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AN INVESTIGATION OF AUDITORY LATERALITY EFFECTS FOR VERBAL AND MELODIC STIMULI AMONG MUSICIANS AND NONMUSICIANS

by

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The purpose of this study was to determine if laterality effects differ for musicians and nonmusicians in the cerebral processing of musical stimuli. It was hypothesized that musicians, due to a more analytical approach to music listening, would demonstrate a right ear (left hemisphere) superiority for melodic stimuli, while nonmusicians would show a left ear (right hemisphere) dominance. Both groups, it was hypothesized, would reveal a right ear superiority for verbal stimuli. Verbal and melodic dichotic listening tasks were administered to a total of 44 musicians and 44 nonmusicians in two separate experiments. Group comparisons were made of right and left ear performance on each of the two auditory tasks. Both groups demonstrated a significant left ear effect for melodic recognition, which failed to support the first research hypothesis. The two groups demonstrated a nonmusicians right ear trend for verbal recall, which resulted in a lack of support for the second research hypothesis. It was concluded that the results of this study provide no evidence for laterality differences between musicians and nonmusicians in the processing of musical stimuli.

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CHAPTER I

THE PROBLEM

Introduction

In recent years there has been a growing interest among music educators, as well as researchers in psychology and the neurological sciences, in the specialized functions of the two cerebral hemispheres of man relative to the perception of his environment and control of his behavior. The question of which hemisphere of the brain processes and stores specific kinds of auditory stimuli is one that may be of prime importance to those music educators who seek further understanding of the means by which musical sound is perceived. Research in psychoacoustics has resulted in the availability of an extensive amount of information regarding the transmission of musical sound, including understanding of the physiological phenomena which occur when sound waves strike the tympanic membrane and enter the inner ear. Information regarding the transmission of neural signals initiated by the sound wave to the brain for processing is less precise. Until approximately twenty-five years ago, little attention was given to the role of the brain in the perception of musical sounds. Compared to the amount of published research on the cerebral processing of speech, the number of available studies on musical perception is still relatively small.

Early research reports of cerebral processing of musical stimuli (Milner, 1962; Kimura, 1964) implied that the right cerebral hemisphere in most individuals is specialized for the mediation of nonverbal input, including music, while the left hemisphere appears to be specialized for verbal abilities. Later research by Levy-Agresti and Sperry (1968) indicated that the functional differentiation of the cerebral hemispheres involves other aspects of human cognition in addition to the processing of verbal and nonverbal stimuli. Levy-Agresti and Sperry have suggested that the left hemisphere is responsible for serial or analytical processing of incoming information whereas the right hemisphere is specialized for parallel or wholistic processing of stimuli.

Bever and Chiarello (1974) have challenged the implication that musical perception is predominantly a function of the right hemisphere. The results of their research imply that environmental factors, such as musical training, can affect the processing strategies of the brain. Bever and Chiarello have concluded that the amount of musical training an individual receives influences which hemisphere of the brain processes musical stimuli. Musically trained listeners, defined in the report of their research as active musical performers with a minimum of four years of formal study on an instrument or voice, appeared to utilize the analytical centers (left hemisphere) of the brain when listening to music. The musically trained listener, according to Bever and Chiarello, tends to hear a melody as a series of related tones and patterns, resulting in processing of the melodic sequence in a linear, sequential mode. Linear processing of incoming information appears to be a left hemisphere mode of operation (Levy-Agresti and Sperry, 1968). For the less musically experienced listener, Bever and Chiarello theorize, the linear relationships within a melody appear to have little relevance.

Therefore, cerebral processing of melodic stimuli for the less experienced music listener tends to be wholistic, i.e., a cognitive activity of the right hemisphere. Bever and Chiarello classified musically inexperienced listeners as persons having less than three years of formal music study, none of which occurred within five years prior to participation in their experiment.

If it can be established that musical training influences the organization and processing strategies of the brain, future pedagogical trends in music may be affected. Although the full import of research in musical information-processing to teaching practices in music education is likely to remain a matter of speculation for some time, an area that would appear to ultimately benefit from this type of research is the measurement and evaluation of music listening skills. The precise means through which students develop effective music listening skills have never been empirically substantiated by music educators, and there is little data from experimental research which deals with problems related to music listening (Gordon, 1971). Since listening is the means through which humans experience and share the art of music, the development of effective music listening skills should be an important goal of music education, for both the general student and the advanced performer (Reimer, 1970).

Current writings on music education (Schwadron, 1967; Reimer, 1970) describe the musically experienced listener primarily in terms of active involvement with the musical stimuli he is able to perceive in a composition. The experienced music listener appears to be more aware than his less experienced counterpart, of temporal and tonal relationships within a musical composition, and is able to relate a knowledge of melody, rhythm, dynamics, tone color, and formal organization to listening experiences. The experienced listener has a developed tonal memory and can remember important musical themes; he can employ a musical vocabulary to describe musical elements perceived. According to Colwell (1970), there is activity and cognitive awareness in the musically experienced listener which heightens the emotional response to the music, and helps to create a genuine aesthetic experience. The musically inexperienced listener, according to Schwadron (1967), has generally had little or no experience with the musical elements which form a composition, and therefore does not tend to perceive relationships which exist among them. For the musically inexperienced listener, the listening experience appears to be primarily passive rather than active; he is aware of a succession of pleasant or unpleasant sounds which arouse positive or negative feelings, depending to some extent upon the nonmusical associations he brings to the listening experience. For the musically uninitiated listener, the cognitive response appears to be limited, if not absent altogether. Since there appears to be a close relationship between the affective and cognitive domains (Colwell, 1970), the intensity of feeling when hearing music may also be limited to the inexperienced music listener, relative to that of the more musically sophisticated individual.

The research of Bever and Chiarello (1974) suggests that the presence of analytical functioning in the experienced music listener and the lack of such activity in the less experienced listener is also manifested by measurable differences between the two in outcomes related to cerebral processing strategies for musical stimuli. If this assertion can be established, then instruments for measuring cerebral responses to auditory stimuli, to be discussed later in this chapter, may provide new indices to musical perception. Auditory tests which can determine the presence or absence of analytical cerebral activity deserve further investigation as potential instruments for identifying music listening behaviors. The present study investigated the relationship between musical experience and musical perception through the use of a dichotic listening technique, which is a different measure than that employed in the Bever and Chiarello (1974) study. A discussion of auditory techniques for lateral dominance, including the dichotic listening technique, is included later in this chapter.

Overview

One of the unique features of the central nervous system of higher animals, including that of homo sapiens, is that each hemisphere of the cerebral cortex receives information primarily from the opposite (contralateral) half of the body. In addition to the input that each cerebral hemisphere receives from the opposite side of the body, there is also a limited degree of communication from the same side of the body (ipsilateral input). This is true for the visual, tactual, motor, and auditory systems. The communication that each hemisphere receives from its own side of the body, in most individuals, is of a gross nature and serves primarily to cue the ipsilateral hemisphere of the presence or absence of stimulation. This ipsilateral input appears to be sufficient to activate the complex cross-referencing system that exists between the two hemispheres, allowing for processing of incoming information in those areas of the brain that are specialized for that information (Gazzaniga, 1970).

The cerebral cortex is actually a double organ consisting of the left and right hemispheres and a connecting bundle of nerve fibres known as the corpus callosum. Reports of studies reveal little detailed knowledge of the circuitry of brain. According to estimates (Dimond, 1974), there are approximately five million cells beneath each square centimeter of surface cortex. Methods of brain research have been inadequate for specifically mapping the cellular connections and functional relationships that exist between cells. While a precise knowledge of how information is processed, stored, and recalled remains elusive, behavioral and physiological studies have contributed much to a general understanding of cortical functioning. Experiments with split-brain patients, for example, have resulted in the availability of information regarding the role of each cerebral hemisphere in speech functions, numerate abilities, spatial functions, and artistic abilities (Gazzaniga, 1970). Through studies with split-brain subjects, it has been concluded that each cerebral hemisphere functions somewhat independently of the other in the processing of incoming information (Sperry, 1968). Each half of the brain appears to be specialized for certain kinds of information, and only after that information has been processed in the brain areas intended to receive it do the functions of one hemisphere integrate with those of the other and culminate in the processes of decision, adaptation, and response (Dimond and Beaumont, 1974). Results from split-brain research illustrate that under conditions of a surgically severed corpus callosum, a treatment administered to some severe cases of epilepsy, the two hemispheres function as two separate brains. With the corpus callosum intact, the two cerebral hemispheres exist in a symbiotic relationship, each complementing the other in maintaining a fluent relationship between the individual and his world (Dimond and Beaumont, 1974). The corpus callosum appears to be of major importance to interhemispheric communication.

On the basis of results from language studies, Gazzaniga (1970) offers a theory of how hemispheric specialization develops in the human brain. According to Gazzaniga, the human infant is born with a split, or partially split, brain. The corpus callosum does not appear to be functional at birth, but develops during the first two years of life. In support of this view, Gazzaniga refers to evidence by Langworthy (1933) and Conel (1941, 1959) which indicates that areas of the nervous system, including the corpus callosum, become myelinated as they become functional. Myelination and over-all development, according to Gazzaniga, are active processes during the first two years of life and continue, though less actively than during the initial years, until puberty. Interhemispheric communication, he concludes, is minimal at birth, but present by age two and increases with age. Between the ages of one and two years, as a result of manipulation of toys and other objects, engram formation takes place in the two hemispheres. As the child explores with the right hand, visual, auditory, and tactual engrams are established in the left hemisphere. Since right hand activity in most people, according to Gazzaniga, appears to be more frequent than left, the left hemisphere acquires an early developmental lead over the right.

The right hemisphere seems to acquire many of the same abilities as the left hemisphere, including language, but lacks the proficiency of the left hemisphere at any stage of development. As development continues, the right hemisphere becomes less and less proficient in language functions, while the left hemisphere acquires prominence in this area. Gazzaniga's theory appears to be consistent with neurological evidence which confirms that left hemisphere damage in a young child does not cause a total disruption of language capacity, as it does in adults. After the corpus callosum becomes functional at approximately age two, it has been observed that left hemisphere lesions become more and more disruptive of language functions, indicating that these processes have become localized in the left hemisphere. The theory proposed by Gazzaniga relative to the development of hemispheric specialization is representative of what is regarded in the research literature as the central line of thought on cerebral dominance (Beaumont, 1974). This theory is complicated by its implication that a one-to-one relationship exists between cerebral dominance and handedness. Available evidence by Penfield and Roberts (1959) and others indicates that no such relationship exists. While there is general agreement among investigators that motor dominance and cerebral dominance for language are related, the precise nature of that relationship has not been established. A summary of research on handedness and cerebral lateralization will appear in Chapter II.

