-handed. A dichotic listening test using sung stimuli was administered. The sung stimuli were varied in complexity of presentation. Results of the dichotic test were recorded as scores for accuracy of verbal reproduction (word scores)

and scores for accuracy of musical reproduction (music scores). Analysis of the date was achieved through the use of multivariate and univariate ANOVA and a studentized range statistic.

Results from the study provided evidence for single hemisphere processing of sung stimuli depending on the complexity of the stimulus. However, there was no effect on the mode of hemisphere processing based on musical training. Therefore, neither hypothesis was statistically significant. The major findings were:

1. Subjects with vocal training did not have significantly more accurate word and music scores than subjects with instrumental or limited musical training.

2. Subjects processed verbal components more accurately with the left hemisphere than with the right hemisphere.

3. Processing efficiency for musical components of sung stimuli can be influenced by verbal complexity.

4. Subjects evidenced reversals of single hemisphere processing for both verbal and musical components depending on the complexity of stimulus presentation.

5. Subjects processed the verbal and musical components of sung stimuli as one unit, rather than as two different elements.

6. Each hemisphere can process sung stimuli independently of the other hemisphere.

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CHAPTER I

THE PROBLEM

Introduction

The theory that verbal and nonverbal stimuli are processed by different cortical hemispheres has created interest among researchers resulting in numerous studies of asymmetry of verbal and nonverbal stimuli. It has been concluded that verbal stimuli are processed by the left hemisphere and nonverbal stimuli are processed by the right hemisphere (Kimura, 1961; Kimura and Folb, 1968). Musical stimuli have been utilized as examples of nonverbal stimuli processed by the right hemisphere. Researchers have used melodies played by an instrument (Kimura, 1964), letters and numbers sung to melodies (Bartholomeus, 1974a), and musical chords (Gordon, 1970).

As a result of the prominence of this theory, researchers have questioned the way stimuli are processed (perceived and/or produced) that combine the properties of verbal and musical stimuli (Critchley, 1972; Dimond, 1972). These questions concern the viability of the theory that verbal and musical components when presented as singing (combination of verbal and musical components) are processed:

1. using bilateral hemisphere involvement--parallel processing of components by both hemispheres;

2. using single hemisphere involvement--processing of components by one hemisphere.

There is conflicting evidence in the literature that appears to support each of the theories. A summary of the studies in support of each theory is discussed in this chapter with hypotheses to be considered in this study in resolving the controversy.

Hemisphere Involvement in Singing

Evidence of Bilateral Hemisphere Processing

Although it has been demonstrated by researchers that differences exist between the two hemispheres in the control of specific behaviors, it has been suggested that each hemisphere also has the capacity to work bilaterally in an integrated fusion of functions with the other hemisphere (Dimond, 1972). This fusion of functions is the result of the transporting action of the corpus callosum. As a result, complex behaviors may not be described as singular responses processed by one hemisphere, but as combined responses processed by both hemispheres: parallel processing of stimuli in the right and left hemispheres (Goodglass and Calderon, 1977).

Singing has been investigated as a behavior involving bilateral hemisphere processing. Goodglass and Calderon (1977) investigated the processing of verbal and musical components in sung stimuli by trained musicians. It was concluded that independent parallel processing may occur in the two hemispheres for the specialized components (verbal and musical) of a complex stimulus: the verbal components were processed by the left hemisphere and the musical components were processed by the right hemisphere.

Support for this conclusion is noted in experiments by Bogen and Gordon (1971 and 1974). They anesthetized one hemisphere of subjects while the subjects were singing. Depending on which hemisphere was anesthetized, the subjects would lose control of the melody or lyrics. If the left hemisphere was anesthetized the subjects continued to sing the melody correctly, but did not sing intelligible words. If the right hemisphere was anesthetized the subjects sang the words rhythmically correctly, but sang amelodically. If the anesthesia was not administered, the subjects sang melody and words correctly and intelligibly. It was concluded that with these subjects, singing involved dual hemisphere control.

Evidence of Single Hemisphere Processing

Critchley (1972) has expressed reservations about the duality of brain function as it relates to language and music. He hypothesized that singing does not need bilateral hemisphere involvement. Damásio and Damásio (1977) offer support for this hypothesis in citing behavioral studies of older patients. These behavioral studies of patients were described as providing evidence for the association of language and music in the left hemisphere. Specifically, researchers described forms of amusia localized in the left hemisphere (amusia is defined as the inability to comprehend music as music). It was concluded that music and language are processed in the left hemisphere.

Additional support for one hemisphere processing of singing is noted in the summary by Benton and Joynt (1960) of behavioral studies of patients with aphasia (inability to speak). However, these researchers reported that singing was maintained in older subjects whose left hemisphere was incapacitated. The quality of melody reproductions and articulation of words was normal in the singing of familiar songs, contrasting with specific disturbances of speech. It was concluded that in patients with aphasia the capacity for singing can be retained in the right hemisphere.

Variables to be Considered in Resolving the Controversy

The conclusions cited in these studies, being diametrically opposed, cause confusion as to whether singing is processed by both hemispheres or by one hemisphere. One reason for the confusion may be the diversity of variables (subjects, procedures, stimuli) employed in the research.

Recently, researchers have utilized the dichotic aural stimulation paradigm of Broadbent (1954) to examine variables that might affect the processing of singing: training of subjects and complexity of stimulus. Goodglass and Calderon

(1977) concluded that (1) with trained musicians the processing of verbal and musical components of a stimulus is the result of hemispheric interaction and (2) each hemisphere can selectively process that component of a complex stimulus for which it is specifically equipped. They argue that the musical training of a subject and the complexity of the stimulus do not affect the processing of singing--the left hemisphere processes the verbal elements of the stimulus and the right hemisphere processes the tonal elements of the stimulus. However, results of other laterality studies (Bever and Chiarello, 1974; Papcun et al., 1974) concerning the effects of musical training and stimulus complexity are contradictory. A discussion of these studies follows.

Training

Bever and Chiarello (1974) have concluded that musical training of a subject may affect which brain hemisphere more efficiently processes musical stimuli. Using subjects with a minimum of four years of formal musical training, Bever and Chiarello demonstrated that trained musicians more efficiently processed melodic stimuli in the left hemisphere. Subjects with less than three years of musical training demonstrated more efficient processing of melodic stimuli in the right hemisphere. It was theorized that due to the subjects' musical training, melodies were processed as a series of sequential tones and patterns using the analytical mode of operation of the left hemisphere. Subjects without musical training processed the melodies holistically using the mode of operation of the right hemisphere.

The type of musical training was not controlled by Bever and Chiarello. It is assumed that subjects with vocal training have specialized skills in the processing of sung stimuli. Therefore, it may be hypothesized that if musical training is important in the processing of sung stimuli, subjects with vocal training will process sung stimuli differently and more efficiently than subjects with other musical training. However, the question then becomes: How does training affect the ability of subjects to process stimuli?

Training establishes a system of patterns in memory from which new stimuli may be matched, patterned, integrated, and recalled (John, 1972). Perception involves an internal synthesis of patterns and a comparison of these patterns with a new pattern under analysis (Stevens and Halle, 1967). It may be assumed that a new auditory pattern, a stimulus, will be compared with an existing pattern. As more patterns are matched and integrated into memory, the perceiver has the increased ability to discriminate among stimuli. When a stimulus is matched to an existing pattern, it is labeled as meaningful; when a stimulus does not match an existing pattern, it is labeled as nonmeaningful (John, 1972). With increased integration of patterns, a perceiver with training may effect meaning to increasingly complex stimuli that match existing patterns in memory (Miller, 1956). If training allows a subject to perceive more complex stimuli, then the results of the Bever and Chiarello study may be attributed to be the result of the stimulus complexity. If the stimulus complexity is to be considered, how do variations in stimulus complexity affect laterality effects?

Complexity

Support for the influence of training on laterality effects was demonstrated by Papcun, et al., (1974). Morse code signals were presented dichotically to experienced Morse code operators and to subjects ignorant of Morse code. Experienced Morse code operators demonstrated a consistent right ear advantage. Inexperienced subjects also demonstrated a right ear advantage, until the stimuli became longer than seven elements (an element was defined as a dot or dash). A left ear advantage was demonstrated by inexperienced subjects for stimuli longer than seven elements. It was theorized that as the stimuli became more complex, inexperienced subjects switched from an analytical and sequential mode of processing to a holistic mode of processing. The longer stimuli were too complex for analysis by the left hemisphere and were processed by the right hemisphere.

A possible explanation of these results is found in a study by Bartz, et al., (1967). The researchers investigated the perception of stimuli with variances in complexity using the dichotic listening technique. It was suggested that when dichotic stimuli differ in "attention value," the more attentionable stimulus is processed first and the less attentionable stimulus is filtered to temporary storage to be processed later. The difficulty in processing stimuli causes subjects to develop a strategy of listening to and processing stimuli in one ear while a "filter" shunts the stimuli of the other ear into a short-term memory storage (Broadbent, 1957). Bartz concluded that the more attentionable stimulus is processed more efficiently by the ear contralateral to the hemisphere that is specialized for processing the stimulus. As the complexity of the stimulus increases, ear asymmetry increases in favor of the more efficient ear.

The conclusions of Papcun, et al. (1974) and Bartz, et al. (1967) suggest a plateau effect for hemisphere processing. This processing plateau is the maximum level of processing efficiency of one hemisphere. As the plateau is reached in one hemisphere, a switch is made to the other hemisphere. The switch in hemisphere processing is theorized to be the result of the training of the subject and the complexity of the stimulus. By varying the complexity of the stimulus, different processing strategies may be evidenced for each subject depending on their training and the complexity of the stimulus.

It is assumed that by varying the complexity of a musical stimulus, processing strategies will be different for subjects depending on their musical training and the complexity of the stimulus. Therefore, it may be hypothesized that subjects with musical training will process variations of stimulus complexity differently than subjects with limited musical training.

Purpose of the Study

There is conflicting evidence concerning auditory laterality effects for sung stimuli. The evidence from previous research is contradictory and a theory of bilateral hemisphere processing or single hemisphere processing of sung stimuli is untenable.

Subjects may utilize bilateral or single hemisphere processing of sung stimuli depending on the training of the subject and the complexity of the stimulus. Therefore, the purpose of the present study is to test the viability of bilateral or single hemsiphere processing of sung stimuli as it may relate to the musical training of subjects and the complexity of the stimulus.

Two hypotheses serve as a basis for investigation:

1. Subjects with vocal training will process sung stimuli differently than subjects with other musical training

2. Subjects with musical training will process variations in complexity of sung stimuli differently than subjects with limited musical training.

Results of the study can be used by researchers to support and propose models of perception. In addition, information about the processing of sung stimuli may be used to better understand the singing behavior.

CHAPTER II

RELATED LITERATURE

The human brain contains two hemispheres which perform specific functions. Many specialized functions have often been described as belonging to a specific hemisphere. The left hemisphere has been described as utilizing a linear mode of operation which processes information sequentially, analytically, and logically. The right hemisphere has been described as utilizing a gestalt mode of operation which processes information holistically (Ornstein, 1972, p. 51). The difference in hemisphere function is labeled hemisphere asymmetry or laterality.

Recently, researchers have become interested in brain hemisphere asymmetry and auditory stimuli. Of particular interest both to music researchers and scientists has been the involvement of each hemisphere in the processing of verbal and musical components of singing. The present chapter contains discussions of (1) major studies in the processing of singing by researchers in behavioral abnormalities, EEG assessment, hemisphere depression, and dichotic listening, (2) attention and music, and (3) memory and music.

Behavioral Abnormalities and Singing

Since 1894, Hughlings Jackson and other neurologists, neurosurgeons, and psychiatrists have presented neurological evidence of the differential specialization of the cerebral hemispheres. Of primary importance are case studies of subjects with incapacitated hemispheres due to accident, illness, or surgery (Ornstein, 1972, p. 69).

Amusia (incapacity for musical activity) and aphasia (incapacity for verbal activity) have been thought to result from lesions in the left hemisphere (Damásio and Damásio, 1977). Edgren (1895) described patients with various combinations of amusia and aphasia. Most patients had either aphasia plus amusia or aphasia without amusia, but very few patients had amusia without aphasia. Henschen (1926) also believed that musical capacity was similar to verbal capacity and exhibited similar pathological forms. However, he also supported the hypothesis that the right hemisphere could perform some functions of the left hemisphere if the left hemisphere were destroyed. An example was given of the ability of a patient with left hemispherectomy who could sing, but could not speak.

Additional support for the processing of music and language in the left hemisphere is evidenced in the studies of patients with amusia (Feuchtwanger, 1930). The patients were described as having amusia plus aphasic disturbances. Ustvedt (1937), Wisenburg and McBride (1935), and Nielsen (1946) also recorded their observations and opinions about amusia and aphasia in the left hemisphere.

In contrast to these observations is the work of Botez and Wertheim (1959) and Wertheim and Botez (1961). Behavioral studies of musicians were presented in which musicians were described as having lost certain musical abilities, but language abilities were reported to be normal or near normal. Botez and Wertheim found problems in an amateur musician after right hemispherectomy in singing intonation and tempo. The subject was able to transpose individual sounds an interval of a fourth or fifth, but could not transpose melodies. When accompaniment was played, the subject could sing. However, the subject could not accompany singing of his instrument, the accordion.