The evidence cited by Gazzaniga (1970) indicates that at an early age, the two cerebral hemispheres have the potential for many different functions, but with maturity there is a tendency in most individuals toward cerebral lateralization (hemispheric specialization) of cognitive functions. As stated previously, there is an indication that the left hemisphere is specialized for sequential functions, such as language, while the right hemisphere appears to be involved with the mediation of wholistic input. The right hemisphere, although possessing some language abilities, deals more efficiently with nonverbal data (Levy-Agresti and Sperry, 1968). Spatial abilities, such as those which deal with recognition of forms or faces, are typically thought to be right hemisphere functions. Artistic endeavor and the ability of man to imagine, visualize, and attend to sensory stimuli such as art or music are also thought to be related to right hemisphere abilities (Ornstein, 1972). Dimond and Beaumont (1974) indicate that right hemisphere activity also includes certain processes related to creativity, including inventive, exploratory, and improvisatory aspects of mental activity.

Since much of the research that has been done has dealt with speech disorders, generally involving a left hemisphere malfunction, much is known of the activities of the left side of the brain. According to Gazzaniga (1970), the predominant function of the right hemisphere, by contrast, is still unidentified. Gazzaniga theorizes from the results of many split-brain experiments, that the primary function of the right hemisphere may be to allow for "echo time" in the processing of incoming information. He indicates that there is reason to suspect that the right hemisphere serves to qualify signals made by the left. Gazzaniga cites a study by Hall, Hall, and Lavoie (1968), in which it was reported that patients with right cerebral lesions did not qualify verbal statements made to the extent that this behavior was observed in patients with left cerebral lesions. Gazzaniga concluded that this reverberation time may serve the purpose of enabling the system to check and cross-check propositions initiated by the left hemisphere. The right hemisphere may provide necessary "processing space" for incoming information.

Musical Abilities and the Brain

Of particular importance to music educators are the specialized roles of the two cerebral hemispheres in the processing of musical stimuli. Clinical evidence cited by Bogen and Bogen (1969) appears to indicate that both hemispheres share a role in determining musical behavior. Brain lesions in the right hemisphere have been known to cause deficiencies in the recognition of musical sounds, while left hemisphere lesions have resulted in a loss of the ability to understand musical symbolism, and consequently the ability to read music. In a survey of musical functions of the two hemispheres, Bogen and Bogen cite examples of patients whose musical abilities were impaired due to brain lesions. One case involved an orchestra conductor with severe aphasia (left hemisphere lesion) who showed no loss in the direct reproduction of a melody, but had difficulty in articulating song texts and reading music notation. Bogen and Bogen also describe the case of Maurice Ravel, who suffered a trauma to the left hemisphere at the peak of his career. As a result, Ravel lost the ability to read music, although he retained the ability to play and sing from memory. Wada and Rasmussen (1960) developed a physiological test for determining the lateralization of brain functions, which has been employed in the study of cerebral localization of musical abilities. The Wada and Rasmussen method involves the injection of sodium amytal into the circulatory system of one hemisphere at a time, temporarily incapacitating that hemisphere. Bogen and Bogen reported a study in which observations were made of patients who were asked to sing before and during administration of sodium amytal into the right internal carotid artery. During the resulting incapacity of the right hemisphere, it was found that subjects' articulation of song texts was slurred but intelligible, rhythm was preserved, but singing was amelodic with a limited tonal range.

Auditory Testing Techniques for Lateral Dominance

In addition to the Wade and Rasmussen (1960) physiological test for determining the lateralization of brain functions, certain auditory investigative techniques have also been developed. A dichotic listening technique (Broadbent, 1954) has proven to be useful in researching the role of the brain in acoustical information-processing. Originally utilized in studies of speech perception, the dichotic listening technique has since been adapted by Kimura (1964) and others for the study of musical perception. The origin of the term "dichotic" is uncertain, but apparently refers to the dichotomous presentation of aural stimuli which is characteristic of this technique.

The dichotic listening technique is the procedure typically used for determining lateralization of various brain functions with regard to auditory stimuli, and involves the simultaneous presentation of two different stimuli, one to each ear, through stereo earphones. Recall or recognition data have typically been used as dependent variables in conjunction with this paradigm, with scores determined for each ear. If, for example, the left ear score is superior to the right on a dichotic listening task, the right hemisphere is considered to be "dominant" or primarily responsible for mediating the cognitive processes required of that particular task. The following example is typical of a dichotic test item and employs a recognition procedure:

Right Ear:		"903"				
Both Ears:	(voice on tape) "Number 1"		"144	903	023	124"
Left Ear:		"124"				

The relative effectiveness of the two procedures used for obtaining data in dichotic listening studies, recall or recognition of stimuli, has been examined by Broadbent and Gregory (1964) and Kimura (1967). No differences in the results have been found when the two methods have been compared. Investigators typically employ one or the other, or both, in dichotic listening studies. Generally, the recall paradigm is favored in tests of verbal perception, while the recognition procedure is employed in tasks involving musical or other nonverbal perception.

The assumption of the dichotic listening technique, which has been verified by electrophysiological evidence (Rosenzweig, 1951), is that for most individuals the contralateral pathways between the ears and the cerebral hemispheres are stronger than the corresponding ipsilateral pathways. Therefore, stimuli presented to the ear opposite the hemisphere specialized for that type of stimuli tend to be processed more efficiently than stimuli presented to the ipsilateral ear. Kimura (1973b) has shown that laterality findings obtained from dichotic listening tasks tend to parallel those established by the sodium amytal technique for the same subjects. Other clinical evidence (Milner, 1962) also has established the dichotic listening technique as a valid means of determining lateralization of brain functions.

The research of Bever and Chiarello, which showed that laterality effects for musical stimuli differ for musicians and nonmusicians employed a monaural listening task. Their experiment involved melody and excerpt recognition tasks in which information was presented to only one ear at a time. A review of the literature on monaural and dichotic listening methodologies reveals general agreement among researchers that monaural listening conditions evince no laterality effects and that dichotic listening procedures are necessary for detecting lateral dominance for auditory stimuli (Calearo and Antonelli, 1963; Dirka, 1964; Kimura, 1967; Satz, 1968). Theoretically, the monaural listening procedure appears to be much less defensible than the dichotic listening technique as a means of determining lateral dominance. Regardless of the theories, Bever and Chiarello appear to be the first published researchers to demonstrate laterality effects using a monaural listening paradigm. Bever and Chiarello also reported a replication of their findings based on a different group of subjects and a different dependent variable (reaction time). Consequently, their data must be respected and are worthy of further investigation.

Purpose of the Study

The purpose of the present study was to test the generality of the Bever and Chiarello assertion that differences exist in cerebral activity between musicians and nonmusicians in the perception of musical stimuli. Instead of the monaural listening technique employed by Bever and Chiarello, the present research utilized dichotic listening conditions. The assumptions upon which this study was based include the following:

1. The dichotic listening technique is a valid measure for detecting laterality effects with regard to auditory stimuli.

2. Right or left ear superiority in conjunction with a particular stimulus on a dichotic listening task is indicative, for most individuals, of opposite cerebral hemispheric dominance for that stimulus.

The hypotheses for the present study were as follows:

1. Under dichotic listening conditions which employ melodic stimuli, musicians will demonstrate a right ear superiority in the recognition of test melodies, while nonmusicians will show a left ear superiority.

2. Under dichotic listening conditions which employ verbal stimuli, both groups will demonstrate a right ear superiority in the recall or recognition of verbal lists.

Musicians were defined in this study as: (1) persons having a minimum of seven years of formal study on an instrument or voice, and (2) who are currently active as performers. Seven years was chosen as the minimum level of musical training because this level would offer an advantage for the detection of laterality effects over the four-year minimum level established by Bever and Chiarello for their musically experienced subjects. Seven years also appeared to represent an average amount of time spent in applied music study among freshman music majors at Winthrop College in Rock Hill, South Carolina, which was to be the target population for the musicians group in this experiment. Non-musicians were defined as: (1) persons who have received less than three years of formal instruction in music, none of which has occurred within five years prior to this study, and (2) who are not presently involved in any musical activity other than informal listening or occasional singing or playing in social settings. This definition of the nonmusicians is the same as that established by Bever and Chiarello (1974). Formal music instruction was defined as instruction on an instrument or voice through private or class lessons. General music instruction, such as that received in the elementary or junior high schools is excluded from this definition of formal music instruction.

CHAPTER II

RELATED LITERATURE

Technological advances in recent years have provided a means through which researchers have been able to assemble an extensive amount of information on the anatomy and the resulting psychological ramifications of the human brain. This resulting growth is manifested in the literature and has partially produced a paradoxical situation in that a complete understanding of the functions of the two cerebral hemispheres remains elusive. The researchers who have investigated the role of the brain in musical information processing present a confusing montage of separate and often contradictory interpretations of this cerebral activity. The present chapter contains (1) a review of the major studies, primarily dichotic listening studies, which have dealt with the cerebral processing of musical stimuli, (2) a discussion of the research findings on the relationship between handedness and cerebral dominance, and (3) a summary of the current state of research on the cerebral processing of musical stimuli.

A researcher who has made significant contributions to the literature on cerebral dominance is Doreen Kimura. Kimura (1964) developed a dichotic listening procedure which involved the discrimination of melodic patterns. Subjects in this study included twenty female student and postgraduate nurses. The musical backgrounds of the subjects were not reported.

Two auditory tasks, including a verbal test and melodies test, were administered to the subjects. The verbal test employed a recall procedure while the melodies test used a recognition procedure. Results of this study indicated that subjects were able to identify a melody presented to the left ear more efficiently than one presented to the right ear, while the opposite was true for the verbal task. On the basis of the results of this study and those of two earlier experiments which dealt with speech perception under dichotic listening conditions (Kimura, 1961a, 1961b), Kimura concluded that in auditory perception, the left hemisphere appears to be specialized for the perception of verbal material, while the right hemisphere is responsible for the mediation of certain non-verbal input, such as music. The results of the Kimura (1964) study were consistent with an earlier clinical study by Milner (1962), who administered the Seashore Measures of Musical Talent to thirty-eight patients with temporal lobe lesions. Twenty-two of the patients had lesions of the left hemisphere; sixteen patients had right hemisphere lesions. It was reported that in all cases the left hemisphere was dominant for speech. The results indicated that damage to the right hemisphere makes certain kinds of auditory discrimination difficult, comparisons of tonal patterns and perception of differences in tone quality being the most conspicuously impaired.

Kimura's speculation regarding the perception of musical sound found support in a study by McCarthy (1969), who administered a dichotic listening test consisting of verbal and tonal stimuli to subjects chosen from an introductory music course for elementary education majors. Both portions of the test, verbal and tonal, employed a recognition procedure. Subjects in the McCarthy experiment showed superior right ear scores for recognition of verbal stimuli and superior left ear scores in the recognition of tonal stimuli. These results supported McCarthy's hypothesis, and Kimura's earlier work, that under dichotic listening conditions subjects will more easily recognize tonal patterns presented to the left ear and verbal stimuli presented to the right ear. Cook (1973) also studied melodic perception under dichotic listening conditions. Cook administered a melodic perception test to twenty freshman music majors, and the results appeared to support earlier findings that musical stimuli are processed more efficiently in the right hemisphere than in the left. The study by Cook appears to be one of the few which have employed musicians as subjects.