Benton and Joynt (1960) reported the story of a man who had an illness that resulted in paralysis of the right side of the body. The man could not speak, but could sing certain hymns learned before his illness. Another patient was also described that had his left hemisphere removed (Smith, 1966). The man could not speak, but could sing "America" and "Home on the Range." Additional evidence of left hemispherectomy and continued ability to sing is reported by Gordon and Bogen (1974, p. 126-136), and Smith and Burkland (1966).

Wertheim (1977) in reviewing behavioral studies and music stated that proof of localization for musical activities was inconclusive. However, he also observed that in some case studies lesions of the right hemisphere resulted in instrumental and vocal amusia.

Behavioral studies of musicians and nonmusicians have produced conflicting results concerning the laterality of singing. Differences in the localization of singing may occur from the ability of the neural system to adapt to pathological aberrations in normal neural patterns (Henschen, 1926; John, 1972; Rose, 1973). It should be noted that most of the subjects in these studies sang familiar songs.

EEG Assessment and Singing

Electroencephalographic (EEG) assessment was first used by Berger in the 1920's. He taped a set of recording electrodes to a subject's scalp and recorded the continuous bursts of electrical activity in the brain. Characteristic rhythms were recorded and named: alpha waves, beta waves, delta waves and theta waves (Rose, 1973, p. 89-90).

Infants as young as six months of age were administered EEG tests while being held by their mothers. Tape recordings of singing were played and the greatest electrical activity was measured in the right hemisphere (Gardiner, 1976). It was concluded that lateralization of hemisphere function is present at birth (Gardiner and Walter, 1977).

Herron (1974) investigated laterality of music and language for stutterers and nonstutterers using EEG. She reported that stutterers and nonstutterers processed a speaking task and a singing task differently. This task involved singing the words presented in the speaking task. Nonstutterers utilized left hemisphere processing of words and right hemisphere processing of melody. Stutterers were inconsistent in verbal and musical processing. Herron concluded that stutterers may have a lack of hemisphere dominance with each hemisphere in competition with the other in the processing of words and music.

<u>Hemisphere Depression and Singing</u>

When brain surgery is being contemplated for a subject, the subject may be injected with a small amount of sodium amobarbital into the right or left common carotid artery. The result is a temporary depression or anesthetization of the corresponding cerebral hemisphere and contralateral hemiparalysis. The functions of the depressed hemisphere are temporarily lost (Wada and Rasmussen, 1960).

Bogen and Gordon (1971) were the first to report the use of this technique in assessing lateralization of musical tasks. After injecting the sodium amobarbital and depressing the right hemisphere, the researchers asked the subjects to sing familiar songs, such as "London Bridge" or "Happy Birthday." It was requested that subjects avoid using words by substituting the consonant-vowel "la." The singing was interspersed with other tasks whose function was to determine the paralysis of the left side of the body. Singing was affected in all subjects, but speech remained unaffected.

Although the songs were amelodic, they were recognized by the use of correct rhythm.

During the anesthetization of the left hemisphere, one subject evidenced no vocalization for two minutes. Melodic singing occurred just before the return of single word repetition (Bogen and Gordon, 1971). Another subject was silent for seven minutes, after which singing and speaking returned. It was concluded that the contribution of the left hemisphere in singing tasks is uncertain. Continued research (Gordon and Bogen, 1974) clarified the role of the right hemisphere for musical activities and the left hemisphere for verbal activities. It was hypothesized that singing is a bilateral function requiring the cooperation of both hemispheres.

The results of these studies appear conclusive: the left hemisphere processes words and the right hemisphere processes melody during singing tasks. However, it should be noted that (1) the singing tasks involved the singing of familiar songs and (2) the patients suffered from behavioral abnormalities that necessitated their participation in the hemisphere depression tests.

Dichotic Listening and Singing

The dichotic listening technique developed by Broadbent (1954) has been used extensively in testing brain laterality of normal subjects. With the use of prepared tape recordings and stereo earphones, different stimuli are simultaneously directed to each ear. The subjects are instructed to identify or recall the stimuli.

The assumption of the dichotic listening technique is that by presenting contrasting stimuli to both ears dichotically, stimuli will be processed more efficiently in the hemisphere that is specialized for processing those stimuli (Broadbent, 1954).

The dichotic technique has been used in few tests involving sung stimuli. Bartholomeus and others (1973) have investigated lateralization of singing. Using melodic stimuli performed on a violin or sung to vowels, consonant-vowel syllables, or digits, they found no significant differences between left and right ear scores on any of the four tasks. Additional testing (Bartholomeus, 1974b) produced no significant differences between ears for singing or speaking tasks. The stimuli used in the tests were similar except that one set of stimuli was spoken and one set of stimuli was sung. It is observed that the lack of lateralization may be due to the high levels of overall accuracy of report as described by the researcher. Steven (1973) also reported that when a subject was presented dichotically sung vowels, consonant-vowel syllables, or digits, there were no demonstrated differences in left and right ear scores for the melodic or verbal components of the stimuli.

Parallel processing of singing stimuli has been demonstrated when letter sequences were sung (Bartholomeus, 1974).

Different sequences of letters were sung to different melodies by different singers. The subjects were required to recognize letter sequence, melody, and singer's voice. Results indicated a significant right ear superiority for letter sequence recognition, a significant left ear superiority for melody recognition, and a significant ear by task interaction. No significant differences existed between ears for recognition of voices. It was concluded that laterality effects in audition are not determined only by stimulus characteristics, but also by task requirements.

Goodglass and Calderon (1977) investigated parallel processing of verbal and tonal material in trained musicians, who in standard dichotic testing conditions had right ear superiority for verbal stimuli and left ear superiority for tonal stimuli. Parallel processing was induced by using stimuli with variations in complexity: spoken numbers superimposed on piano tones and competing digits sung to competing tonal patterns. The task requirements were also varied in complexity. A right ear advantage for digits and a left ear advantage for tones was demonstrated with all stimuli and task variations. It was concluded that (1) task requirements do not affect the magnitude of left ear advantage for tones or right ear advantage for digits and (2) independent parallel processing may occur in the two hemispheres for the specialized components (verbal or musical) of a complex stimulus.

The results of the dichotic tests of singing are confusing. By varying testing approaches researchers may be effecting different processing modes of different subjects. It is noted that the results of these tests appear to conflict with the results of Bever and Chiarello (1974) concerning the effect of training on the perception of music and with the behavioral studies concerning one hemisphere processing of singing. It appears that a dichotic test of singing is needed that utilizes not only a melodic stimulus, but also a verbal stimulus that is more representative of the singing behavior. Such stimuli might utilize words in a sentence format sung to tones in a melodic fragment. By using stimuli that are more representative of the singing act, a subject may process the singing stimulus as one unit rather than as two elements (Morrell, et al., 1967). It may be of importance to compare the results of music majors and nonmusic majors using the sung stimulus approach of Goodglass and Calderon (1977) and stimuli more representative of the singing behavior.

Attention and Music

A person's world is a montage of stimuli that is filtered or selected by the sensory systems and processed by the brain and central nervous system. It is a function of the sensory systems to filter and select stimuli that are important and relevant to a person. The brain and nervous system then process the information from the senses into meaningful data. This processing involves additional filtering and selecting of stimuli received by the senses (Ornstein, 1972 and 1974). The process of selection of stimuli has been labeled attention (Masterton and Diamond, 1973, p. 433).

The attending procedure involves a hierarchical relay of coded neural information by each neural structure to the next higher structure (Ornstein, 1972, p. 32). In the auditory system each structure passes neural information to the next higher structure in the pathway from the ear to the cortex (Figure 1). Each structure in the auditory system is known to behave in at least three ways:

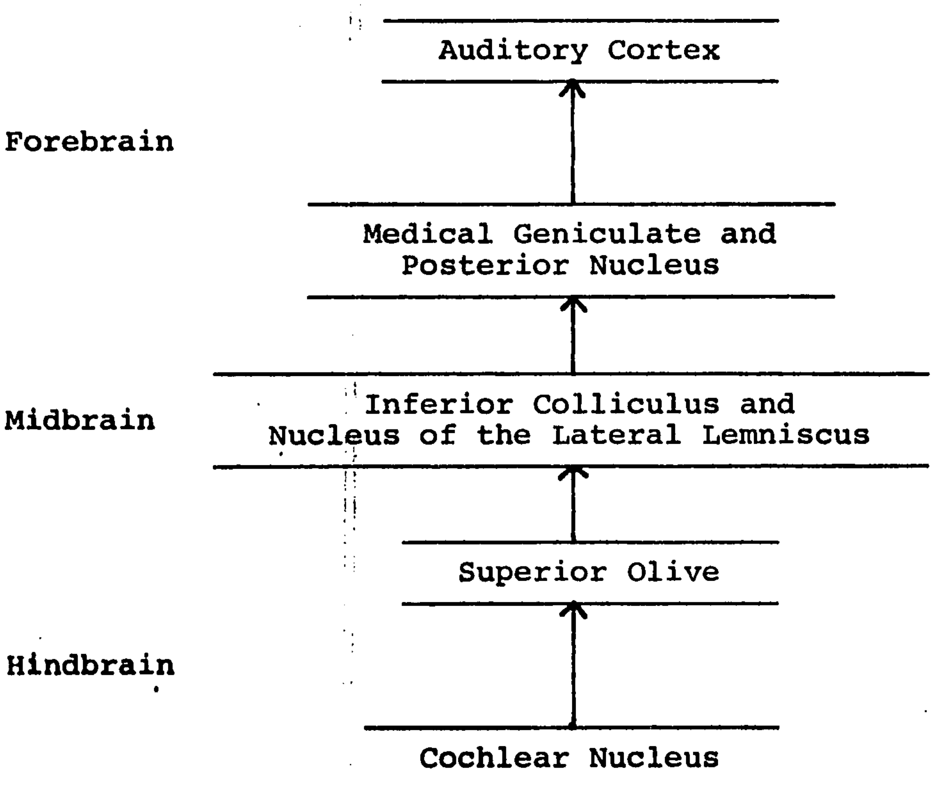
1. Transforms neural input into a neural output which always differs from the input
2. Distributes neural outputs to a variety of non-auditory structures
3. Modulates input by efferent fibers that descend to lower auditory structures (Masterton and Diamond, 1973, p. 428).

Therefore, in the auditory system each neural structure from the cochlear nuculei to the cortical nuculei may be assumed to be attending to selected components of a stimulus (Masterton and Diamond, 1973, p. 434).

Most researchers in the attending procedure of the auditory systems have investigated the responses of the total auditory system. Broadbent and Gregory (1963) investigated the ability of the auditory system to selectively filter auditory stimuli. They concluded that the filtering process was attributable to an attention mechanism and that attention could be diverted without voluntary effort or conscious awareness of a subject. It was assumed that changes in attention were the result of monitoring of auditory input by a high level of the brain.

FIGURE 1

SCHEMATIC SUMMARY OF THE CENTRAL AUDITORY SYSTEM



(Masterton and Diamond, 1973)

Oswald and others (1960) also concluded that even in sleep auditory input is monitored at a high level and that when the input is significant, the system responds. Different auditory stimuli evoked EEG arousal responses of varying magnitude in sleeping subjects, with some sounds and words having greater arousal properties than others. It was assumed that for most people the attending process involves involuntary selective filtering by the auditory system.

A technique used to investigate selective attention of auditory stimuli is the dichotic listening test. Simultaneous stimuli are presented through stereo earphones to a subject who is instructed to respond in a designated manner. By examining a subject's responses, the attending process may be investigated. It will be assumed that differences in ear scores in dichotic tests with musical stimuli are the result of attending differences of the auditory system for each ear.

Memory and Music

Memory is the capacity to store and retrieve experiences. Recently, researchers working in the area of physiological bases of memory have attempted to evidence some permanent change in neural functioning produced by experiences (McGaugh, 1966). The researchers have demonstrated that experiences may effect permanent neural changes (Bennett, et al., 1964), but not necessarily during or immediately after an experience (McGaugh, 1966).

Many authors have noted that the past experience of an organism (man) in performing movements and in observing the consequences of these movements helps to establish how a stimulus is perceived (Held and Freeman, 1963; Mackay, 1951; Ornstein, 1972). Miller and others (1951) proposed a model of auditory perception in which a catalogue of auditory patterns are matched with a catalogue of articulatory gestures. These gestures may have several components, including tactual and kinesthetic sensations, motor commands, and feeling states. When a stimulus is perceived it activates a number of neural centers. A catalogue of relations between auditory patterns and articulatory gestures is established at an early age. As a child initiates an articulatory gesture, an auditory pattern results from the activity, and an association develops between the gesture and the sound. New associations are established for new articulatory gestures. This model of auditory perception has been described as a theory of articulatory reference (Halle and Stevens, 1964; Liberman, et al., 1967; Stevens, 1960; Stevens and Halle, 1967).

Halstead (1967) refers to the perception of experience of an individual as a factor of memory--immediate, intermediate, and remote. McGaugh (1966) clarifies memory as a three-memory trace system: immediate memory for several minutes; short-term memory which develops within a few seconds or minutes and lasts for several hours; and long-term memory which consolidates slowly and lasts indefinitely.

Additional research (Barondes and Cohen, 1966; Flexner, et al., 1963) substantiates this description and suggests that each experience activates each memory trace. It appears that the three-memory traces utilize the same neural structures, but use them differently (John, 1972; Norman, 1968).