Spellacy (1970) attempted to isolate the various components of music that are relevant in the demonstration of ear preference. Subjects were first administered a verbal task and screened on the basis of a demonstrated right ear superiority for verbal stimuli. Only those subjects who revealed a right ear preference for verbal stimuli were included in the testing for musical material. Subjects remaining in the experiment were tested for recognition of four kinds of dichotically presented stimuli: melodies, timbre, frequency patterns, and temporal patterns. Another purpose of this study was to investigate the influence of memory on auditory asymmetry, which involved the measurement of performance on the listening tasks following (1) a twelve-second retention interval, and (2) a five-second retention interval. The results showed a significant right hemisphere dominance in the recognition of melodies following the five-second interval. The ear differences for timbre, frequency patterns, and temporal patterns were not significant. Observed differences in the perception of frequency patterns, according to Spellacy, suggest that these may play an important role in the demonstration of a left ear dominance for musical stimuli. The failure of subjects to demonstrate laterality effects for the twelve-second interval, according to Spellacy, suggested that if memory processes were involved in producing ear differences under dichotic stimulation, they were most evident under conditions of relatively short memory span. The twelve-second interval may have been sufficiently long for memory traces from both ears to have completely decayed. Spellacy suggested that the failure of subjects to demonstrate an ear preference for timbre, frequency patterns, and temporal patterns may be traceable to the use of a five-second retention interval, which may be a relatively long interval for the retention of unfamiliar stimuli.

A study by Robinson and Solomon (1974) challenged what they considered to be Kimura's (1964) implication that all nonspeech auditory stimuli are processed by the right hemisphere. In this study, subjects listened to dichotically presented pairs of rhythmic pure-tone patterns, and were able to correctly identify the patterns heard in the right ear significantly more than in the left. Robinson and Solomon concluded that these findings supported the hypothesis that rhythm provides a set of reference points to which elements of speech are attached. Rhythmic patterning provides a structure which serves as support or series of cues for the words to be remembered. Robinson and Solomon concluded that both speech and rhythm require sequential organization, for which the left hemisphere appears to be better adapted than the right. The findings of Robinson and Solomon (1974) were consistent with those of Halperin, Nachshon, and Carmon (1973), who also concluded that rhythmically patterned stimuli are processed more efficiently in the left hemisphere than in the right.

Much of the research that has been done in the area of cerebral dominance has been conducted by persons outside the field of music. In addition, few researchers appear to have utilized musically trained subjects. Gordon (1970) employed college band members as subjects in a study in which digits, melodies, and chords were presented in dichotic listening tasks. The digits test in this experiment used a recall procedure; the remaining tests employed a recognition procedure. The results of this work indicated that only the chords test showed any significant left-right differences in ear dominance. The results of the digits test and the melodies test indicated no significant ear differences. Gordon speculated that the failure of subjects to demonstrate an ear preference for melodies was due to the rhythmic aspect of the melodies interacting with the tonal patterns. Gordon's findings for melodic perception among his subjects were inconsistent with those of Kimura (1964), Spellacy (1970), and Cook (1973), whose subjects demonstrated a left ear superiority for melodies. Bever and Chiarello (1974), in a discussion of the Gordon experiment, suggested the possibility of left-right differences in cerebral processing among musicians and nonmusicians as a reason for this discrepancy. Bever and Chiarello appear to have been unaware of the Cook (1973) study, which also employed musicians (freshman music majors). Cook's subjects revealed a left ear superiority for musical stimuli, which was consistent with earlier studies which used nonmusicians.

Bever and Chiarello (1974) appear to be the first researchers to make direct comparisons between musicians and nonmusicians in regard to the processing of musical stimuli. Their data reveal that musicians were able to recognize a two-note excerpt from a twelve to eighteen-note melody better than nonmusicians. In a melody recognition task, musicians demonstrated a left hemisphere superiority compared to the right hemisphere superiority of nonmusicians. Bever and Chiarello concluded that musicians are more analytical in the cognitive processing of music, and therefore process music in the left hemisphere. Nonmusicians, who were not able to perform the two-note recognition task in the experiment, appeared to assume a more wholistic approach to the perception of music. Processing of musical stimuli for the nonmusicians therefore takes place in the right hemisphere, according to Bever and Chiarello. These researchers concluded that training in music causes a shift in hemispheric specialization for the processing of musical stimuli.

The Bever and Chiarello findings are unusual in at least one respect. The methodology employed in the experiment consisted of a monaural listening task in which subjects heard the test melodies and excerpts in one ear at a time. Most studies of this nature (Gordon, 1970; Halperin, Nachshon, and Carmon, 1973; Kimura, 1964; Robinson and Solomon, 1974; Spellacy, 1970; McCarthy, 1969; Cook, 1973) utilize the dichotic listening technique, described in Chapter I, in which two different stimuli are presented to the subject simultaneously, one to each ear. The monaural technique, prior to the Bever and Chiarello study, has been found to be inadequate for the detection of laterality effects (Calearo and Antonelli, 1963; Dirks, 1964; Kimura, 1967; Satz, 1968). Bever and Chiarello, however, appear to be the only investigators who have made direct comparisons between musicians and nonmusicians and have reproduced their findings, using a different group of subjects and a different dependent variable (reaction time). It would appear to be useful to study the behavior of musicians and nonmusicians, as Bever and Chiarello have, but to utilize the dichotic listening technique of other investigators.

Handedness and Cerebral Dominance

Because of the relationship which may exist between motor dominance and cerebral dominance, handedness is a variable that must be considered in the design of a dichotic listening study. Therefore, this section of the present chapter will deal with the state of research on the relationship between handedness and cerebral dominance.

The relationship between handedness and cerebral organization has been the subject of numerous investigations, but currently there appears to be no general consensus regarding the nature of this relationship. The present state of research on handedness is one of confusion, which seems to be due primarily to difficulty in establishing firm criteria for the classification of handedness. Investigators have employed a wide variety of measures for defining "right," "left," and "mixed" handedness, and have treated handedness as a continuous variable, a dichotomous variable, and as a trichotomous variable (Beaumont, 1973). The many contradictions which presently surround this topic make it difficult to arrive at generalizations regarding the nature of manual preference.

The method of handedness classification most typically used by researchers employing dichotic listening procedures is a statement and/or demonstration of hand preference for certain motor tasks, most often handwriting, by subjects (Curry, 1967; Dirks, 1964; Halperin, Nachshon, and Carmon, 1973; Nebes, 1971; Robinson and Solomon, 1974; Spellacy, 1970; Studdert-Kennedy and Shankweiler, 1970). Kimura (1961a, 1964, 1967) gave no indication of the methods she employs for determining handedness of subjects. Beaumont (1973) has cited two handedness questionnaires designed to identify the preferred hand for various motor tasks: (1) the Oldfield Sinistrality Index (Oldfield, 1969) yields a handedness quotient ranging from 100 to -100, indicating the extremes of right and left handedness, and (2) Annett's Handedness Questionnaire (Annett, 1970), a measure similar to the Oldfield Sinistrality Index.

The development of handedness in humans has been examined by Zangwill (1960) and Gazzaniga (1970), who have proposed that the localization of speech in the left hemisphere is related to right-handed dominance. Russell, Neuringer and Goldstein (1970) take an opposing view, and suggest that while speech appears to be almost without exception a left hemisphere function, there are many degrees of motor dominance. Beaumont (1973), in a review of the literature on handedness, concludes that there are probably a number of links between neural structures in the left hemisphere and control of the preferred hand in human performance, but the relationship between the two has not been defined.

Despite the confusion surrounding the relationship of handedness to cerebral organization, a number of investigators have attempted to define proportions of right and left-handed populations with regard to the cerebral lateralization of speech functions. Branch, Milner, and Rasmussen (1964) have estimated that ninety percent of right-handed persons and over sixty percent of left handed individuals have speech functions located in the left hemisphere. These estimates were made on the basis of their work with the sodium amytal technique (Wada and Rasmussen, 1960) on a clinical population. The difference in ear dominance patterns between normal right and left-handed groups has been found to correspond approximately to this estimate (Bryden, 1967; Satz, Achenbach, Pattishall, and Fennell, 1965). Levy (1974) estimates that approximately eighty-nine percent of the population appear to be right handed, and approximately 99.67% of these have left hemisphere language dominance. Of the remaining eleven percent of non-right-handed persons, Levy estimates that approximately fifty-six percent have left hemisphere language dominance and forty-four percent right language dominance. Levy's estimates are based upon a survey of the major studies which have been done on the relationship of cerebral dominance to manual preference.

Dimond and Beaumont (1971, 1972, 1973) conducted a series of experiments designed to examine the relationship of handedness to cerebral dominance. Annett's Handedness Questionnaire (Annett, 1970) was employed as the measure of handedness for subjects. The results of these experiments, which involved a series of verbal, numerate, and visual tasks, indicated that the brain of the right-handed persons appears to be more clearly lateralized for particular functions than that of the left-handed individual. No differences between the handedness groups were found which related to the stimuli employed or to the kind of responses demanded by the tasks. Differences related to interaction between level of complexity and integration required by the tasks were found between the handedness groups. The brain of the right-handed person, according to Dimond and Beaumont, appears to be characterized by a system of specialized units linked by a series of long but well organized neural pathways. The brain of the left hander, by contrast, seems to be made up of smaller units than those of the right hander, and are connected by short diffuse links. The result is less specialization and greater homogeneity of function in the brain of the left-handed individual. This more diffuse organization results in a disadvantage for rapid simple communication, but an advantage for complex integrative activity. Musical performance may be a type of complex integrative activity for which the left-handed individual is well suited. In a study by Quinan (1922), it was found that among one hundred musicians sixteen were left handed, while among one hundred machinists, only four were left handed. Handedness as a factor in the choice of music as an occupation is an area which deserves further investigation.

The relationship between ear asymmetry on dichotic listening tasks and handedness was examined by Kimura (1961a), who found that the majority of subjects (ninety-three out of one hundred-three) whose left cerebral hemispheres were specialized for speech functions were right handed. Most of the subjects with speech-dominant right hemispheres (nine out of twelve) were left handed.

The results of a dichotic listening task administered to these subjects indicated that the ear opposite the dominant hemisphere is more efficient for recall of verbal stimuli, regardless of handedness. Kimura did not indicate her criteria for handedness classification in this study. The sodium amytal technique of Wada and Rasmussen (1960) was used for the identification of the speech-dominant hemisphere of each subject.