Broadbent (1954) hypothesized that the difference in ear reports of dichotic stimuli is the result of memory and attention. He proposed a model of perception that included processing of stimuli by the hemisphere specialized for that stimuli and storage of other stimuli for later processing. The stimuli from one ear were attended and stimuli from the other ear were stored. Norman (1968) proposed that a channel of attention is chosen based on the pertinence or meaningfulness of stimulus. The pertinence of a stimulus is based on the expectations of the perceiver which are the result of past experiences (Eccles, 1966; Norman, 1968; Ornstein, 1972).

It is assumed that in dichotic listening experiments differences in ear reports result from memory traces established in a hemisphere that is specialized for a particular stimulus (Gazzaniga, 1974). A right ear advantage for verbal stimuli is the result of expectations of the left hemisphere based on auditory patterns established in memory. A left ear advantage for musical stimuli is the result of expectations of the right hemisphere based on auditory patterns established in memory.

If the memory systems utilize the same structures, different modes of retrieval are needed for each category of memory trace (Norman, 1968). When a stimulus matches patterns in storage, then the stimulus characteristics are anticipated and effectively perceived by the structures specialized for that stimulus. When a stimulus does not match patterns in storage, then the stimulus is not anticipated or effectively perceived. Due to the rapid decay of material in immediate memory (Norman, 1966; Waugh and Norman, 1965), it appears that recall or recognition tasks utilizing immediate memory will be biased toward stimuli that are meaningful and attended by the structures specialized for that material. The memory traces of stimuli that are not meaningful may decay before processing (Norman, 1968).

Material in long-term storage is permanent, but needs cues to retrieve it. These cues are established relations with the memory trace and are formed from experiences (Mandler, 1975, p. 24). When the cues are not activated, then the memory is not retrieved (Snyder, 1974, p. 221).

Memory storage and retrieval of memory appear to be lateralized. When a subject is performing a task that is usually the specialty of one hemisphere, the other hemisphere is not activated (Ornstein, 1972, p. 62; Ornstein and Galin, 1974). Confusion and interference in perception appear if both hemispheres are activated (Galin, 1974; Nelson, 1978; Ornstein, 1972).

The result of musical training is that many musical experiences are stored and accessible in all memory traces. These memory traces are then used as a basis for more effective perception of musical stimuli. There is evidence that as an experience is repeated, it may become habituated with the memory traces of the repeated experience lateralized. The memory traces may be a function of the right hemisphere (Tart, 1975, p. 110). Galin (1976) hypothesized that memory traces reside in both hemispheres, but are activated only by the hemisphere that is specialized for that mode of retrieval or task utilized in processing. Depending on the task used in testing, differences in ear reports in dichotic testing can be the result of the task required: sequential processing and the left hemisphere or holistic processing and the right hemisphere.

Differences in reports of singing using various testing techniques described earlier in this chapter appear to be the result of activation of different memory traces. Singing of old songs activates habituated behaviors and permanent memory storage. Singing of melodies and verbal combinations may activate immediate or short-term memory traces and require different modes of processing, i.e., sequential or holistic. It appears evident that activation of different memory traces in the hemispheres is an integral function in the processing of singing.

CHAPTER III

PROCEDURE

Overview

A dichotic listening test was designed to test the following hypotheses:

1. Subjects with vocal training will process sung stimuli differently than subjects with other musical training.

2. Subjects with musical training will process the variations in complexity of sung stimuli differently than subjects with limited musical training.

To test the hypotheses a three-factor experimental design with repeated measures of two factors was used (Winer, 1971, p. 571). The three independent variables were labeled (1) musical training, (2) ear presentation, and (3) complexity of stimulus presentation. The dependent variables were scores for accuracy of verbal reproduction (word scores) and musical reproduction (music scores).

Subjects

Subjects for the study were chosen according to type of musical training of the subject:

1. training in vocal music
2. training in instrumental music
3. limited training in music

Subjects with musical training were defined as junior or senior university undergraduate music majors. Students with vocal music training were defined as students who have designated voice as their major instrument concentration. Students with instrumental music training were defined as students who have designated piano or an orchestral or band instrument as their major instrument concentration. Subjects with limited musical training were defined as junior or senior university undergraduate students with limited training in music.

Ten subjects per level were selected as the size of the testing sample based on a priori power analysis for alpha = .05, large effect size, and power = .80. The total number of subjects participating in the experiment was thirty. A questionnaire was employed to select and categorize subjects by level of musical training (see appendix). The questionnaire assessed formal and informal musical experiences for the preceeding eight years. Eight years was chosen as the time reference which would include college and secondary experiences for most subjects. Formal musical experiences were defined as private or class study in singing or playing a musical instrument. Informal musical experiences were defined as singing or playing an instrument without the aid of private or class study.

Criteria for selection of subjects with vocal music training, as indicated on the questionnare, were:

1. four years or more of formal experiences in voice

study during the preceding eight years, with at least three years of formal experiences in voice study during the preceding four years;

2. four years or more of participation in an organization for vocal performance during the preceding eight years, with at least three years of experiences in an organization for vocal performance during the preceding four years;

3. three years or less of informal musical experiences with an instrument during the preceding eight years;

4. three years or less of formal study with a musical instrument during the preceding eight years;

5. three years or less of participation in an organization for instrumental performance during the preceding eight years, with no participation during the preceding three years.

Criteria for selection of subjects with instrumental music training, as indicated on the questionnaire, were:

1. four years or more of formal experiences in instrument study during the preceding eight years, with at least three years of formal experience in instrument study during the preceding four years;

2. four years or more of participation in an organization for instrumental performance during the preceding eight years, with at least three years of formal experiences in an organization for instrumental performance during the preceding four years;

3. three years or less of informal musical experience with voice during the preceding eight years;

4. three years or less of formal study in voice during the preceding eight years;

5. three years or less of participation in an organization for vocal performance during the preceding eight years, with no participation during the preceding three years.

Criteria for selection of subjects with limited musical training, as indicated on the questionnaire, were:

1. three years or less of formal experiences in voice or musical instrument study during the preceding eight years, with no formal experiences in voice or musical instrument during the preceding three years;

2. three years or less of participation in an organization for vocal or instrumental performance during the preceding eight years, with no formal experiences in an organization for vocal or instrumental performance during the preceding three years;

3. three years or less of informal musical experiences with voice or musical instrument during the preceding eight years.

Pilot Study

A pilot study was conducted at the Brevard Music Center, Brevard, North Carolina. Fifteen male and fifteen female subjects were chosen based on the criteria previously listed.

Subjects were matched across training levels for academic classification and number of years of training.

Only subjects who indicated on the questionnaire that they were right-handed were used in the study. It has been suggested (Denckla, 1978, p. 250; Goodglass and Quadfasel, 1954) that handedness may be a factor in variability of subject responses in dichotic listening tests. In order to control for possible variation in subject responses, only right-handed subjects were selected.

Subjects with vocal music training averaged 4.2 years of vocal training, 2.7 years of instrumental training, and 6.8 years of participation in a vocal music organization. Subjects with instrumental music training averaged 0.7 years of vocal training, 5.9 years of instrumental training, and 6.9 years of participation in an instrumental music organization. Subjects with limited musical training averaged 0.3 years of vocal training, 0.7 years of instrumental training, and 1.7 years of participation in an ensemble of either instrumental or vocal emphasis.

Subjects were administered a Sweep Frequency Screening, testing pure tone octaves from 50 to 8 kHz at a twenty-decible level. The purpose of the hearing screen was to evaluate hearing efficiency and control for hearing deficiencies that might affect the results of the test. All selected subjects had normal hearing acuity as defined by the American National Standards Institute (ANSI, 1969--see glossary).

Testing was administered on a Qualitone Acoustic Appraiser (met ANSI Hearing Threshold Level) with TDH-39 earphones and MX-41/AR cushions in an Industrial Acoustics Company Sound Booth. Subjects were asked to reproduce pitches, within the range of pitches used in the dichotic test stimuli (C_4-G_4), as sung by the investigator. All subjects correctly reproduced each of the pitches.

The purpose of the pilot study was to demonstrate the effectiveness of the dichotic test and to provide results for comparison with the main study.

Main Study

The main study was conducted at the State University College at Fredonia, New York. Fifteen male and fifteen female subjects were selected based on the criteria previously listed. Subjects were matched across training levels for academic classification and number of years of training. Only subjects who indicated on the questionnaire that they were right-handed were used in the study.

Subjects with vocal music training averaged 5.7 years of vocal training, 2.5 years of instrumental training, and 6.3 years of participation in a vocal music organization. Subjects with instrumental music training averaged 0.7 years of vocal training, 7.4 years of instrumental training, and 6.1 years of participation in an instrumental music organization. Subjects with limited musical training averaged 0.4

years of vocal training, 0.8 years of instrumental training, and 1.7 years of participation in an ensemble of either instrumental or vocal emphasis.

Subjects' hearing efficiency was evaluated as described in the pilot study. Testing was administered on a Grason-Stadler 1701 Audiometer (met ANSI Hearing Threshold Level specifications) with TDH-39 earphones.

Preparation of Test Tapes

Test tapes were prepared using a variation of the dichotic aural stimulation technique reported by Kimura (1964) and Broadbent (1954). This technique is based on the assumption that the connection or neural pathway from an ear to its contralateral hemisphere is stronger than to its ipsilateral hemisphere. By presenting contrasting stimuli to both ears dichotically, more efficient processing will be evidenced by the hemisphere that is specialized for those stimuli if the stimuli are presented to the contralateral ear.

A variation in the procedure was the addition of a recall task for the stimuli. Broadbent and Gregory (1964) have demonstrated that the use of a recall or recognition strategy for dichotic tests does not contribute to ear differences for accuracy of report of stimuli. The Kimura paradigm for dichotic tests containing musical stimuli utilized a recognition strategy for musical stimuli. The reason for using the recognition strategy is reported to be the difficulty of requiring listeners to reproduce musical stimuli. The musical stimuli for this study were controlled to aid in the recall procedure: limited range of pitch (middle C or C_4 through G on the second line of the treble clef or G_4), limited rhythmic variance (quarter and eighth notes), limited starting pitch (C_4, E_4, G_4) and use of diatonic pitches only (C_4, D_4, E_4, F_4, G_4).

The second variation in the testing technique was the complexity of stimuli presentation. Three levels or classifications of stimuli complexity were utilized:

1. identical music to each ear with different verbal sets to each ear (Figure 2)

2. different music to each ear with identical verbal sets to each ear (Figure 3)

3. different music to each ear with different verbal sets to each ear (Figure 4)

Satz (1968) demonstrated that ear asymmetry increased as the complexity of presentation increased. In the present study the complexity was varied by increasing the number of verbal and/or musical differences between ear presentations. In presentation one the verbal complexity was increased by utilizing a different word set to each ear. In presentation two the musical complexity was increased by utilizing a different melody to each ear. In presentation three a different word set and melody were presented to each ear to produce

FIGURE 2

EXAMPLE OF STIMULI COMPLEXITY 1

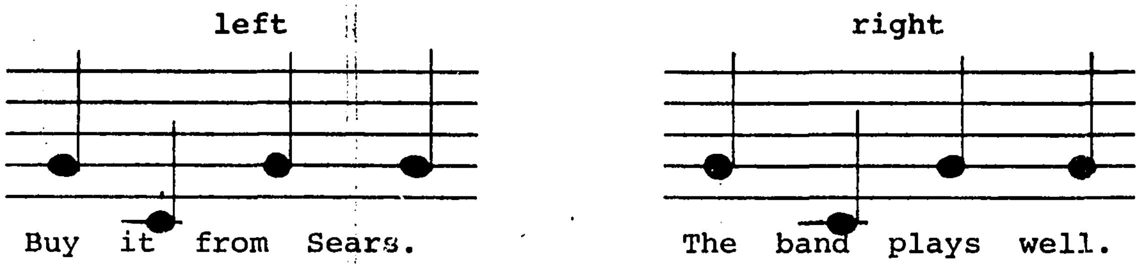


FIGURE 3

EXAMPLE OF STIMULI COMPLEXITY 2

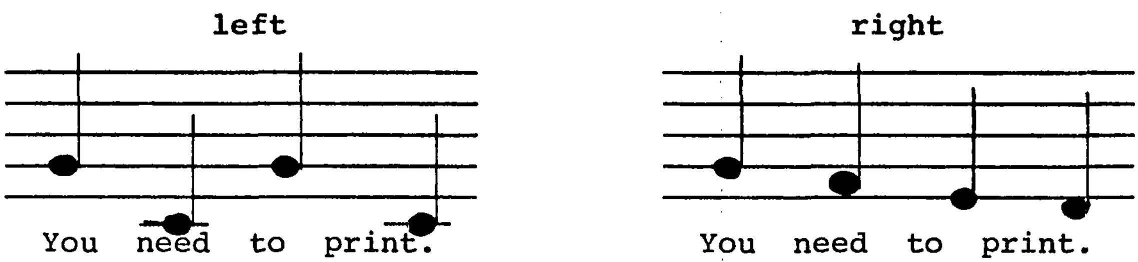
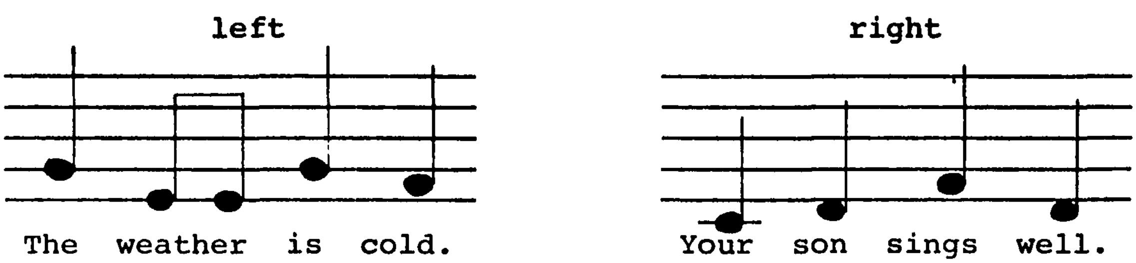


FIGURE 4

EXAMPLE OF STIMULI COMPLEXITY 3



the greatest verbal and musical complexity.

Forty melodies and forty sentences were composed according to the previously listed criteria. In addition, the music was composed using traditional sequences of pitches and the words were composed using logical sentences. For purposes of this study it was assumed that the stimuli were representative of the singing behavior: salient verbal and musical stimuli. Salient verbal stimuli may be defined as a series of words that utilize traditional grammatical patterns of verbal communication: a sentence. Salient musical stimuli may be defined as a series of tones that utilize traditional patterns of pitch relationships: a melody.

Ten examples of each of the three stimuli presentations were randomly formulated from the sentences and melodies. Five examples of each stimuli presentation were randomly selected and arranged as Test A (see appendix). The remaining five examples of each stimuli presentation were randomly arranged as Test B (see appendix).

Instructions, Test A, and Test B were recorded by the investigator on a TEAC four-channel tape recorder. Copies were made on a Kenwood KX 1030 two-channel cassette tape recorder for ease in administration. The stimuli were recorded at a rate of 60 beats per minute, with each stimulus lasting four seconds. Preceding each stimulus was a rhythmic, spoken count (1--2--3--4) recorded on the test tapes.

After each stimulus was twelve seconds of silence. The paradigm of the test is represented in Figure 5.

FIGURE 5

DICHOTIC TEST PARADIGM

Spoken Count	Dichotic Stimulus	Silence
4 Seconds	4 Seconds	12 Seconds

The subjects were required to vocally repeat the stimuli during the time interval of twelve seconds. The rhythmic, spoken count (1--2--3--4) recorded on the test tapes notified the subject that the period of response had ended and that a new stimuli set would be presented.

The prepared tapes consisted of a pretest preparation with instructions, examples of test stimuli, and intensity level setting (see appendix). The subjects were advised in the tape-recorded instructions to vocally repeat in any order the stimuli presented to each ear. The subjects were advised to repeat as much as possible of each stimulus if they were not able to repeat each stimulus in total.

Administration of Test Tapes

Test A and Test B each required five minutes and were presented with a five-minute interval between tests as a control for bias effects of test order. Half of the subjects were presented Test A before Test B. Half of the subjects were presented Test B before Test A. Each subject reversed earphones at the end of the first test. Counterbalancing procedures to negate tape bias are listed in Figure 6.

The test tapes were administered with the Kenwood KX 1030 tape recorder and Koss Pro 4/AAA headphones in a quiet room. The intensity level was set at a comfortable level as determined by the responses of three subjects not participating in the study. A calibration tone was used to insure that the equipment remained in calibration from one test administration to another. At each test administration, the intensity level of the tone was adjusted to the same value using a Vu meter. All subject responses (vocal repetition of stimuli) were tape recorded on a separate tape recorder for later analysis.

Each subject's responses from Test A and Test B were evaluated as to number of beats correctly reproduced from the original stimulus for each stimulus component (verbal and musical), for each ear, and for each complexity variation. Each melodic fragment contained one pitch or two repeated pitches on each of the four beats of the stimulus. A beat with repeated pitches on an eighth note rhythm was labeled a correct response only when both of the pitches were reproduced. Each word set contained one word, one syllable, or two syllables on each of the four beats of the stimulus. A beat with two syllables was labeled a correct

FIGURE 6

COUNTERBALANCING PROCEDURES

Subject	Test Order	Earphone Placement First Test--Second Test
1	A-B	Right on Right--Right on Left
2	B-A	Right on Right--Right on Left
3	A-B	Right on Left --Right on Right
4	B-A	Right on Left --Right on Right
5	A-B	Right on Right--Right on Left
6	B-A	Right on Right--Right on Left
7	A-B	Right on Left --Right on Right
8	B-A	Right on Left --Right on Right
9	A-B	Right on Right--Right on Left
10	B-A	Right on Right--Right on Left
11	A-B	Right on Left --Right on Right
12	B-A	Right on Left --Right on Right
13	A-B	Right on Right--Right on Left
14	B-A	Right on Right--Right on Left
15	A-B	Right on Left --Right on Right
16	B-A	Right on Left --Right on Right
17	A-B	Right on Right--Right on Left
18	B-A	Right on Right--Right on Left
19	A-B	Right on Left --Right on Right
20	B-A	Right on Left --Right on Right
21	A-B	Right on Right--Right on Left
22	B-A	Right on Right--Right on Left
23	A-B	Right on Left --Right on Right
24	B-A	Right on Left --Right on Right
25	A-B	Right on Right--Right on Left
26	B-A	Right on Right--Right on Left
27	A-B	Right on Left --Right on Right
28	B-A	Right on Left --Right on Right
29	A-B	Right on Right--Right on Left
30	B-A	Right on Right--Right on Left

response only when both syllables were reproduced correctly.

Each subject's responses were matched to the original stimulus for verbal and musical correctness. Separate scores for words and melody were given. A score of "4" for words meant that the subject reproduced all words of the stimulus correctly. A score of "4" for melody meant that the subject reproduced all pitches of the stimulus correctly. The response evaluation is represented schematically in Figure 7.

FIGURE 7

RESPONSE EVALUATION SCHEMATIC

	Left Ear					Right Ear				
Words (beats)	0	1	2	3	4	0	1	2	3	4
Melody (beats)	0	1	2	3	4	0	1	2	3	4

An example of a given stimulus, subject response, and response evaluation is represented in Figure 8.

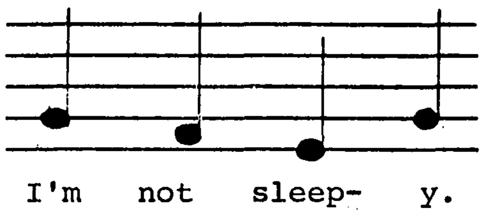
All responses were totaled for each subject and entered as raw scores into the appropriate level of the statistical design. A 3 x 3 x 2 design for repeated measures was used (Winer, 1971, p. 539). Analysis of the data was achieved through the use of univariate and multivariate ANOVA and the Newman-Keuls procedure for repeated measures.

FIGURE 8

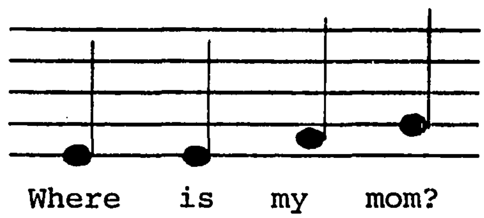
EXAMPLE OF STIMULUS, SUBJECT RESPONSE, AND RESPONSE EVALUATION

Given Stimulus

Left Ear

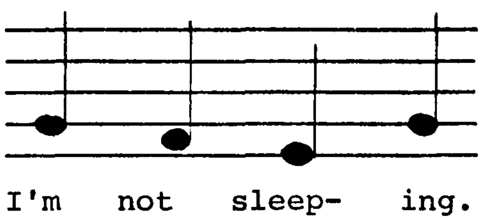


Right Ear

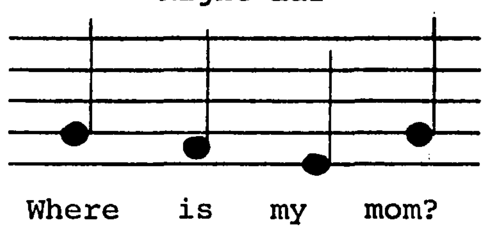


Student Response

Left Ear



Right Ear



Response Evaluation

	Left Ear					Right Ear				
Words (beats)	0	1	2	③	4	0	1	2	3	④
Melody (beats)	0	1	2	3	④	0	①	2	3	4

The univariate ANOVA was used for each of the two dependent measures: word scores and music scores. In addition to the mean and standard deviation for the general model, the coefficient of variation was also listed. The coefficient of variation is the percentage of variation obtained by dividing the standard deviation by the mean. The statistic is used to compare the variability of scores in different tests. Means for each main effect and interaction were also listed.

Based on F_{max} tests for homogeneity of variance, all tests for main effects and interactions used within-subject terms as error terms. All means for each significant main effect and two-way interactions were ranked from highest to lowest. The Newman-Keuls test for significance was used to describe statistical differences between all possible pairs of means (Winer, 1971, p. 528).

Multivariate ANOVA using the Hotelling-Lawley Trace Statistic, was also utilized in the analysis of the data. The Hotelling-Lawley test described the characteristic root vector of the matrix derived from the variances of word scores and music scores.

In multivariate ANOVA the effect of independent variables on two or more dependent variables is observed simultaneously. The multivariate ANOVA generally contains more information about the total effect of the independent variables than does the univariate ANOVA. In effect, the ratio of between-subject variance to the within-subject variance is maximized.

CHAPTER IV

RESULTS

Data were obtained in a pilot study and a main study. Analysis of the data for these studies was achieved through the use of univariate and multivariate analysis of variance for repeated measures. The univariate ANOVA was used for each of the dependent variables: word scores and music scores. Due to the nature of the stimuli--verbal and musical elements combined--multivariate ANOVA was also used. The Newman-Keuls test for significance of ordered means was utilized to provide descriptions of statistical differences between all possible pairs of means.

Abbreviations used in analysis of data are shown in Table 1.

TABLE 1

ABBREVIATIONS USED IN ANALYSIS OF DATA

G	Group
V	Vocal Training Group
I	Instrumental Training Group
L	Limited Training Group
E	Ear
LE	Left Ear
RE	Right Ear
C	Complexity of Stimuli Presentation
P1	Complexity Presentation One
P2	Complexity Presentation Two
P3	Complexity Presentation Three

Pilot Study

The mean, standard deviation, and coefficient of variation are listed in Table 2. The mean response for word scores represented 82% correct. The mean response for music scores represented 61.75% correct. While the standard deviations were similar for both word and music scores, the coefficient of variation indicated that music scores had a higher relative variability. The higher coefficient of variation for music scores appeared to indicate that repetition of musical elements were more difficult than repetition of verbal elements.

TABLE 2

MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION: PILOT STUDY

	Mean	Standard Deviation	Coefficient of Variation
Words	32.8167	5.5792	17.0012%
Music	24.7000	5.2842	21.7000%

The analysis of variance for word scores is found in Table 3. There were significant differences in the main effects of ear and complexity of presentation and in the interactions of group by complexity and complexity by ear. There was no significant difference in the group effect. In Table 5, it is observed that the right ear score was highest and that complexity presentation two was highest.

The left ear score for complexity of presentation two was higher than right ear scores for all presentations (Table 6).

TABLE 3

ANOVA FOR WORDS: PILOT STUDY

Source	df	SS	F	p
Model	125	8542.05	2.20	0.0008*
Error	54	1680.90		
Corrected Total	179	10222.95		
Group	2	421.20	2.48	0.1204
Error	27	2290.92		
Ear	1	464.01	10.20	0.0036*
G x E	2	165.64	1.82	0.1812
Error	27	1227.85		
Complexity	2	1774.03	38.61	0.0001*
G x C	4	284.67	3.10	0.0228*
Error	54	1240.63		
C x E	2	505.01	8.11	0.0008*
G x C x E	4	168.09	1.35	0.2635
Error	54	1680.90		

*$p < .05$

The analysis of variance for music scores is in Table 4. There were significant differences in the main effects of group and complexity of presentation and in the interactions of complexity by ear and group by complexity by ear. There was no significant difference for ear effect. In Table 5, it is observed that the vocal group scored highest and that complexity presentation one was highest. The right ear score for complexity presentation one was greatest and the left ear scores were greatest for complexity presentations two and three.

TABLE 4

ANOVA FOR MUSIC: PILOT STUDY

Source	df	SS	F	p
Model	125	13251.97	3.80	0.0001*
Error	54	1507.83		
Corrected Total	179	14759.80		
Group	2	2020.43	11.56	0.0002*
Error	27	2358.70		
Ear	1	80.00	1.07	0.3107
G x E	2	126.70	0.85	0.4406
Error	27	2023.97		
Complexity	2	4932.10	142.96	0.0001*
G x C	4	106.07	1.54	0.2045
Error	54	931.50		
C x E	2	325.03	5.82	0.0051*
G x C x E	4	347.47	3.11	0.0224*
Error	54	1507.83		

$^*p < .05$

TABLE 5

PILOT STUDY MEANS: MAIN EFFECTS

Main Effect	Word Mean	Music Mean
Group		
V	34.3167	27.9833
I	33.4167	26.0167
L	30.7167	20.1000
Ear		
LE	31.2111	25.3667
RE	34.4222	24.0333
Complexity		
P1	31.0000	31.4667
P2	37.2333	23.9167
P3	30.2167	18.7167

As shown in Table 8, only the word means for complexity presentation two is significantly different. Complexity presentation two had minimum complexity for words. With maximum complexity for words in complexity presentations one and three, there were no statistical differences.

As indicated in Table 9 the word mean for complexity presentation two is significantly different for all groups. It is also observed that subjects with vocal training performed superior to the other groups for complexity presentations one and three.