Curry (1967) compared left- and right-handed subjects on verbal and non-verbal dichotic listening tasks and found no significant ear differences between the handedness groups for any of the tasks. Curry based his classification of handedness on a statement and demonstration of hand preference by subjects. These findings appear to be in conflict with those of Satz, Achenbach, Pattishall, and Fennell (1965) who found that among subjects with superior right ear scores on a dichotic verbal test, the left-handed subjects had smaller ear difference scores. Subjects in this study were required to demonstrate hand preference on a number of motor tasks. The results of the Curry (1967) study and the work of Satz, Achenbach, Pattishall, and Fennell (1965) are indicative of the conflicting findings that presently characterize the state of research on handedness and its relation to cerebral organization. With regard to results obtained in dichotic listening studies, the ear dominance effect is apparently independent of motor dominance. Although researchers typically treat left- and right-handed subjects as separate groups in these studies, there appears to be little justification for doing so except for the possible reduction in error variance that may result.

Summary

On the basis of the studies cited in this chapter, a summary of known laterality effects for the processing of auditory stimuli and the relationship of handedness to cerebral dominance may be stated as follows:

1. In auditory perception, the left cerebral hemisphere for most individuals appears to be specialized for linear, sequential processing, such as that required for speech perception.

2. The right cerebral hemisphere for most individuals appears to be specialized for wholistic perception, and acts primarily as a synthesizing organ in the mediation of auditory input.

3. Data on the lateralization of the various dimensions of music show conflicting results. The data of Halperin, Nachshon, and Carmon (1973) and Robinson and Solomon (1974) imply that the rhythmic aspect of music is processed by the speech hemisphere of the brain. Milner (1962) and Spellacy (1970) found no hemispheric specialization for rhythm. Milner (1962) found that the right hemisphere is primarily responsible for the perception of timbre, whereas Spellacy (1970) found no lateralization for this aspect of music. Other aspects of music which have been studied, including tonal patterns (Milner, 1962; McCarthy, 1969), melodies (Kimura, 1964; Spellacy, 1970; Cook, 1973; Gordon, 1970), and chords (Gordon, 1970) are generally considered to be mediated by the right hemisphere.

4. Evidence in favor of employing dichotic rather than monaural stimulation in studies of cerebral lateralization for auditory stimuli appears to be substantial (Calearo and Antonelli, 1963; Dirks, 1964; Kimura, 1967; Satz, 1968). Although there is general agreement among researchers that monaural listening tasks evince no laterality effects, the research of Bever and Chiarello has cast some doubt on this position.

5. There is some evidence that musicians and non-musicians utilize different cerebral processing strategies in the perception of musical stimuli. Musicians, according to Bever and Chiarello (1974), tend to process music in the analytical left hemisphere, while nonmusicians reveal a wholistic (right hemisphere) processing of musical stimuli.

6. The relationship between handedness and cerebral dominance has not been defined, due in part to the lack of firm criteria for the classification of handedness. There appears to be general agreement among researchers that some link exists between neural structures in the brain and manual preference, but the relationship between the two has not been determined. Evidence of ear dominance on dichotic listening tasks appears to be independent of handedness, and there seems to be no real justification for treating left- and right-handed subjects as separate groups in dichotic listening studies.

CHAPTER III

PROCEDURES AND RESULTS

The purpose of the present study was to test the generality of the Bever and Chiarello (1974) assertion that differences in cerebral activity exist between musicians and nonmusicians in the perception of musical stimuli. Instead of the monaural listening technique employed in the Bever and Chiarello study, the present study utilized dichotic listening conditions. Two separate dichotic listening tests employing verbal and melodic stimuli were administered to two groups of subjects, musicians and nonmusicians. The total number of correct scores for left and right ears was computed for all subjects, followed by group and ear comparisons for each of the two auditory tasks. Two separate experiments, using different subjects, were conducted in this study. The first experiment served as a pilot experiment, the primary purpose of which was to enable the investigator to make final adjustments in the design and testing procedures prior to the main experiment. The present chapter includes (1) an exposition of the procedures employed in the preparation of the test tapes, (2) a description of the procedures and results of the pilot experiment, and (3) a description of the procedures and results of the main experiment.

Preparation of the Test Tapes

Subjects

Subjects utilized in the preparation of the test tapes included 16 females and 2 males randomly selected from among volunteers recruited from the School of Music and Department of Psychology at Winthrop College in Rock Hill, South Carolina. Seventeen subjects classified themselves as right handed and 1 as left handed. Seven subjects were music majors and 11 were not music majors. The ages of the subjects ranged from 18 to 32 years, with a mean age of 21 years. No attempt was made to balance the number of musicians and nonmusicians in this group of subjects since the primary purpose of this initial step in the study was to prepare the tapes and not to compare the two groups. There were, in addition, no attempts to balance groups on the basis of sex. This decision was based upon the observation that there appears to be nothing in the literature to suggest that sex is a variable in cerebral dominance. An audiometer test was administered to all subjects in this group to determine absolute hearing thresholds for both ears. A Maico 18 audiometer was employed for the audiometric examination. Prior to the hearing tests, a technician calibrated the audiometer to International Standards Organization (ISO) specifications. The audiometric testing procedures were conducted through the auspices of the Audiological Services at Winthrop College in an acoustically treated room by an experienced audiologist. A method approved by the American Academy of Opthamology and Otolaryngology was employed to determine mean hearing loss in subjects. This method consists of (1) obtaining the mean threshold levels for each ear at 500, 1000, and 2000 Hz, and (2) substracting 26 decibels from this average and multiplying the remainder by 1.5% (Newby, 1972). Hearing loss is defined, according to this method, as mean hearing thresholds exceeding 25 decibels in either ear. No subjects in this initial group were diagnosed as suffering from hearing loss.

Procedures

To discriminate between right and left hemispheric responses, a dichotic listening test (as supported by the literature) must meet two criteria. First, the test must be sufficiently difficult that a condition of perceptual rivalry exists between the contralateral and ipsilateral auditory pathways (Kimura, 1961a, 1967; Dirks, 1964; Satz, Achenbach, Pattishall, and Fennell, 1965; Bryden, 1962). It has been demonstrated that ear asymmetry increases as task difficulty is increased. For example, dichotic listening tasks which contain verbal lists of three to six parts reveal a greater degree of ear asymmetry among subjects than tasks which contain shorter lists (Satz, 1968). It has also been shown that with faster rates of stimulus presentation (in excess of 100 beats per minute) there is an increase in ear asymmetry (Bryden, 1962). The second criterion for a satisfactory dichotic listening test is that it must be free of biases produced by consistent differences in intensity, frequency, or synchronization of the stimuli in one of the two auditory channels. It is apparent that differences in stimulus production would tend to affect the internal validity of the study. Reversing the earphones for subjects has proven to be a satisfactory method for controlling the possibility of a contamination due to a bias in the recorded stimuli or equipment (Broadbent and Gregory, 1964; Kimura, 1961a, 1964; Studdert-Kennedy and Shankweiler, 1970; Dirks, 1964; McCarthy, 1969; Gordon, 1970). This procedure was incorporated into the standard testing procedure for the present study.

Preparation of the Verbal Test

Preparation of the Verbal Test involved a relatively long period of experimentation prior to the completion of the final test tape. Four different versions of a verbal test were prepared, three of which were discarded due to the presence of biasing factors. All tests in the present study were recorded on a Sony TC-252D dual-channel tape recorder and presented to subjects individually by means of Koss Pro-1 stereo earphones. The intensity output of the equipment was determined by recording a 1000-cycle sine tone on magnetic tape. The testing intensity level was set at 72 decibels for all tests, which was determined to be a comfortable loudness level by subjects assisting in the preparation of the tapes. This level was maintained throughout the testing by periodic calibrations with a sound-level meter.

Verbal Test I consisted of two practice trials and thirty test items, and employed a multiple-choice recognition task. The paradigm chosen for this test was similar to that employed by Broadbent and Gregory (1964) and McCarthy (1969). Each item on the test consisted of (1) an item identification number presented binaurally, (2) a dichotic presentation of three pairs of randomly selected digits (0 through 9) spoken at a rate of 112 beats per minute, and (3) a binaural presentation of four groups of three digits each, one of which was identical to the set of digits spoken into the right ear, and one identical to the set of digits spoken into the left ear. The voice on the tape was that of the investigator. An example of a test item in Verbal Test I is presented in Diagram 1.

DIAGRAM 1

VERBAL TEST I PARADIGM

Right Ear:		"903"	
Both Ears:	(recorded on tape) "Number 1"		"932 903 124 194"
Left Ear:		"124"	

Subjects were instructed to indicate on an answer sheet (Appendix A) the set(s) of digits they were able to recognize by marking the correct serial position(s) of those sets of digits among the four possible answers. Verbal Test I was administered to 10 of the 18 subjects selected for this portion of the study. Results of this administration are reported in Table 1.

On the basis of these results, Verbal Test I was discarded because it apparently failed to satisfy the difficulty criterion stated previously. A grand mean of 43.9 (73%) correct responses out of a possible score of 60 indicated that the test was insufficiently difficult to produce asymmetry in the hemispheric responses of subjects. This was also evident from reports from subjects who indicated little difficulty in responding to either ear or to both ears.

TABLE 1

INDIVIDUAL SCORES AND EAR MEANS FOR
VERBAL TEST I

Subject	Right Ear	Left Ear	Combined Ear Scores
1	21	25	46
2	29	29	58
3	23	24	47
4	15	15	30
5	26	24	50
6	16	18	34
7	24	17	41
8	21	21	42
9	26	28	54
10	19	18	37
10	$\bar{X}$ = 22	$\bar{X}$ = 21.9	$\bar{X}$ = 43.9
	SD = 4.49	SD = 4.81	SD = 9.94

Ten subjects, including two that had participated in the previous experiment with Verbal Test I, were selected to receive Verbal Test II. The two subjects who had received the previous Verbal Test were included in the second group of subjects so that subjective comparisons of the two tests could be obtained. Verbal Test II employed the same recognition paradigm as Verbal Test

I. The sets of digits employed in the second test were lengthened to five digits in each and the rate of presentation to 120 beats per minute. Ear asymmetry appeared to be increased via the use of five-digit groups, but the tape contained a recording inconsistency which was revealed by the earphone reversal technique. The first three subjects were tested with the right and left earphones on the corresponding ears. Each of these subjects demonstrated a right ear superiority for the Verbal Test II. The fourth subject, who was tested with the earphones in the reverse order, revealed a left ear superiority. This subject was retested with the earphones in the same placement as the first three subjects, and revealed a right ear superiority on the re-test. Aural examination of the tape by the investigator revealed a consistent difference in the pitch of the voice in one channel of the dichotic presentations that had not been identified previously. It was apparent that this difference was systematically influencing the results of the tests. A fifth subject was tested and retested in the same manner as subject four, and similar results were identified in the scores. Test and retest results obtained from subjects four and five are presented in Table 2. Testing was discontinued after the fifth subject, and Verbal Test II was discarded.