TABLE 6

PILOT STUDY MEANS: TWO-WAY INTERACTIONS

Interactions		Word Mean	Music Mean
Group X Ear			
V	LE	34.0000	29.6333
	RE	34.6333	26.333
I	LE	31.5333	26.7667
	RE	35.3000	25.2667
L	LE	28.1000	19.7000
	RE	33.3333	20.5000
Group X Complexity			
V	P1	32.9500	33.9500
	P2	37.5000	26.6000
	P3	32.5000	23.4000
I	P1	32.1000	33.0500
	P2	39.6000	25.1500
	P3	28.5500	19.8500
L	P1	27.9500	27.4000
	P2	34.6000	20.0000
	P3	28.6000	12.9000
Complexity X Ear			
P1	LE	27.9000	30.2333
	RE	34.1000	32.7000
P2	LE	37.9667	25.5667
	RE	36.5000	22.2667
P3	LE	27.7667	20.3000
	RE	32.6667	17.1333

TABLE 7

PILOT STUDY MEANS: THREE-WAY INTERACTIONS

Group	Complexity	Ear	Word Mean	Music Mean
V	P1	LE	31.9000	35.4000
		RE	34.0000	32.5000
	P2	LE	38.3000	27.5000
		RE	36.7000	25.7000
	P3	LE	31.8000	26.0000
		RE	33.2000	20.8000
I	P1	LE	29.5000	32.6000
		RE	34.7000	33.5000
	P2	LE	39.6000	26.4000
		RE	39.5000	23.9000
	P3	LE	25.5000	21.3000
		RE	31.6000	18.4000
L	P1	LE	22.3000	22.7000
		RE	33.6000	32.1000
	P2	LE	36.0000	22.8000
		RE	33.2000	17.2000
	P3	LE	26.0000	13.6000
		RE	33.2000	12.2000

TABLE 8

TESTS ON WORD MEANS OF PILOT STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY

Ordered Levels	P2	P1	P3	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	37.23	31.00	30.21		
37.23		6.23*	7.02*	3	3.19
31.00			0.79	2	3.05

*$p < .05$

In Table 10, the left ear presentation two word mean is the only left ear word mean that was significantly different from the other means. Right ear complexity presentations were greater than the left ear presentations for complexity presentations one and three.

Music means for each group (see Table 11) indicate that subjects with vocal training and subjects with instrumental training did not perform significantly different. However, both groups performed significantly greater than subjects with limited training.

As shown in Table 12, the music mean for each complexity presentation is significantly different. Presentation one (minimum complexity for music) was different from presentations two and three (maximum complexity for music).

TABLE 9

TESTS ON WORD MEANS OF PILOT STUDY USING NEWMAN-KEULS PROCEDURE: GROUP X COMPLEXITY

Ordered Levels	IP2	VP2	LP2	VP1	VP3	IP1	LP3	IP3	LP1	r	$s_{\bar{E}} q_{.95}(r,54)$
Ordered Means	39.60	37.50	34.60	32.95	32.50	32.10	29.60	28.50	27.95		
39.60		2.10	5.00*	6.65*	7.10*	7.50*	10.00*	11.10*	11.65*	9	4.57
37.50			2.90	4.55*	5.00*	5.40*	7.90*	9.00*	9.55*	8	4.47
34.50						3.50	5.00*	6.10*	6.65*	7	4.36
32.95						0.85	3.35*	4.45*	5.00*	6	3.68
32.50							2.90	4.00*	4.55*	5	3.52
32.10							2.50*	3.60*	4.15*	4	3.31
29.60									1.65	3	3.00
28.50										2	2.49

*$p < .05$

TABLE 10

TESTS ON WORD MEANS OF PILOT STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY X EAR

Ordered Levels	P2LE	P2RE	P1RE	P3RE	P1LE	P3LE	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	37.97	36.50	34.10	32.67	27.90	27.77		
37.97		1.47	3.87*	5.30*	10.07*	10.20*	6	4.29
36.50			2.40	3.83*	8.60*	8.73*	5	4.09
34.10				1.43	6.20*	6.33*	4	3.85
32.67					4.77*	4.90*	3	3.49
27.90						0.13	2	2.90

*$p < .05$

TABLE 11

TESTS ON MUSIC MEANS OF PILOT STUDY USING NEWMAN-KEULS PROCEDURE: GROUP

Ordered Levels	V	I	L	r	$s_{\bar{E}}q_{.95}(r,27)$
Ordered Means	27.98	26.02	20.10		
27.98		1.96	7.88*	3	5.99
26.02			5.92*	2	4.95

*p < .05

TABLE 12

TESTS ON MUSIC MEANS OF PILOT STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY

Ordered Levels	P1	P2	P3	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	31.47	23.92	18.72		
31.47		7.55*	12.75*	3	3.19
23.92			5.20*	2	3.05

*p < .05

In Table 13, the right ear presentation one is noted as the only right ear music mean that is significantly different from any left ear music mean. The presentation three left ear mean is noted as being significantly different from presentation three right ear mean and indicates left ear superiority for music under maximum complexity.

Multivariate ANOVA using the Hotelling-Lawley Trace Statistic for testing the equality of mean vectors for the dependent variables of main effects and interactions is presented in Table 14. Characteristic roots and F approximations are given. Significance for an effect not previously observed in the univariate analysis of both dependent variables (group, ear, group by complexity) may be explained as being the result of common variance of the dependent variables.

By using the multivariate ANOVA, the dependent measures are considered as a single response. Analysis of a single response may contain more information about the total effect of the independent variables than would a series of responses as considered in the univariate ANOVA. Therefore, results of the multivariate ANOVA indicated that there was some correlation between the dependent measures. When the word and music scores were considered as a single response, additional significance was observed for the effects of group and ear and the interaction of group by complexity.

TABLE 13

TESTS ON MUSIC MEANS OF PILOT STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY X EAR

Ordered Levels	P1RE	P1LE	P2LE	P2RE	P3LE	P3RE	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	32.70	30.23	25.57	22.27	20.30	17.13		
32.70		2.47	7.13*	10.43*	12.40*	15.57*	6	4.06
30.23			4.66*	7.96*	9.93*	13.10*	5	3.88
25.57				3.30*	5.27*	8.44*	4	3.65
22.27					1.97	5.14*	3	3.31
20.30						3.17*	2	2.75

*$p < .05$

TABLE 14

MULTIVARIATE ANOVA USING THE HOTELLING-LAWLEY TRACE STATISTIC: PILOT STUDY

Variable	Characteristic Root	Percent	F	p
Group	0.8872	100.00	5.55	0.0009*
Ear	0.7993	100.00	10.39	0.0005*
G x E	0.1370	95.38	0.90	0.4725
Complexity	5.3334	78.90	87.88	0.0001*
G x C	0.2375	68.43	2.26	0.0289*
C x E	0.3008	63.34	6.17	0.0002*
G x C x E	0.2342	96.04	1.58	0.1382

*$p < .05$

Main Study

Analysis of the results of the main study showed general support for the findings of the pilot study. Therefore, only the important differences between the two studies will be discussed in the data presentation for the main study.

The mean, standard deviation, and coefficient of variation for both dependent measures are listed in Table 15. The mean response for word scores represented 79.40% correct. The mean response for music scores represented 59.38% correct. Although both means were less than the corresponding pilot study means (see Table 2), the coefficient of variation for music scores was approximately the same. However, the coefficient of variation for word scores was lower.

TABLE 15

MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION: MAIN STUDY

	Mean	Standard Deviation	Coefficient of Variation
Words	31.7611	4.6931	14.7763%
Music	24.7000	5.2842	21.7000%

The analysis of variance for word scores is found in Table 16. There were significant differences in the main effects of ear and complexity of presentation and in the interaction of complexity by ear. There was no significant difference observed for the interaction effect of group by complexity as in the pilot study (see Table 3). In Table 17, it is observed that the right ear score was higher and that complexity presentation two was highest. Table 19 shows that the left ear score for complexity of presentation two was higher than right ear scores for all presentations.

The analysis of variance for music scores is presented in Table 17. There were significant differences in the main effects of group and complexity of presentation and in the interaction of complexity by ear. There was no significance for the three-way interaction as observed in the pilot study (see Table 4). In Table 18, it is observed that the instrumental group scored highest whereas the vocal group scored

TABLE 16

ANOVA FOR WORDS: MAIN STUDY

Source	df	SS	F	p
Model	125	10937.36	3.97	0.0001*
Error	54	1189.37		
Corrected Total	179	10937.36		
Group	2	653.51	2.56	0.0961
Error	27	3448.38		
Ear	1	956.81	17.27	0.0003*
G x E	2	107.78	0.97	0.3909
Error	27	1495.58		
Complexity	2	2163.21	48.46	0.0001*
G x C	4	95.76	1.07	0.3792
Error	54	1205.37		
C x E	2	765.01	17.37	0.0001*
G x C x E	4	45.96	0.52	0.7202
Error	54	1189.37		

*$p < .05$

highest in the pilot study (see Table 5). A right ear trend is also noted in Table 18.

TABLE 17

ANOVA FOR MUSIC: MAIN STUDY

Source	df	SS	F	p
Model	125	13151.65	3.95	0.0001*
Error	54	1438.10		
Corrected Total	179	14589.75		
Group	2	1313.20	4.76	0.0169*
Error	27	3723.05		
Ear	1	116.81	1.84	0.1863
G x E	2	46.98	0.37	0.6943
Error	27	1715.05		
Complexity	2	4428.40	88.52	0.0001*
G x C	4	6.70	0.07	0.9915
Error	54	1350.90		
C x E	2	353.64	6.64	0.0026*
G x C x E	4	96.92	0.91	0.4649
Error	54	1438.10		

*p $<$ .05

Comparisons of the means of the pilot study and the main study indicated that the left ear scores of subjects with vocal training were lower in the main study. Particularly affected were the left ear scores for complexity presentations one and three. The right ear music scores of subjects with instrumental and limited training were higher for complexity presentation three.

TABLE 18

MAIN STUDY MEANS: MAIN EFFECTS

Main Effect	Word Mean	Music Mean
Group		
V	31.7167	24.0167
I	34.1167	26.9167
L	29.4500	20.3167
Ear		
LE	29.4556	22.9444
RE	34.0667	24.5556
Complexity		
P1	30.6000	30.1167
P2	36.4667	23.1167
P3	28.2167	18.0167

TABLE 19

MAIN STUDY MEANS: TWO-WAY INTERACTIONS

Interactions			Word Mean	Music Mean
Group	X	Ear		
V		LE	28.6333	22.8333
		RE	34.8000	25.2000
I		LE	32.8667	26.8333
		RE	35.3667	27.0000
L		LE	26.8667	19.1667
		RE	32.0333	21.4667
Group	X	Complexity		
V		P1	30.5500	30.0500
		P2	37.3000	23.7000
		P3	27.3000	18.3000
I		P1	32.9000	33.5000
		P2	39.2000	26.1500
		P3	30.2500	21.1000
L		P1	28.3500	26.8000
		P2	32.9000	19.5000
		P3	27.1000	14.6500
Complexity	X	Ear		
P1		LE	26.6333	27.6000
		RE	34.5667	32.6333
P2		LE	37.0667	24.0333
		RE	35.8667	22.2000
P3		LE	24.6667	17.2000
		RE	31.7667	18.8333

TABLE 20

MAIN STUDY MEANS: THREE-WAY INTERACTIONS

Group X	Complexity X	Ear	Word Mean	Music Mean
V	P1	LE	25.6000	26.1000
		RE	35.5000	34.0000
	P2	LE	37.6000	24.6000
		RE	37.0000	22.8000
	P3	LE	22.7000	17.8000
		RE	31.9000	18.8000
I	P1	LE	30.8000	33.1000
		RE	35.0000	33.9000
	P2	LE	40.0000	27.2000
		RE	38.4000	25.1000
	P3	LE	27.8000	20.2000
		RE	32.7000	22.0000
L	P1	LE	23.5000	23.6000
		RE	33.2000	30.0000
	P2	LE	33.6000	20.3000
		RE	32.2000	18.7000
	P3	LE	23.5000	13.6000
		RE	30.7000	15.7000

As shown in Table 21, only the word mean for complexity presentation two was significantly different. Complexity presentation two had minimum complexity for words.

TABLE 21

TESTS ON WORD MEANS OF MAIN STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY

Ordered Levels	P2	P1	P3	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	36.47	30.60	28.22		
36.47		5.87*	8.25*	3	3.63
30.60			2.38	2	3.47

*p < .05

In Table 22, the left ear presentation two word mean was the only left ear word mean that was significantly different from the other means. Right ear complexity presentations were better than the left ear presentations for complexity presentations one and three.

TABLE 22

TESTS ON WORD MEANS OF MAIN STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY X EAR

Ordered Levels	P2LE	P2RE	P1RE	P3RE	P1LE	P3LE	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	37.07	35.87	34.57	31.77	26.63	24.67		
37.07		1.20	2.50	5.30*	10.44*	12.40*	6	3.61
35.87			1.30	4.10*	9.24*	11.20*	5	3.44
34.57				2.80*	7.94*	9.90*	4	3.24
31.77					5.14*	7.10*	3	2.94
26.63						1.96	2	2.44

$^*p < .05$

Music means for each group (see Table 23) indicated that subjects with instrumental training performed significantly different than subjects with vocal and limited training. There was no significant difference between vocal and instrumental training groups in the pilot study (see Table 11). Analysis of the differences in the results indicate that the scores of the vocal group were lower in the main study. Instrumental and limited group scores were approximately the same.