Verbal Test III was modeled after Verbal Test II, but was not administered to subjects. The test tape was aurally examined by two specialists, one a musician and one a psychologist. Both reported no difficulty in identifying the stimulus in either ear, which was indicative of a lack of perceptual rivalry between the contralateral and ipsilateral auditory pathways. It was suggested by both examiners that the recognition paradigm of the test may be an inadequate

TABLE 2

TEST AND RETEST SCORES FOR SUBJECTS 4 AND 5
FOR VERBAL TEST II

Subject 4				Subject 5			
Test		Retest		Test		Retest	
R. Ear	L. Ear	R. Ear	L. Ear	R. Ear	L. Ear	R. Ear	L. Ear
6	24	27	1	0	30	28	0

method of testing laterality effects for verbal stimuli. This explanation for the difficulties with the test tape was rejected because there is evidence in the literature that the two procedures of recall and recognition are equally effective (Broadbent and Gregory, 1964; Kimura, 1964, 1967). A more plausible explanation appeared to be that because of subjects' familiarity with verbal stimuli, it is more difficult to construct a test that provides adequate discriminating power with a recognition paradigm than one which employs recall.

As a result of the previous attempts to construct a valid test, a recall procedure was employed in the development of the fourth revision of the Verbal Test (Appendix B). This test contained three practice trials and thirty test items. Randomly selected consonants were used in place of digits to increase from ten (digits) to twenty (consonants) the number of choices available for the construction of the verbal lists. No consonant was used more than once in each dichotic test item. Each test item in Verbal Test IV consisted of (1) an identification number presented binaurally, (2) a dichotic presentation of three pairs of consonants spoken at a rate of 112 beats per minute, and (3) ten beats of silence. To avoid the possibility of a bias due to frequency differences in the recorded stimulus, consonants were spoken at the same pitch level for both channels when recording the dichotic items. An example of a test item in Verbal Test IV is given in Diagram 2. Verbal Test IV was administered to eleven subjects, six of whom had received at least one of the earlier Verbal Tests. As stated previously, subjects were administered more than one of the tests in order to obtain subjective comparisons of the various tests. Subjects were instructed to record on an answer sheet (Appendix B) during the ten beats of silence, all the letters that could be recalled "in the order that they could best recall them." A response was scored as correct if all three letters from either set of consonants were reported in the correct order. The results of the administration of Verbal Test IV are given in Table 3.

DIAGRAM 2

VERBAL TEST IV PARADIGM

Right Ear:		"DFG"	
Both Ears:	(voice on tape) "Number 1"		(ten beats of silence)
Left Ear:		"RTC"	

TABLE 3

INDIVIDUAL SCORES AND EAR MEANS FOR
VERBAL TEST IV

Subject	Right Ear	Left Ear	Combined Ear Scores
1	10	6	16
2	23	15	38
3	6	16	22
4	20	7	27
5	29	18	47
6	10	4	14
7	11	3	14
8	7	17	24
9	18	4	22
10	14	9	23
11	11	9	20
11	$\bar{X}$ = 14.45	$\bar{X}$ = 9.83	$\bar{X}$ = 24.27
	SD = 7.20	SD = 5.67	SD = 10.11

The results of Verbal Test IV indicated that this edition of the test was more difficult than Verbal Test I, and that conditions of perceptual rivalry between the contralateral and ipsilateral pathways was present. A grand mean of 24.27 (40%) out of a possible total of 60 was obtained, which contrasted sharply with the grand mean of 43.9 (73%) found in the results of Verbal Test I. Subjects who had received earlier versions of the Verbal Test reported that one ear tended to be more efficient for responding to the task than the other, and attempts to attend to the less-favored ear resulted in difficulty in completing the task. The expected right ear superiority for verbal stimuli was evident in the left and right ear means. A t test for matched samples revealed a significant difference between the two means ($t = 1.90$). Reversal of the earphones for 6 of the 11 subjects and reversal of the earphones at the midpoint of the test for all subjects revealed no obvious changes in direction of ear response, which indicated a lack of tape or equipment bias. The lack of equipment biases was also evident when a comparison of means for the first and second halves of the test, based on dominant ear scores, showed no significant differences. These data are reported in Table 4.

TABLE 4

COMPARISON OF MEANS FOR FIRST AND SECOND HALVES OF VERBAL TEST IV BASED ON DOMINANT EAR SCORES

First Half (15 items)	Second Half (15 items)	t	p
$\bar{X} = 7.09$	$\bar{X} = 9.18$	1.22	n.s.

Although there were large individual differences in the test scores for Verbal Test IV, it was concluded that this test met the criteria as defined at the outset of this chapter. The large differences in the test scores could be controlled, if necessary, through the manipulation of test instructions. For example, instead of permitting subjects free choice of ear, or ears, to attend to, they could be instructed to attend to a particular ear (Kimura, 1967) or to both ears simultaneously (Robinson and Solomon, 1974 Kimura, 1964; McCarthy, 1969). For the pilot experiment, however, a decision was made to employ the instructions which allowed subjects freedom of choice of ear(s) to attend to.

Preparation of the Melodies Test

The Melodies Test contained three practice trials, thirty test items, and employed a recognition procedure. Each test item consisted of (1) an item identification number presented binaurally, (2) a dichotic presentation of two melodic fragments (four beats each in length, m.m. = 112) played on a soprano recorder, and (3) four melodic fragments presented binaurally, one of which was identical to the melodic fragment presented to the right ear, and another identical to the fragment presented to the left ear. An example of a Melodies Test item is presented in Diagram 3.

DIAGRAM 3

MELODIES TEST PARADIGM

Right Ear:	Melodic fragment A	
Both Ears: "Number 1"		Choices: 1, 2, 3, 4
Left Ear:	Melodic fragment B	

All melodic fragments were composed by the investigator and encompassed a range extending from D' to D". Subjects were instructed to indicate which melodic fragment(s) they were able to identify by marking the correct serial position(s) on an answer sheet (Appendix B). The paradigm selected for the Melodies Test was similar to those procedures employed by Kimura (1964) and Gordon (1970). The Melodies Test constructed for the present study differed from those of earlier studies in that original melodic fragments were employed. Both the Gordon and Kimura studies employed pre-existing melodies from the Baroque and Classical literature.

The Melodies Test was administered to ten of the eighteen subjects selected for preparation of the test tapes. All subjects who received the Melodies Test had participated in the earlier administrations of the Verbal Tests. The results of the Melodies Test appear in Table 5.

The results of the Melodies Test indicated a difficulty level comparable to that of Verbal Test IV. A grand mean of 25.7 (43%) correct responses out of a possible score of sixty was similar to the grand mean of 24.27 (40%) correct responses obtained for Verbal Test IV. Subjects reported difficulty in attending to and identifying both melodic fragments in the test items, which indicated the presence of perceptual rivalry between the contralateral and ipsilateral auditory pathways. No dominant left or right ear effect was noted in the results ($t = .63$), but since both musicians and nonmusicians were included in the testing, no ear effect was expected. In the administration of the Melodies Test half of the subjects (5) received the test with the right earphone on the right ear and the left

TABLE 5

INDIVIDUAL AND MEAN EAR SCORES FOR MELODIES TEST - INITIAL DATA

Subject	Right Ear	Left Ear	Combined Ear Scores
1	7	14	21
2	17	9	26
3	14	10	24
4	9	11	20
5	7	16	23
6	12	25	37
7	12	15	27
8	20	9	29
9	19	4	23
10	22	5	27
10	$\bar{X}$ = 13.9	$\bar{X}$ = 11.8	$\bar{X}$ = 25.7
	SD = 5.42	SD = 6.08	SD = 4.87

earphone on the left ear for the first 15 items. For the remaining 15 items the earphones were placed in reverse position. The opposite procedure was implemented for the remaining 5 subjects. A comparison of dominant ear means for the first and second halves of the test revealed no significant difference, which indicated a lack of equipment bias. These data are reported in Table 6.

TABLE 6

COMPARISON OF MEANS FOR FIRST AND SECOND HALVES OF THE MELODIES TEST, BASED ON DOMINANT EAR SCORES

First Half (15 items)	Second Half (15 items)	*t*	p
$\bar{X} = 8.3$	$\bar{X} = 9.0$	.72	n.s.

As in Verbal Test IV, large individual differences were observed in the test scores, but it was concluded that the Melodies Test was a satisfactory test for the identification of laterality effects in the processing of musical stimuli. The large differences in the test scores could be controlled, if necessary, through the manipulation of test instructions.

Pilot Experiment

Following the preparation of the test tapes, a pilot experiment was conducted for the purpose of making final adjustments in testing procedures and experimental design prior to the main experiment.

Subjects

Musicians

The musicians group consisted of 13 females and 7 males selected from a pool of 40 graduate and undergraduate music majors. Volunteers were informed that they would be participating in an experiment involving auditory perception and to qualify, a minimum background of 7 years of formal music study was required.

Subjects were randomly selected for the pilot experiment and had participated in the preparation of the test tapes. Each subject was requested to complete a questionnaire (Appendix B) designed to obtain information regarding (1) extent of musical background, (2) handedness, (3) history of hearing problems, if any, and (4) schedule of free time during which testing could be done. The ages of the musicians ranged from 19 to 35 years, with a mean age of 23 years. Of this group, 3 classified themselves as left-handed, 16 as right-handed, and 1 as ambidexterous. The group consisted of 11 keyboard players (piano, organ, and harpsichord), 6 vocalists, and 3 instrumentalists. The subjects indicated a range of 7 to 16 years of formal study in their areas of applied music, with a mean of 11.33 years. All subjects in the musicians group had presented or were preparing to present a public recital, and all were currently participating in at least one college performing organization. Thirteen subjects had secondary instrument experience with an average of 4.3 years of formal study in the secondary area. Subjects in the pilot experiment underwent the same audiometric testing as described for subjects who participated in the preparation of the test tapes. One of the subjects from the musicians group possessed a hearing loss which exceeded the standards set for the study, and was replaced by means of random selection from the subject pool.

Nonmusicians

The sample of nonmusicians of 15 females and 5 males randomly selected by the same procedures described above from among 40 volunteers recruited from psychology classes at Winthrop College. Volunteers for the nonmusicians group were also told that they would be participating in an experiment involving auditory perception, and to qualify they must be nonmusicians with no more than three years of music lessons within the five years preceding the study. No subject among the nonmusicians had participated in the preparation of the test tapes. The ages of the nonmusicians ranged from 19 to 38 years, with a mean age of 24 years. Each subject in the nonmusicians group was also requested to complete a questionnaire designed to obtain the same information requested from the musicians. The nonmusicians group represented various areas of study at Winthrop College, including psychology, education, biology, and history. No music majors were included in this group. Of the nonmusicians, 4 classified themselves as left-handed, 15 as right-handed, and 1 as ambidexterous. Of the total group, 5 had studied music formally for an average of 2.5 years. No music instruction among these five subjects had taken place in the five years prior to this study. The remaining 15 subjects indicated backgrounds of no formal music study. Twelve subjects indicated that they were currently participating in music on an informal basis, such as playing guitar by ear or singing in church choirs. All subjects indicated on the questionnaire that they were unable to read music beyond identification of note names on the staff or limited recognition of note values. All subjects received audiometer tests prior to testing. No subjects in this group were found to have hearing loss.