TABLE 23

TESTS ON MUSIC MEANS OF MAIN STUDY USING NEWMAN-KEULS PROCEDURE: GROUP

Ordered Levels	I	V	L	r	$s_{\bar{E}}q_{.95}(r,27)$
Ordered Means	26.92	24.02	20.32		
26.92		2.90*	6.60*	3	3.31
24.02			3.70*	2	2.73

*p .05

As shown in Table 24, the music mean for each complexity presentation was significantly different. Presentation one with minimum complexity for music was different from presentations two and three with maximum complexity for music.

In Table 25, the presentation one right ear mean was observed to be significantly different from all means. The left ear mean was greater than the right ear mean for presentation two, but not for presentation three. As shown in Table 13, a left ear effect for music is observed for presentation three in the pilot study.

TABLE 24

TESTS ON MUSIC MEANS OF MAIN STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY

Ordered Levels	P1	P2	P3	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	30.12	23.12	18.02		
30.12		7.00*	12.10*	3	3.85
23.12			5.10*	2	3.67

*$p < .05$

TABLE 25

TESTS ON MUSIC MEANS OF MAIN STUDY USING NEWMAN-KEULS PROCEDURE: COMPLEXITY X EAR

Ordered Levels	P1RE	P1LE	P2LE	P2RE	P3RE	P3LE	r	$s_{\bar{E}}q_{.95}(r,54)$
Ordered Means	32.63	27.60	24.03	22.20	18.83	17.20		
32.63		5.03*	8.60*	10.43*	13.80*	15.43*	6	3.97
27.60			3.57*	5.40*	8.78*	10.40*	5	3.79
24.03				1.83	5.20*	6.83*	4	3.56
22.20					3.37*	5.00*	3	3.23
18.83						1.63	2	2.69

*$p < .05$

Multivariate ANOVA using the Hotelling-Lawley Trace Statistic for testing the equality of mean vectors for the dependent variables of main effects and interactions is in Table 26. Characteristic roots and F approximations are given. Significant differences are noted for the effects of ear, complexity, and complexity by ear. In the pilot study significance was also observed for the effects of group and group by complexity. The differences appear to be the result of lower variability of word scores for each group in the main study.

TABLE 26

MULTIVARIATE ANOVA USING THE HOTELLING-LAWLEY TRACE STATISTIC: MAIN STUDY

Variable	Characteristic Root	Percent	F	p
Group	0.3687	99.48	2.32	0.0700
Ear	0.8100	100.00	10.53	0.0004*
G x E	0.0735	96.13	0.48	0.7520
Complexity	3.2836	65.26	65.41	0.0001*
G x C	0.0795	95.10	0.54	0.8216
C x E	0.6434	91.16	9.18	0.0001*
G x C x E	0.0682	67.69	0.66	0.7295

*$p < .05$

CHAPTER V

SUMMARY AND CONCLUSIONS

Introduction

Investigators (Kimura, 1961; Shankweiler, 1966) have concluded that verbal stimuli are processed by the left cerebral hemisphere and musical stimuli are processed by the right cerebral hemisphere. Other researchers (Critchley, 1972; Dimond, 1972) have questioned the mode of cerebral processing of stimuli with combinations of verbal and musical components. These questions concern the viability of theories that verbal and musical components when presented as singing (combination of verbal and musical components) are processed:

1. using bilateral hemisphere involvement--parallel processing of components by both hemispheres

2. using single hemisphere involvement--processing of both components by one hemisphere.

These theories appear to be diametrically opposed. Variables have been considered by other researchers that might affect the processing of musical stimuli: musical training of subjects (Bever and Chiarello, 1974) and complexity of the stimulus (Goodglass and Calderon, 1977). The present study was designed to test the viability of bilateral or single hemisphere processing of sung stimuli as it may be influenced by the musical training of subjects and the complexity of the stimulus.

Two hypotheses served as a basis for investigation:

1. Subjects with vocal training will process sung stimuli differently than subjects with other musical training

2. Subjects with formal musical training will process variations in complexity of sung stimuli differently than subjects with limited musical training.

Sung stimuli were presented to subjects with vocal training, instrumental training, or limited musical training. All subjects were either college juniors or seniors. Results from the study provided evidence for single hemisphere processing of sung stimuli depending on the complexity of the stimulus. However, there was no effect on the mode of hemisphere processing based on musical training (these findings were also supported by a pilot study). Therefore, neither hypothesis was statistically significant.

Results and Discussion

Subjects were administered a dichotic listening test using sung stimuli. Responses were evaluated for accuracy of reproduction of the components--verbal and musical--of the stimuli. Results were recorded as scores for accuracy of verbal reproduction (word scores) and scores for accuracy of musical reproduction (music scores). Analysis of the data was achieved through the use of multivariate and univariate ANOVA and a studentized range statistic. A discussion of the results are subsequently categorized by main effect.

Group

Subjects were assigned to one of three groups, based on the musical training of subjects. The three groups of musical training were entitled vocal, instrumental, and limited. Based on multivariate ANOVA, there were no significant differences between the word and music scores of each group (Table 26). In the multivariate ANOVA the word scores and music scores were considered as a single response. Results of the univariate ANOVA revealed significant differences in the music scores for each group (Table 17), but not in word scores (Table 16). In the univariate ANOVA the word scores and music scores were analyzed independently. Subjects with instrumental training had significantly more accurate music scores than subjects with vocal training or subjects with limited musical training (Table 23). Subjects with vocal training had significantly more accurate music scores than subjects with limited musical training. It was expected that, due to their training, subjects with vocal training would have significantly more accurate word and music scores than the other subjects in the study.

Results of the multivariate ANOVA for group effect were not supported by the pilot study (Table 14). Results from the univariate ANOVA revealed that music scores of subjects with vocal training were superior to music scores of subjects with instrumental training, but not significantly different (Table 11). The differences in the pilot study and main study can be explained by the fact that more accurate word and music scores for subjects with vocal training were obtained in the pilot study. Specifically, the verbal and musical components of stimuli presented to the left ear of subjects with vocal training were more accurately reproduced in the pilot study than in the main study. Comparisons of work and music scores for subjects with instrumental and limited musical training in the pilot and main studies revealed no corresponding differences in the accuracy of reproduction. It appears that if training does effect differences in the ability to process sung stimuli, it affects the processing of stimuli presented to the left ear of subjects with vocal training. A plateau effect for hemisphere efficiency is suggested as a reason for the difference in processing accuracy. As a subject receives vocal training, the ability of the right hemisphere to process sung stimuli is affected. As the efficiency of the right hemisphere increases, the processing of sung stimuli can switch from the left hemisphere to the right hemisphere.

The effect of training on right hemisphere processing efficiency is in contrast to the conclusions of Bever and Chiarello (1974). They concluded that the processing ability of the left hemipshere is affected by training. The stimuli used by Bever and Chairello were melodies played by an instrument, whereas the stimuli employed in this study were sentences sung to melodies. A possible explanation for the lack of support for the findings of Bever and Chiarello may be that sung stimuli are perceived differently than stimuli played by an instrument. The combination of verbal and musical components in sung stimuli may necessitate different processing strategies than the strategies used for stimuli without the verbal component. If different processing strategies are utilized, then training may affect the hemispheres differently.

Ear

Subjects were presented stimuli to both ears simultaneously using a dichotic listening technique. The assumption of researchers using the technique is that by presenting contrasting stimuli to both ears dichotically, stimuli will be processed more efficiently in the hemisphere that is specialized for processing those stimuli (Broadbent, 1954). Results of tests utilizing the technique are often given as ear scores and are assumed to represent involvement by the contralateral hemisphere.

Results of the multivariate ANOVA revealed a significant ear effect (Table 26). Treatment of the data using univariate ANOVA showed significant differences in word scores (Table 16), but not in music scores (Table 17). The right ear effect for words is in agreement with the literature.

The lack of a significant ear effect for music is in contrast to the findings of Goodglass and Calderon (1977). One reason for the lack of significance appears to be the mediating effect of variations in complexity of stimulus presentation. This mediating effect is a statistical balance resulting from more accurate music scores for the left ear than the right ear for one variation in stimulus complexity and more accurate music scores for the right ear than the left ear for another variation (stimulus complexity is discussed in the next section). Therefore, different modes of processing appear to be used for the different complexity variations.

The group by ear interaction was not significant. A subject's mode of processing sung stimuli was not significantly affected by musical training.

Complexity

The complexity of stimulus presentation was varied by increasing the number of verbal and/or musical differences between ear presentations. Presentation one (P1) utilized different words sung to the same melody for each ear.

Presentation two (P2) utilized identical words sung to different melodies for each ear. Presentation three (P3) utilized different words sung to different melodies for each ear.

The complexity effect was significant based on both multivariate and univariate ANOVA (Table 26, Table 16, and Table 17). Results of the univariate ANOVA for words revealed that all subjects reproduced the verbal component of the sung stimuli more accurately when the words had minimum complexity (P2) than when the words had maximum complexity (P1, P3). However, there was not a significant difference between word scores for stimuli of maximum complexity (P1, P3).

Results of the univariate ANOVA for music revealed that all subjects reproduced the musical component of the sung stimuli more accurately when the music had minimum complexity (P1) than when the music had maximum complexity (P2, P3). There was a significant difference between music scores for stimuli with maximum complexity (P2, P3). The difference between the complexity variations P2 and P3 appear to be the result of interaction with the verbal complexity. Therefore, the musical component was processed more accurately when presented with minimum verbal complexity (P2) than when presented with maximum verbal complexity (P3). This finding indicates that processing efficiency for musical components of sung stimuli can be influenced by verbal complexity.

The complexity by ear interaction was also significant based on multivariate and univariate ANOVA and indicated single hemisphere processing of both verbal and musical components in sung stimuli. However, analysis of the data revealed reversals of hemisphere processing for both verbal and musical components depending on the complexity of stimulus presentation (Table 19). When the stimulus presentation had maximum complexity for words and minimum complexity for music (P1), there was a right ear advantage for both verbal and musical components. When the stimulus presentation had minimum complexity for words and maximum complexity for music (P2), there was a left ear advantage for both verbal and musical components. When the stimulus presentation had maximum complexity for both words and music (P3), there was a right ear advantage for both verbal and musical components. However, in the pilot study there was a right ear advantage for the verbal component and a left ear advantage for the musical component in P3.

The reversals of ear dominance indicated differences in the processing strategies based on the stimulus complexity. In P1 the left hemisphere processed both components in the sung stimuli. In P2 the right hemisphere processed both components. In P3 the left hemisphere processed both components. Subjects appear to have processed the verbal and musical components of a sung stimulus as one unit rather than as two different elements (John, 1972).

Based on assumptions of the dichotic listening paradigm (Broadbent, 1954), the reversals of ear dominance can be the result of attending differences of the hemispheres. Subjects may have attended to that component of the sung stimulus with maximum complexity. Therefore, in P1 the verbal component was more complex than the musical component and was more attentionable. In P2 the musical component was more complex than the verbal component and was more attentionable. The result of presenting stimuli with variations in complexity is that the hemisphere that is more efficient for processing the more attentionable component--verbal or musical--may become efficient in processing the other component. In effect, the stimulus may be processed as a unit by the hemisphere that is more efficient for processing that component of the stimulus with maximum complexity.

With maximum complexity for both verbal and musical components (P3), the left hemisphere was more efficient for both components. With maximum complexity, stimuli may be processed according to component priority (Norman, 1968). Therefore, verbal components may be more attentionable than musical components, given maximum complexity for both components.

The difference in the pilot study for P3 appears to be the result of more accurate reproduction of the musical component for subjects with vocal training in the pilot study. As discussed previously in this chapter, the processing efficiency of a hemisphere (plateau effect) may be influenced not only by training, but also by stimulus complexity. In effect, subjects with vocal musical training may utilize bilateral hemisphere processing for verbal and musical components in sung stimuli, when presented with maximum complexity. With maximum complexity the left hemisphere processes the verbal component and the right hemisphere processes the musical component. However, the reason for the more accurate reproduction of the musical component by subjects with vocal training in the pilot study was not evident.

Conclusions

Implications for a Theory of Single Hemisphere Processing of Sung Stimuli

The data from the present study render information to be considered in support of a theory of processing of sung stimuli. The results are incompatible with the theory of Goodglass and Calderon (1977) of bilateral hemisphere processing, which describes the simultaneous processing of verbal components by the left hemisphere and the musical components by the right hemisphere. The results of this study do support a theory of single hemisphere processing of sung stimuli.

In contrast to previous research (Bartholomeus, 1974b; Bogen and Gordon, 1971; Kimura, 1964; Shankweiler, 1966), verbal and musical components of sung stimuli can be processed by either hemisphere. However, both components of a sung stimulus appear to be processed as a single unit by one hemisphere, instead of two elements processed by opposite hemispheres. In effect, each hemisphere can process sung stimuli independently of the other hemisphere. This conclusion is in accord with a theory of hemispheric interference (Galin, 1974; Nelson, 1978; Ornstein, 1972) which proposes that hemispheric interaction produces interference in processing and that only one hemisphere can be functionally dominant.

Influence of Training and Complexity of Stimulus

In contrast to Bever and Chiarello (1974) who proposed laterality effects for musical stimuli based on training, the present study did not reveal significant differences in the processing of sung stimuli based on musical training. However, the complexity of stimulus presentation did affect the processing efficiency of each hemisphere.