Testing Procedure in Pilot Experiment

The pilot experiment consisted of the Verbal Test (IV) and Melodies Test administered to each of the forty subjects described above. The tests were administered individually by means of the Sony TC-252D dual-channel tape recorder and Koss Pro-1 stereo earphones that were used in the preparation of the test tapes. The intensity level was set and maintained at 72 decibels, which had been determined to be a comfortable level by subjects during the preparation of the tapes. The earphone reversal technique described previously was employed as a precaution against equipment biases. Half of the subjects in each of the two test groups were administered the Verbal Test first, and the other half received the Melodies Test first. A break of five minutes between the two tests was standard procedure as a further control for biases due to order of the tasks.

Before each test, subjects received a verbal standardized explanation of the test format presented by the investigator, and shown a sample test item. No explanation of the purpose of the test was given, although subjects were invited to return following completion of the experiment to discuss the findings. Each item on the Verbal Test consisted of three pairs of consonants presented dichotically at a rate of 112 beats per minute. Subjects were instructed to record on an answer sheet all the letters that could be recalled in the order that they were recalled. A response was considered correct if all three letters from either set of consonants were reported in the correct order. A recognition procedure was used for the Melodies Test. For each test item, subjects heard two different melodic fragments presented dichotically, followed by a four-choice recognition task.

Subjects were instructed to indicate which melodic fragment(s) they were able to identify by marking the correct serial position(s) on an answer sheet. For both the Verbal Test and the Melodies Test, scores for the left and right ears were recorded for each subject. Total testing time for each individual was thirty minutes.

Results of the Pilot Experiment

The mean number of correct ear responses and standard deviations for the Verbal and Melodies Tests for both groups are given in Table 7. Analysis of

TABLE 7

MEANS AND STANDARD DEVIATIONS[1] FOR LEFT AND RIGHT EARS FOR THE VERBAL TEST AND THE MELODIES TEST--PILOT STUDY

	Verbal			Melodies		
	R.	L.	Combined	R.	L.	Combined
Musicians	16.35 (8.21)	11.10 (7.21)	13.72 (5.91)	17.05 (8.41)	10.40 (6.78)	13.92 (3.61)
Nonmusicians	13.05 (7.94)	10.60 (6.66)	11.82 (6.13)	12.15 (8.41)	11.65 (6.99)	11.90 (2.16)
Total	14.70 (8.14)	10.85 (6.90)	12.77 (6.25)	14.60 (8.73)	11.03 (6.83)	12.91 (3.58)

[1]Standard deviations in parentheses.

the data in the pilot experiment employed a two-way repeated measures design in two separate analyses of variance for the verbal and melodies dependent variables.

The A factor (musical training) was treated as an independent groups factor with repeated measures on the B (ears) factor. A significant right ear superiority for verbal stimuli was found across the two groups (Table 8). Neither ear was dominant for melody recognition in either group (Table 9). A significant groups effect was found in the results of the Melodies Test, but this is of no theoretical interest since it probably indicates only that the musicians group found the Melodies Test less difficult than the nonmusicians. As evinced in the large standard deviations which characterized the results for both auditory tests, there was considerable variation among the individual scores in the pilot experiment. The cause of this variance appeared to originate with the test instructions, which were possibly too unstructured for the difficulty level of the tests. The instructions were also inappropriate for the design of the study, since both the right and left ear measures were taken simultaneously. This increased the dependence of those two scores. For example, a high left ear score usually implied a low right ear score. It was suspected on the basis of the large within-subjects error that the repeated measures analysis was not appropriate for the data. Consequently, the data were analyzed using a nonparametric technique.

Left ear scores were compared with right ear scores for each of the four conditions (musicians and nonmusicians, verbal and melodies tasks) using Wilcoxon's test for matched samples. None of the comparisons reached statistical significance, except for the difference between ears found on the Melodies Test when performed by musicians. The mean right ear score of 17.45 was found to be significantly larger ($p < .05$) than the mean left ear score of 10.40.

TABLE 8

ANOVA TABLE FOR THE VERBAL TEST COMPARING MUSICIANS AND NON-MUSICIANS FOR LEFT AND RIGHT EAR PERFORMANCE--PILOT EXPERIMENT

Source of Variance	SS	d.f.	MS	F	p
Between Subjects	761.95	39			
Groups	72.20	1	72.20	3.98	n.s.
Error	698.75	38	18.15		
Within Subjects	4,054.20	40			
Ear	296.45	1	296.45	7.56*	.01
Groups x Ear	39.20	1	39.20	.40	n.s.
Error	3,718.55	38	97.86		

*significant at the .01 level

TABLE 9

ANOVA TABLE FOR THE MELODIES TEST COMPARING MUSICIANS AND NONMUSICIANS FOR LEFT AND RIGHT EAR PERFORMANCE--PILOT EXPERIMENT

Source of Variance	SS	d.f.	MS	F	p
Between Subjects	378.89	39			
Groups	82.02	1	82.02	10.50*	.01
Error	296.87	38	7.81		
Within Subjects	4,895.50	40			
Ear	285.02	1	285.02	2.46	n.s.
Groups x Ear	214.50	1	214.50	1.85	n.s.
Error	4,395.98	38	115.68		

*significant at the .01 level

This difference was only marginally significant since the calculated value of the Wilcoxon test was 46 and the appropriate critical value for that test was also 46. The results of these comparisons are reported in Table 10.

In view of the marginal significance obtained between the right and left ear scores on the Melodies Test for musicians and to factors concerned with probability pyramiding which can occur when making multiple comparisons, a decision was made to employ a methodology in the main experiment that would both reduce error variance and be consistent with a true repeated measures design. This change in methodology concerned primarily the test instructions.

TABLE 10

RESULTS OF COMPARISONS OF LEFT AND RIGHT EAR SCORES FOR MUSICIANS AND NONMUSICIANS FOR THE VERBAL AND MELODIES TESTS USING WILCOXON'S TEST FOR MATCHED SAMPLES

Group	Verbal Test	Melodies Test
Musicians	Calculated Value = 80.5	Calculated Value - 46
	Critical Value = 52 (n.s.)	Critical Value = 46*
Nonmusicians	Calculated Value = 60.5	Calculated Value = 88
	Critical Value = 52 (n.s.)	Critical Value = 46 (n.s.)

*significant at the .05 level

Instead of allowing subjects a free choice of ear to attend to during the tests, subjects were instructed in the main experiment to attend to one ear for the first 15 test items and to the opposite ear for the remaining 15 items. There is precedent in the research literature for this testing procedure. According to the results of a study by Kimura (1967), attention to a given ear under dichotic listening conditions does not significantly affect the direction of ear dominance. Ear difference scores will be smaller, but accuracy of ear report, according to Kimura, will still be greater for the dominant ear. This testing procedure appeared to offer more structure for the test instructions which was apparently required to reduce the variation in scores due to individual responses to the testing situation. These instructions were also consistent with the repeated measures design, which assumes there will be no carry-over of effects and correlated scores.

Analysis of the results of hearing threshold tests and their relation to ear performance on the Verbal and Melodies Tests was conducted to determine the necessity of including audiometric testing of subjects as part of the procedures in the main experiment. A Pearson Product-Moment correlation coefficient of -.05 was found between ear difference scores on hearing threshold tests and ear difference scores on the dichotic listening tests of the pilot experiment. Therefore, a decision was made to discontinue the hearing threshold tests, but to disqualify subjects who reported a history of hearing problems. This decision was supported by a review of the literature, which revealed a number of dichotic listening studies which did not include audiometric testing of subjects in the procedures (Robinson and Solomon, 1974; Broadbent and Gregory, 1964; Satz, Achenbach, Pattishall, and Fennell, 1965; Kimura, 1964; Gordon, 1970). Among these studies the measure typically employed to rule out hearing loss was a statement relative to history of hearing impairments from the subjects utilized in the studies. Subjects with histories of hearing ailments were disqualified from participation in these experiments.

A comparison of mean scores for left-handed subjects and right-handed subjects was done for the Verbal Test to determine if internal validity was threatened by the inclusion of left-handed subjects in the test groups. The results of this comparison are reported in Table 11. No significant differences were found between the mean ear scores of the two groups, which confirmed the observation that laterality effects for dichotic listening tasks tend to be independent of handedness.

TABLE 11

COMPARISON OF MEANS FOR LEFT-HANDED AND RIGHT-HANDED SUBJECTS OF THE VERBAL TEST--PILOT EXPERIMENT

	Right-Handed Subjects	Left-Handed Subjects	t	p
Right Ear	13.86	18.67	.67	n.s.
Left Ear	11.67	7.29	.80	n.s.

Main Experiment

Subjects

Musicians

Twelve males and 12 females, aged 19 to 30 years, were randomly selected by the procedures described previously from among 35 graduate and undergraduate music majors. The mean age of the group was 24 years. No subject in this group had participated in the previous experiments. Among the musicians, 12 were keyboard players, 8 were singers, and 4 were instrumentalists. Two subjects classified themselves as left-handed, and the remainder as right-handed. The range of formal music study for the group extended from 7 to 20 years, with a mean of 10.5 years. Twelve subjects had secondary instrument experience with an average of 5.16 years of formal study in the secondary area. All subjects were currently participating in at least one performing college musical organization, and all subjects had presented or were preparing to present a public recital. No subjects reported any history of hearing problems.

Nonmusicians

Six males and 18 females, aged 19 to 28 years, were randomly selected from among 35 volunteers recruited from psychology classes at Winthrop College. The mean age of the nonmusicians group was 22 years. No subject in this group had participated in the previous experiments. Among the group, 2 subjects classified themselves as left-handed and the remainder as right-handed. Seven subjects reported an average of 2.16 years formal music training, none of which had occurred within five years prior to this study. Seventeen subjects reported backgrounds of no formal study in music. Ten subjects indicated participation in musical activities on an informal basis, such as singing in church choirs. All subjects among the nonmusicians reported inability to read music beyond limited recognition of note names on the staff or note values. No subjects reported any history of hearing problems.

Testing Procedure Main Experiment

Both the Verbal Test and Melodies Test were administered to subjects in the musicians and nonmusicians groups. The same equipment that had been used in the preparation of the test tapes and the pilot experiment were employed in the main experiment. The intensity level for testing was set and maintained at 72 decibels. Before each test, subjects were presented with a verbal explanation of the test format by the investigator and shown a sample test item. No explanation of the purpose of the test was given. For the Verbal Test, subjects were instructed to attend to and record on an answer sheet (Appendix B) all the consonants that could be recalled from one ear for the first 15 test items and to follow the same procedure for the opposite ear during the remaining 15 items. A response was considered correct if all three consonants from the attended ear were reported in the correct order. For the Melodies Test, which employed a recognition paradigm, subjects were instructed to attend to and identify among the four choices the melodic fragment presented to one ear for the first 15 test items and the melodic fragment presented to the opposite ear for the remaining 15 items. A response was considered correct if the serial position of the melodic fragment heard in the attended ear was indicated on the answer sheet (Appendix B). All factors and materials in the main experiment were counterbalanced to prevent any bias due to the order of the tasks or stimulus materials. The counterbalancing procedures employed in this experiment are reported in Diagram 4.

DIAGRAM 4

COUNTERBALANCING PROCEDURES--
MAIN EXPERIMENT

Subject	Task Order	Earphone Placement	Order of Ear Attention
1	Verbal-Melodies	Right on Right	Left - Right
2	Verbal-Melodies	Right on Right	Right - Left
3	Verbal-Melodies	Left on Right	Left - Right
4	Verbal-Melodies	Left on Right	Right - Left
5	Melodies-Verbal	Right on Right	Left - Right
6	Melodies-Verbal	Right on Right	Right - Left
7	Melodies-Verbal	Left on Right	Left - Right
8	Melodies-Verbal	Left on Right	Right - Left
9	Verbal-Melodies	Right on Right	Left - Right
10	Verbal-Melodies	Right on Right	Right - Left
11	Verbal-Melodies	Left on Right	Left - Right
12	Verbal-Melodies	Left on Right	Right - Left
13	Melodies-Verbal	Right on Right	Left - Right
14	Melodies-Verbal	Right on Right	Right - Left
15	Melodies-Verbal	Left on Right	Left - Right
16	Melodies-Verbal	Left on Right	Right - Left
17	Verbal-Melodies	Right on Right	Left - Right
18	Verbal-Melodies	Right on Right	Right - Left
19	Verbal-Melodies	Left on Right	Left - Right
20	Verbal-Melodies	Left on Right	Right - Left
21	Melodies-Verbal	Right on Right	Left - Right
22	Melodies-Verbal	Right on Right	Right - Left
23	Melodies-Verbal	Left on Right	Left - Right
24	Melodies-Verbal	Left on Right	Right - Left

Results of Main Experiment

Scores for both the left and right ears were recorded for all subjects in the musicians and nonmusicians groups. The mean number of correct ear responses and standard deviations for the Verbal and Melodies Tests are reported in Table 12.

TABLE 12

MEANS AND STANDARD DEVIATIONS[1] FOR LEFT AND RIGHT EARS FOR THE VERBAL TEST AND THE MELODIES TEST-- MAIN EXPERIMENT

	Verbal			Melodies		
	R.	L.	Combined	R.	L.	Combined
Musicians	12.04 (2.77)	12.25 (1.70)	12.145 (4.46)	12.62 (1.79)	13.50 (2.0)	13.06 (3.32
Nonmusicians	12.58 (1.93)	12.08 (1.95)	12.33 (2.89)	9.42 (2.20)	10.58 (2.78)	10.00 (4.31)
Total	12.31 (2.38)	12.165 (1.81)	12.24 (3.45)	11.02 (2.56)	12.04 (2.81)	11.53 (4.99)

[1]Standard deviations in parentheses.

Analysis of the data in the main experiment employed a two-way repeated measures design in two separate analyses of variance for the Verbal and Melodies Tests. The A factor (musical training) was treated as an independent groups factor with repeated measures on the B factor (ears). A summary of the analyses is presented in Tables 13 and 14.

There was no significant ear effect for verbal stimuli found in the results of the Verbal Test. Across both groups, however, there was a small trend toward right ear preference. There was a significant main effect for ear in the results of the Melodies Test, indicating a left ear superiority for melodic stimuli across the two groups. A nonsignificant interaction between ears and groups indicated that this left ear superiority for melodies was no different for musicians as compared

TABLE 13

ANOVA TABLE FOR THE VERBAL TEST COMPARING MUSICIANS AND NONMUSICIANS FOR LEFT AND RIGHT EAR PERFORMANCE--MAIN EXPERIMENT

Source of Variance	SS	d.f.	MS	F	p
Between Subjects	280.49	47			
Groups	.84	1	.84	.14	n.s.
Error	280.15	46	5.85		
Within Subjects	141.50	48			
Ears	.51	1	.51	.17	n.s.
Groups x Ear	3.02	1	3.02	1.01	n.s.
Error	137.97	46	3.00		

TABLE 14

ANOVA TABLE FOR THE MELODIES TEST COMPARING MUSICIANS AND NONMUSICIANS FOR LEFT AND RIGHT EAR PERFORMANCE--MAIN EXPERIMENT

Source of Variance	SS	d.f.	MS	F	p
Between Subjects	587.41	47			
Groups	225.10	1	225.10	28.57*	.001
Error	362.31	46	7.88		
Within Subjects	118.50	48			
Ears	25.01	1	25.01	12.38**	.005
Groups x Ears	.51	1	.51	.25	n.s.
Error	92.98	46	2.02		

*significant at .001 level
**significant at .005 level

to nonmusicians. The significant groups effect found in the results of the Melodies Test is of no theoretical interest since it probably indicates only that the musicians group found the melodies task less difficult than the nonmusicians group.

CHAPTER IV

DISCUSSION

Summary and Conclusions

Investigators (Kimura, 1964; Milner, 1962) have demonstrated that for most individuals the right ear is superior to the left ear for the perception of verbal stimuli, and that the converse appears to be true for musical perception. Assuming that left or right ear superiority is indicative of opposite cerebral hemispheric dominance (Rosenzweig, 1951), these findings imply that the left hemisphere in humans is primarily responsible for processing verbal stimuli and that the right hemisphere is dominant for the processing of music. Bever and Chiarello (1974), by contrast, have suggested that the musical training an individual receives may be a factor in determining which hemisphere of the brain processes music that is heard. Their data, which were obtained through the use of a monaural listening task, imply that musicians process musical stimuli in the left rather than the right hemisphere. The present study was designed to test the generality of the Bever and Chiarello results through the use of a dichotic listening procedure.

Both verbal and musical stimuli were presented dichotically to musicians and nonmusicians in two experiments which comprised the current study. The results of the two experiments provide no evidence for laterality differences between musicians and nonmusicians for the processing of musical stimuli.

Therefore, the first research hypothesis was not substantiated. It appears that the Bever and Chiarello finding is specific to the monaural listening tasks employed in their experiments. If differences exist between musicians and nonmusicians in the cerebral processing of musical stimuli, the dichotic listening technique appears to be inadequate for detecting those differences. The results of the present study are consistent with those of other investigators (Cook, 1973; Gordon, 1970) who have tested musicians under dichotic listening conditions and apparently found little in their data to indicate that musicians process music any differently than nonmusicians. In general, the data of Cook (1973), Gordon (1970) and the current study suggest that music is processed in the right hemisphere, a finding similar to that established by investigators using nonmusicians as subjects (Kimura, 1964; Milner, 1962; Spellacy, 1970; McCarthy, 1969).

Although a significant right ear superiority for verbal stimuli across the two groups was revealed in the results of the pilot experiment, a significant right ear effect for verbal stimuli did not materialize in the results of the main experiment. Therefore, the second research hypothesis failed to receive support. The absence of ear differences in the results of the main experiment appears to be due to a difficulty level of the Verbal Test that was insufficient for obtaining the necessary perceptual rivalry under the conditions of the test instructions used in that experiment. An examination of the right and left ear means revealed a small right ear trend for nonmusicians, but a left ear trend for musicians. The left ear preference exhibited by musicians for the Verbal Test may have been due to chance, but in view of some accumulation of evidence, possible differences between musicians and nonmusicians in the processing of verbal stimuli cannot be ruled out. The musicians employed as subjects in the previously discussed (1970) experiment failed to demonstrate a right ear superiority for verbal stimuli. In a subsequent replication of the present study, using a different verbal task, musicians appeared to have smaller ear difference scores for verbal stimuli than nonmusicians. It is unfortunate that the Bever and Chiarello (1974) and Cook (1973) studies did not employ verbal tests which might have contributed to additional findings. Is it possible that occupation with the medium of music influences, or is influenced by, cerebral activity with regard to verbal functions?

Implications for Further Research

The inconsistencies between the findings of Bever and Chiarello (1974), who employed a monaural technique, and those of other investigators who have utilized dichotic procedures, illustrate the need for further research into techniques for measuring laterality effects. The dichotic listening technique is typically the procedure employed for determining lateralization of various brain functions with regard to auditory stimuli. Results from dichotic listening studies, however, often fail to reveal proportions of left hemispheric language dominance in the population that are consistent with neurological studies (Levy, 1974). Experiments employing a reaction time paradigm (Rizzolati, Umulta, and Berlucchi, 1971) have demonstrated results that are more consistent with neurological estimates of population left hemisphere language dominance. It is possible that reaction time offers a more accurate means of identifying laterality effects with regard to auditory stimuli than the dichotic listening technique. The findings of Bever and Chiarello (1974), which indicate a faster reaction time for melodic stimuli presented to the right ear than to the left ear among musicians, are deserving of further investigation.

Assuming the eventual identification of a satisfactory means of measuring laterality effects, there is a need for further investigation of the cognitive functions of the brain with regard to musical information processing. Although both clinical observations and psychological experiments with normal subjects have demonstrated that certain musical stimuli are mediated by the right hemisphere, when the various dimensions of music are tested independently, the lateralization data show conflicting results. The data of Halperin, Nachshon, and Carmon (1973) and Robinson and Solomon (1974) imply that the rhythmic aspect of music is processed in the speech hemisphere of the brain. Milner (1962) and Spellacy (1970) found no evidence of hemispheric specialization for the processing of rhythm. Milner (1962) found that the right hemisphere is largely responsible for the perception of timbre, whereas Spellacy (1970) found no lateralization for this dimension of music. If laterality effects do, in fact, exist for some or all of these components of music, are there differences between musicians and nonmusicians? This is a question that must be answered prior to any application of these research efforts to pedagogical concerns of music educators.