As the complexity of stimulus presentation was varied, a shift in hemisphere dominance was evidenced. Thus, a plateau for the processing efficiency of each hemisphere was attained based on the stimulus complexity. The result of varying the complexity of the stimulus was that one component--verbal or musical--of the sung stimulus became more attentionable. As the complexity of the verbal component was increased, the left hemisphere became more efficient for processing the sung stimulus. As the complexity of the musical component was increased, the right hemisphere became more efficient. However, when complexity for both components was increased the left hemisphere became the efficient hemisphere.

These findings may explain the contradictory evidence concerning laterality effects for verbal and musical stimuli. In studies utilizing separate verbal stimuli and musical stimuli (Kimura, 1961; Kimura, 1964; Shankweiler, 1966), subjects processed verbal stimuli with the left hemisphere and musical stimuli with the right hemisphere. The present study supports these findings of functional lateralization depending on the attentionable components of the stimulus. In studies utilizing stimuli that combine verbal and musical components (Bartholomeus, 1974b; Bogen and Gordon, 1971; Goodglass and Calderon, 1977), the findings may be the result of the uniqueness of the combination of the components. Thus, the verbal and musical components are not combined, but presented in parallel. Sung vowels, sung syllables, sung digits, and sung consonant-vowels represent unique combinations that allow each hemisphere to attend to that component for which it is functionally dominant.

However, in the present study, the stimuli were assumed to be more representative of singing behavior than stimuli used in previous studies. Words and melodies were composed using sentences and traditional sequences of pitches. The result of using more representative stimuli is that the stimuli more nearly match past experiences of the subject stored in memory. Galin (1976) suggests that memory traces can reside in both hemispheres, but are activated in a specific hemisphere based on the task required. The results of this study support that conclusion. When the verbal component of a sung stimulus is more attentionable than the musical component, the left hemisphere processes the stimuli more efficiently due to its processing abilities for speech. When the musical component of a sung stimulus is more attentionable than the verbal component, the right hemisphere processes the stimuli more efficiently due to its processing abilities for music.

When the complexity of both components of a sung stimulus is increased, the processing mode for speech (left hemisphere) is utilized. Given equal complexity for both components the verbal component becomes more attentionable. The reason for this finding may be the result of a priority system of attention based on the number of experiences of a subject in memory (Norman, 1968). Therefore, verbal components may have attention priority over musical components given equal complexity for both components.

Importance to Music Education

The results and conclusions of this study concern the processing of sung stimuli. It was assumed that the stimuli utilized in this study were more representative of singing behavior than stimuli used in previous research. The conclusions established in this study would seem to be relevant in applications to singing and singing pedagogy. Thus, the practice of presenting the words separately from the music in a song does not appear to correlate with the processing of verbal and musical components of a sung stimulus as a single unit; an audience may perceive words more effectively than music in complex vocal music; specific styles of vocal music, such as folk music, pop music and country western music, may emphasize the verbal content of a song more than the musical content and may necessitate a dependence on the clarity of the words for perception; specific styles of vocal music, such as art song and opera, may emphasize the musical content of a song more than the verbal content and may necessitate a dependence on musical knowledge for perception; and songs presented in a classroom should be selected not only for verbal qualities, but also for musical qualities.

These applications can be used to better educate students, teachers, audiences, and performers in the processing of singing, as it relates to classroom singing, social singing, vocal concerts, popular music, opera, and other facets of the singing behaviors.

Recommendations

It is recommended that additional research be conducted to investigate variables affecting left ear scores for subjects with vocal training. Differences between the main and pilot studies indicated a plateau effect for hemisphere processing of sung stimuli by subjects with vocal music training. The plateau effect was apparent for right hemisphere processing of musical components. If subjects with vocal training do process sung stimuli differently than other subjects, it may be the result of more efficient right hemisphere processing of musical components.

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APPENDIX A

TEST SCRIPT

TEST SCRIPT

You are participating in an experiment to assess how subjects perceive and produce singing. You will be given two five-minute tests in which you will be asked to listen to six short examples of melodies with words. After listening to two examples you will be asked to reproduce the examples within a given time limit. The two examples will be given at the same time, one in the right ear and one in the left ear.

For example, you may be given the following in the right ear:

At the same time you will be given another example in the left ear:

The two examples, when given at the same time, will be preceded by a count of four and will sound as follows:

Right 1-2-3-4

Left 1-2-3-4

The counts before each set of examples will prepare you for the set of examples. After the four counts the examples will be given. You are asked to reproduce the examples within twelve seconds. To practice, the previous example will be presented in the designated format. Please respond in the given time interval.

Right 1-2-3-4

(12 seconds)

Left 1-2-3-4

(12 seconds)

There are three different types of example sets:

1. The words to each ear are identical, but the melodies to each ear are different.
2. The words to each ear are different, but the melodies to each ear are identical.
3. The words to each ear are different, and the melodies to each ear are different.

Please respond during the given time interval with some response. If you can not reproduce both examples of the set in total, reproduce what you are able to produce. Any response is better than no response. Remember, you will have only twelve seconds to reproduce each example set.

APPENDIX B

QUESTIONNAIRE

QUESTIONNAIRE

The following questionnaire will be used to classify and select subjects to participate in a study of aural perception and singing. Selected subjects will be asked to listen and respond to a prepared tape: the prepared tape will consist of instructions and two five-minute listening tests. The listening tests will consist of short melodies with words. The subject will be asked to reproduce the melodies with words as sung on the prepared tape. Vocal quality will not be important: only the ability to reproduce the melodies with words will be evaluated. Subjects selected to participate in the study will be eligible for a ten-dollar remuneration awarded to the best score in each category: music majors and nonmusic majors. Subjects will be contacted for a time to participate in the listening test.

Steve Mayo

Brevard Music Center

Box 592

Brevard, North Carolina 28712

Name____

General Data

1. Classification: college junior college senior
2. Sex: male female
3. Handedness: right left
4. Major: music-vocal music-instrumental other________

Formal Music Experience

Formal music experience is defined as private or class instruction in music, singing, or in aplying a musical instrument.

5. Number of years of formal study of voice during the preceding eight years (1971-78): 0 1 2 3 4 5 6 7 8

   last year of study:_______
6. Number of years of formal study of an instrument during the preceding eight years (1971-78): 0 1 2 3 4 5 6 7 8

   last year of study:_______
7. Number of years participation in performing music organization of a school, church, or community during the preceding eight years (1971-78): 0 1 2 3 4 5 6 7 8

   last year of participation:________
8. Number of years of formal study of music theory, music appreciation, and/or general music during the last eight years (1971-78): 0 1 2 3 4 5 6 7 8

Informal Music Experience

Informal music experience is defined as singing or playing a musical instrument, or participating in other musical experiences without the aid of private or class lessons.

9. Number of years of informal music experience with voice or an instrument during the last eight years (1971-78):

   0 1 2 3 4 5 6 7 8

   specify:____
10. I go to musical concerts: regularly occasionally never
11. Have you had a history of hearing disorders: yes no
12. If selected, will you be willing to participate: yes no

APPENDIX C

SCORING SHEET AND TABLE

SCORING SHEET

Subject Number:________

Question: 1. 1 2
2. 1 2
3. 1 2
4. 1 2

Question: 5. 0 1 2 3 4 5 6 7 8
6. 0 1 2 3 4 5 6 7 8
7. 0 1 2 3 4 5 6 7 8
8. 0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
9. 0 1 2 3 4 5 6 7 8
10. 0 1 2 3 4 5 6 7 8

Test A				Test B			
Order	Pres.	Ear: ____	____	Order	Pres.	Ear: ____	____
1.	1	M 0 1 2 3 4	0 1 2 3 4	1.	3	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
2.	1	M 0 1 2 3 4	0 1 2 3 4	2.	2	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
3.	2	M 0 1 2 3 4	0 1 2 3 4	3.	3	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
4.	2	M 0 1 2 3 4	0 1 2 3 4	4.	1	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
5.	1	M 0 1 2 3 4	0 1 2 3 4	5.	1	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
6.	2	M 0 1 2 3 4	0 1 2 3 4	6.	3	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
7.	3	M 0 1 2 3 4	0 1 2 3 4	7.	2	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
8.	2	M 0 1 2 3 4	0 1 2 3 4	8.	1	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
9.	3	M 0 1 2 3 4	0 1 2 3 4	9.	1	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
10.	1	M 0 1 2 3 4	0 1 2 3 4	10.	1	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
11.	2	M 0 1 2 3 4	0 1 2 3 4	11.	3	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
12.	3	M 0 1 2 3 4	0 1 2 3 4	12.	2	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
13.	3	M 0 1 2 3 4	0 1 2 3 4	13.	2	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
14.	3	M 0 1 2 3 4	0 1 2 3 4	14.	2	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4
15.	1	M 0 1 2 3 4	0 1 2 3 4	15.	3	M 0 1 2 3 4	0 1 2 3 4
		W 0 1 2 3 4	0 1 2 3 4			W 0 1 2 3 4	0 1 2 3 4

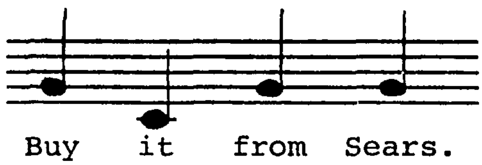
SCORING TABLE

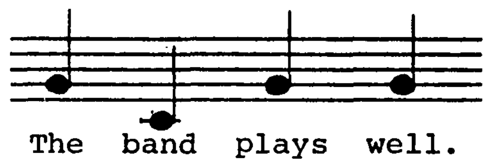
	Presentation					
	1		2		3	
	A	B	A	B	A	B
M-L						
W-R						
W-L						
W-R						

APPENDIX D

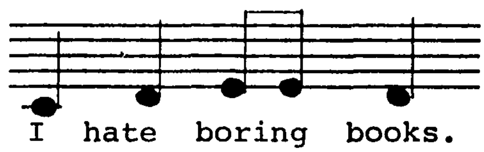
TEST A AND TEST B

TEST A

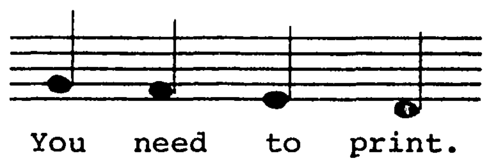

Buy it from Sears.

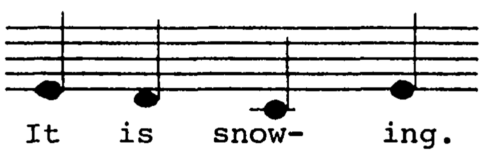

The band plays well.

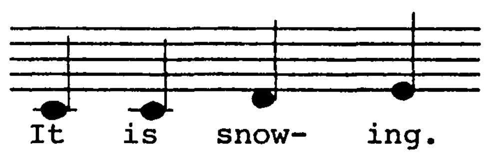

Coffee and sugar, please.


I hate boring books.

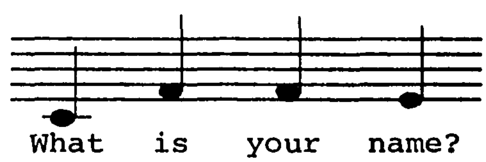

You need to print.


You need to print.


It is snow- ing.


It is snow- ing.

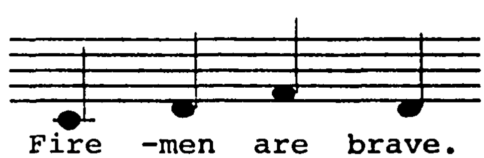

She wears three rings.

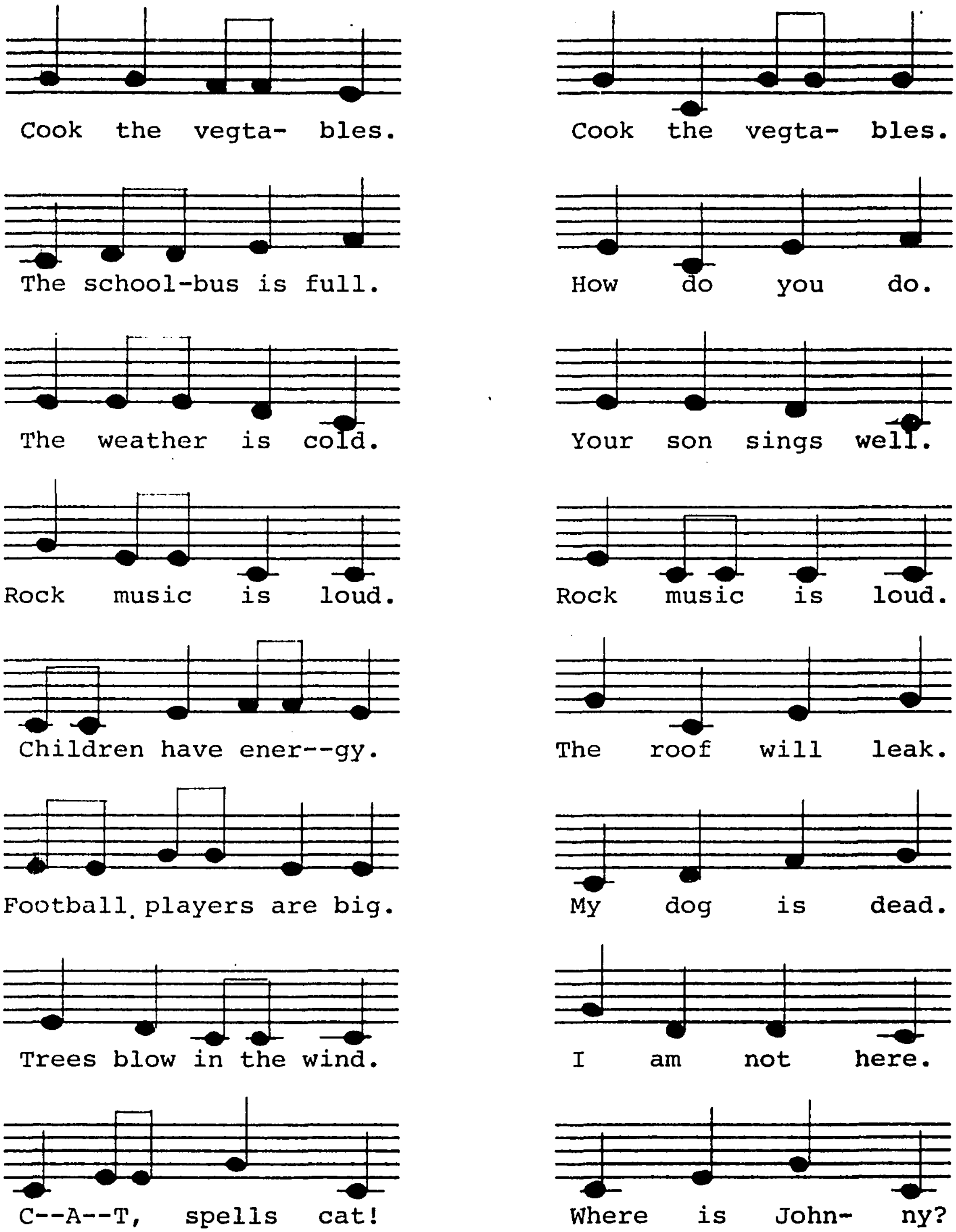

What is your name?


Where are you going.

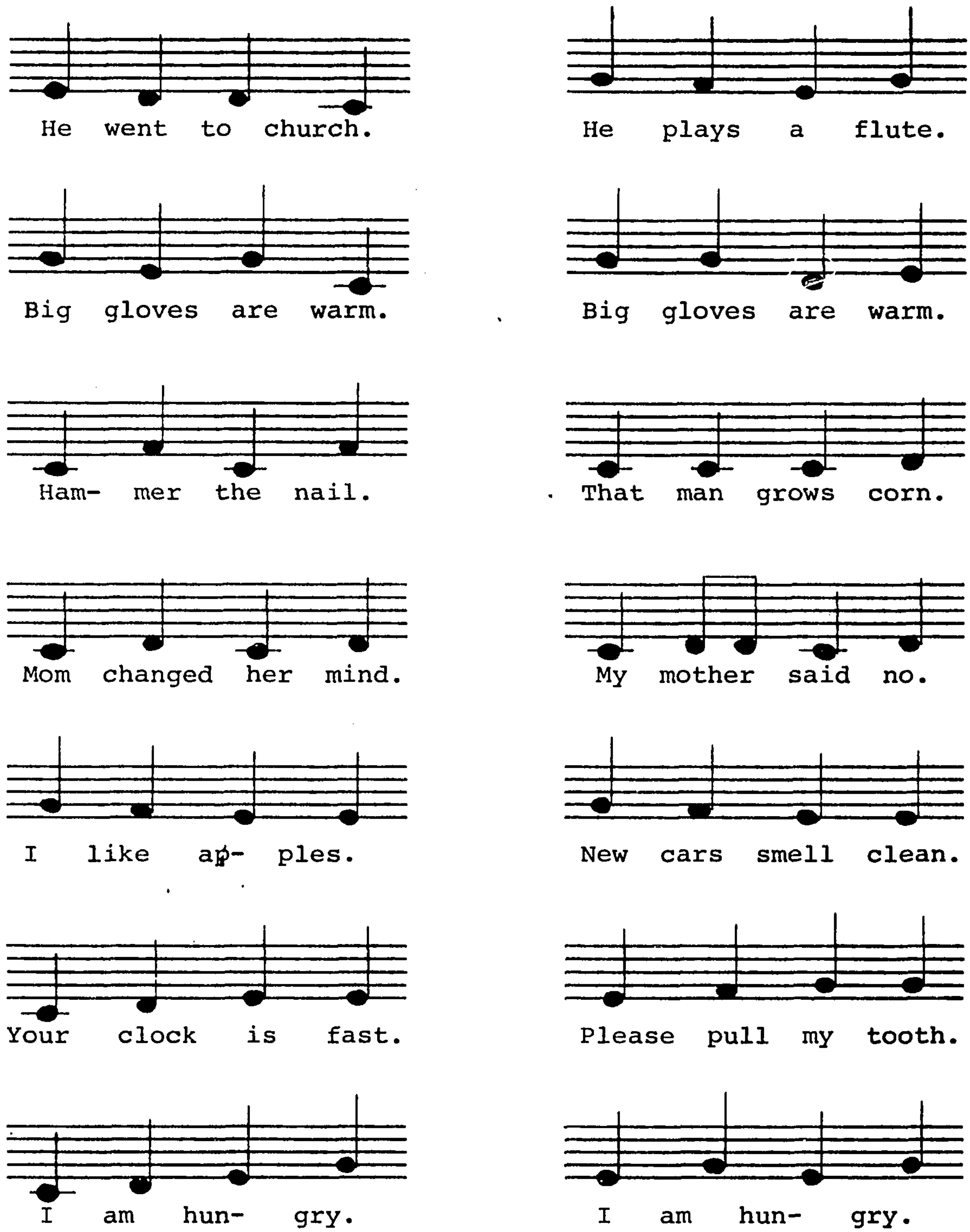

Where are you going.

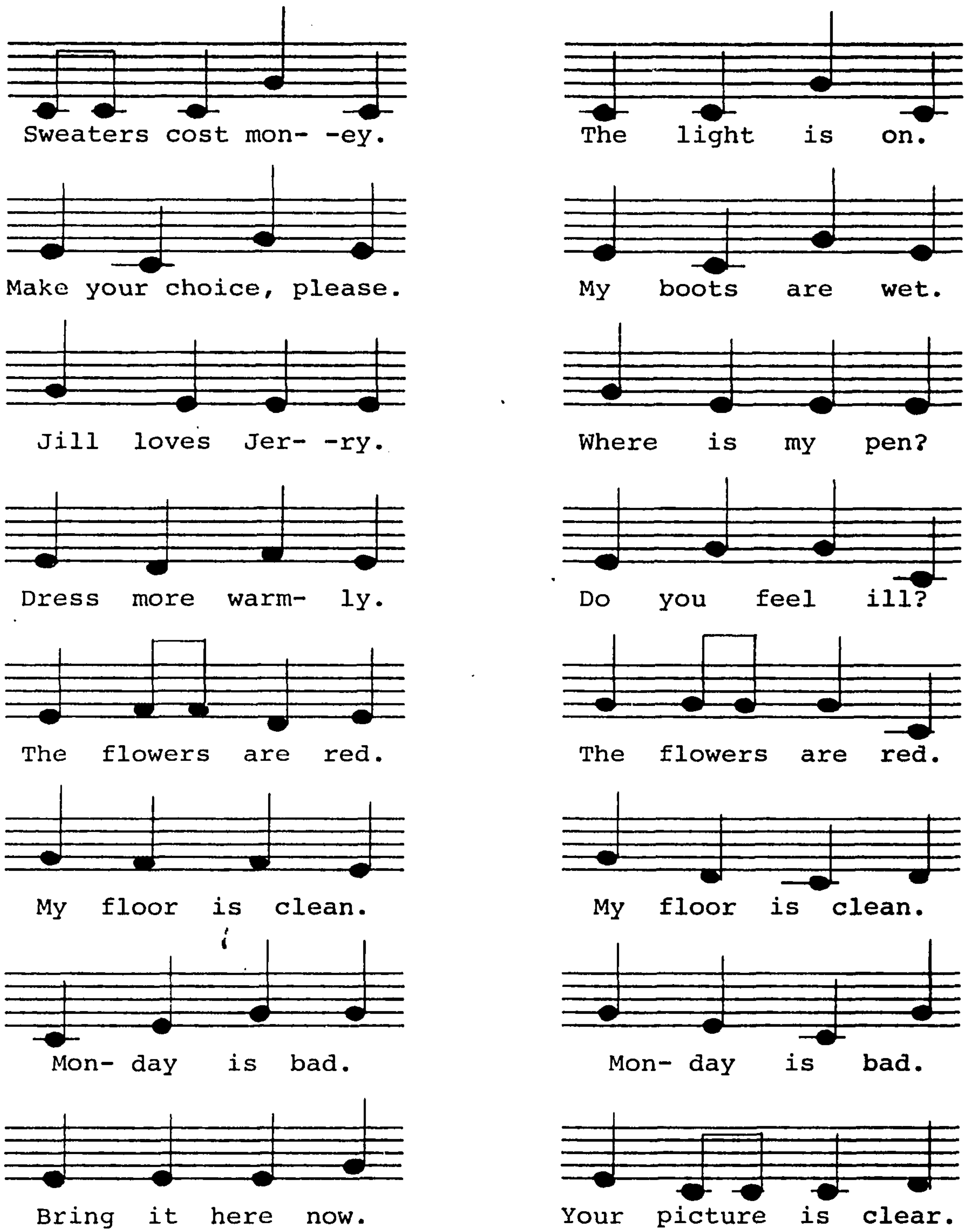

Mom went shop- ping.


Fire -men are brave.


Cook the vegta- bles.
The school-bus is full.
The weather is cold.
Rock music is loud.
Children have ener--gy.
Football players are big.
Trees blow in the wind.
C--A--T, spells cat!
Cook the vegta- bles.
How do you do.
Your son sings well.
Rock music is loud.
The roof will leak.
My dog is dead.
I am not here.
Where is John- ny?

TEST B


He went to church.
Big gloves are warm.
Ham- mer the nail.
Mom changed her mind.
I like ap- ples.
Your clock is fast.
I am hun- gry.
He plays a flute.
Big gloves are warm.
That man grows corn.
My mother said no.
New cars smell clean.
Please pull my tooth.
I am hun- gry.


Sweaters cost mon- -ey.
Make your choice, please.
Jill loves Jer- -ry.
Dress more warm- ly.
The flowers are red.
My floor is clean.
Mon- day is bad.
Bring it here now.
The light is on.
My boots are wet.
Where is my pen?
Do you feel ill?
The flowers are red.
My floor is clean.
Mon- day is bad.
Your picture is clear.

GLOSSARY

Ablation: Surgical destruction of part of the brain

Afferent: Conveying toward; e.g., of nerve impulses into the central nervous system

Alpha waves: EEG pattern when the brain is "at rest" (i.e., not responding to sensory inputs), showing regular waves of large amplitude (see Electroencephalogram)

Amusia: Inability to perceive music

ANSI (1969): American National Standards Institute's Specification for Audiometers (ANSI S3.6--1969); refers to standardization of sound pressure levels which represent audimetric zero for pure tones and for speech

Aphasia: General name for psychological disorders of speech

Ascending reticular activating system: Diffuse net of cells in brain stem concerned with attention, sleep and wakefulness

Brain stem: Central core of brain or "stalk" to which other structures are attached; includes medulla and ascending reticular activating system

Calibration tone: Tone frequently used to insure that experimental equipment remains in calibration from one test to another; assures repeatability of the output signal levels of the equipment

Cerebrum: Brain region originating as bilateral swelling of forebrain and ultimately forming the cerebral hemispheres, the largest brain structures in mammals, concerned with association and coordination of nerve impulses and, in humans, thought and intelligence

Contralateral: Relating to the opposite side

Corpus callosum: Sheet of white matter between the cerebral hemispheres composed of myelinated fibers crossing from one side to the other

Cortex: Superficial layer of tissue usually pertaining to that part of the cerebrum which is rich in nerve-cell bodies and synapses

Efferent: Proceeding away from; e.g., nerves carrying impulses from the central nervous system to effectors

Electroencephalogram (EEG): The recording of electrical brain patterns through electrodes placed on the skull; records include such characteristic wave forms as alpha, delta, etc.

Evoked potential: Neural activity resulting from applied stimulation, e.g., by an implanted electrode

Gestalt: The perception and the organization of mental processes in relation to patterns of sensory stimuli

Habituation: Gradual adaptation to an irritation which, in nerve cells, is signaled by a cessation or reduction in the generation of nerve impulses

Hertz (Hz): Primary measure of stimulus frequency

Hippocampus: Brain region situated in the temporal lobe of the cerebral hemispheres, having a prime, but unknown, role in memory formation

IAC Sound Booth: Prefabricated audiometer test booth

Ipsilateral: Relating to the same side

Learning: General term for a category of changes in an organism whereby behavior becomes modified, other than by drugs or fatigue

MX-41/AR cushion: Commonly mounted on earphones used in experimentation and in audiology clinics; doughnut shaped and made of sponge neoprene

Neuron: A nerve cell

Plasticity: The phenomenon of brain function and structure being changed by experience

Puretone: Sinusoidal acoustic signal described entirely in terms of frequency and intensity

Reticular formation: See Ascending reticular activating system

Split brain: A brain divided surgically into right and left halves so that each half can be trained and tested independently

Sweep Frequency Screening: Audiometric test for quick evaluation of hearing efficiency; subjects administered pure tone pulses at an acceptable decible level (20 db) and required to identify all tones

Synapse: The point where neurons communicate

TDH-39 earphones: Commonly used in psychoacoustic experimentation and in audiometric testing; frequency response is usually limited to 6000 Hz