APPENDIX A

TESTS AND ANSWER SHEETS

VERBAL TEST (IV)

Practice Trials

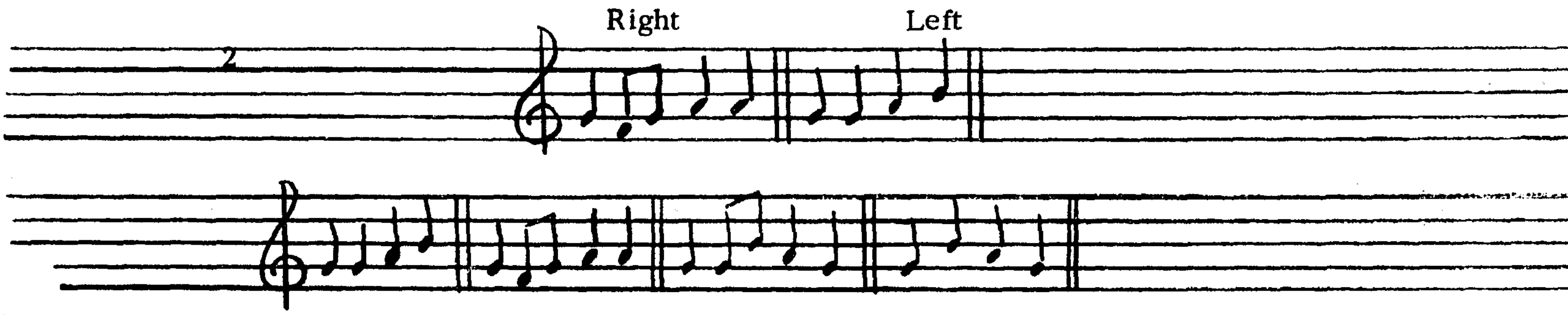
	Left Ear	Right Ear
1.	SGP	BRM
2.	NSQ	PRD
3.	JWX	DCH

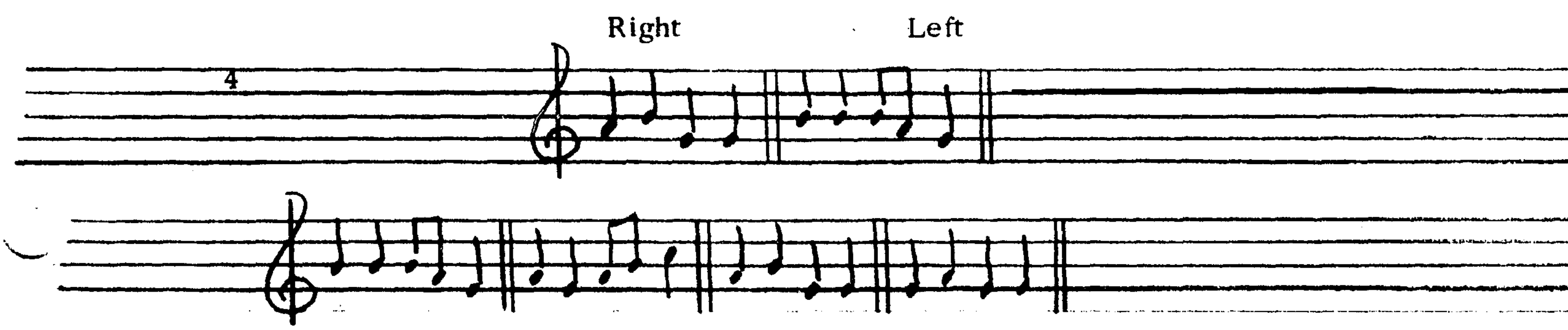
Test

1.	PKG	BFJ	16.	BXG	NPZ
2.	ZRP	MLH	17.	GDP	RST
3.	KRS	ZCG	18.	BCK	JRX
4.	QPX	WCG	19.	MWS	RGX
5.	RZS	BGM	20.	QPC	HZK
6.	NJL	HDF	21.	XPR	LNG
7.	XWM	HCK	22.	SRC	BGN
8.	TRS	JLN	23.	WPF	RJK
9.	BZT	FGR	24.	HKP	ZXN
10.	LQM	PRB	25.	DCG	PLQ
11.	XWT	JFB	26.	LRN	XQZ
12.	SRK	LZH	27.	HCD	JWP
13.	SPQ	FBH	28.	NBH	WMR
14.	NRB	WJX	29.	XPQ	HLM
15.	PRZ	STH	30.	TZP	NSR

MELODIES TEST

Test





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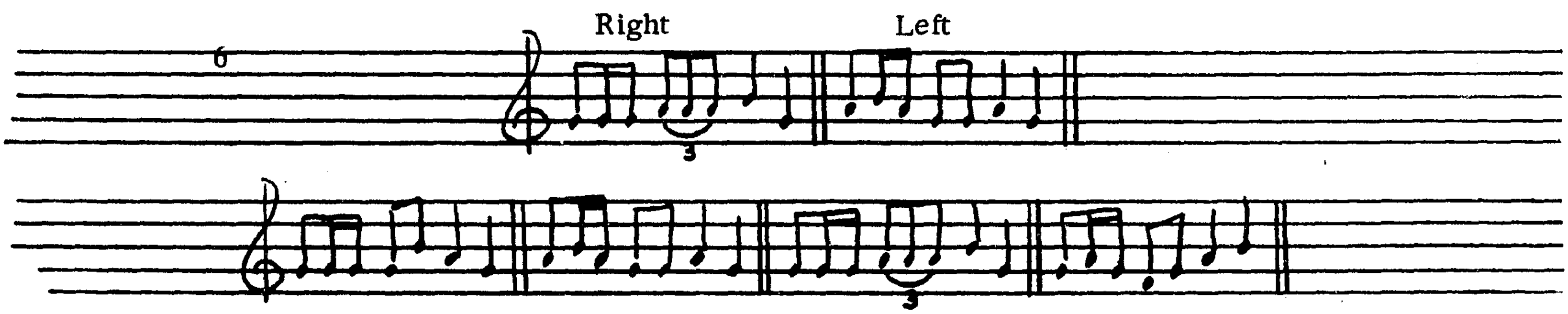

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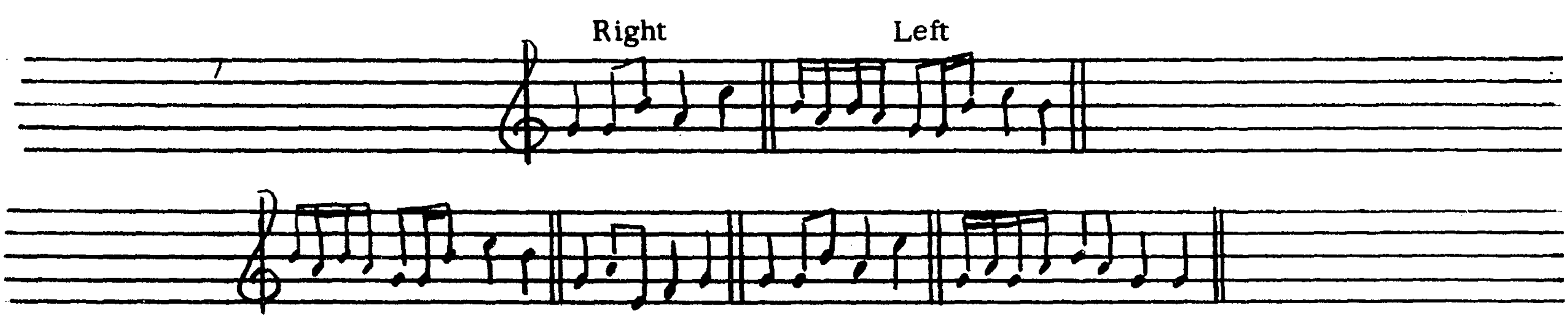

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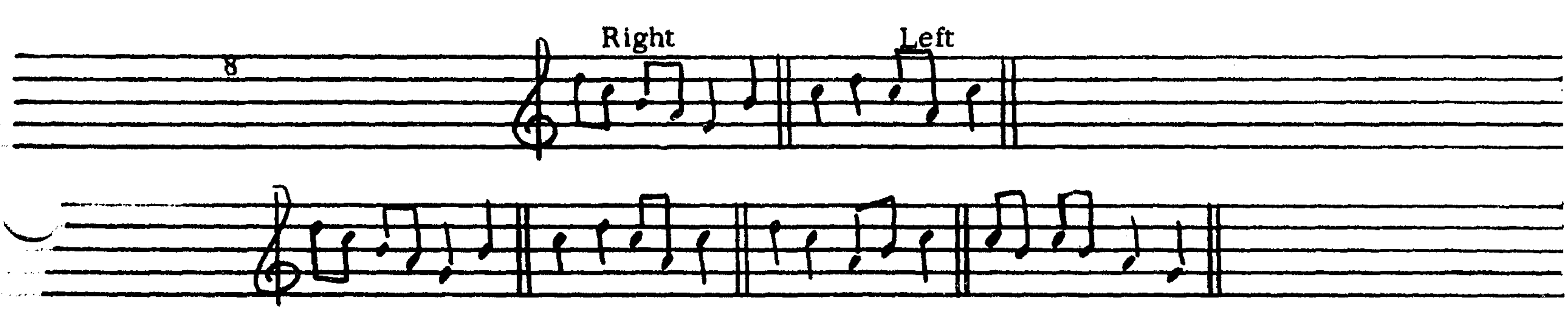


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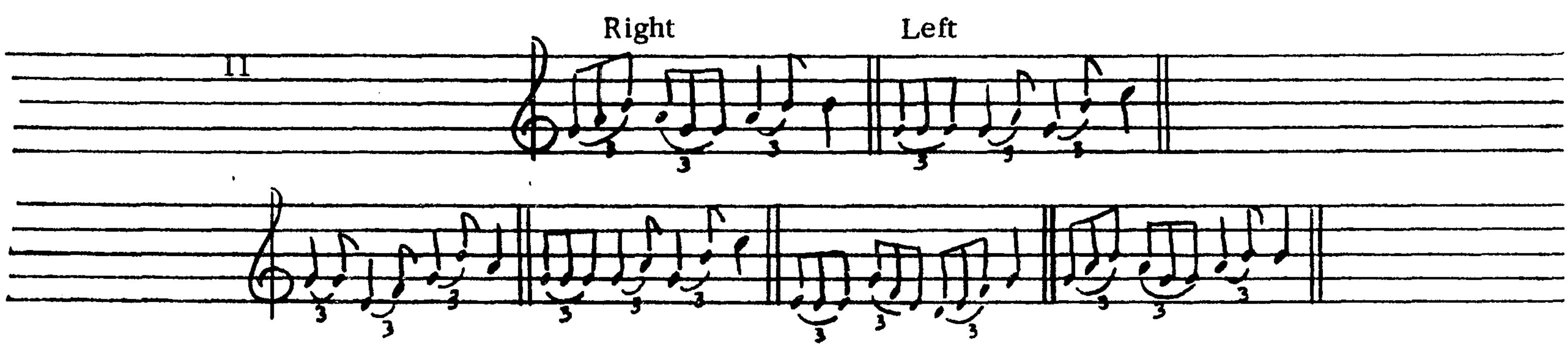
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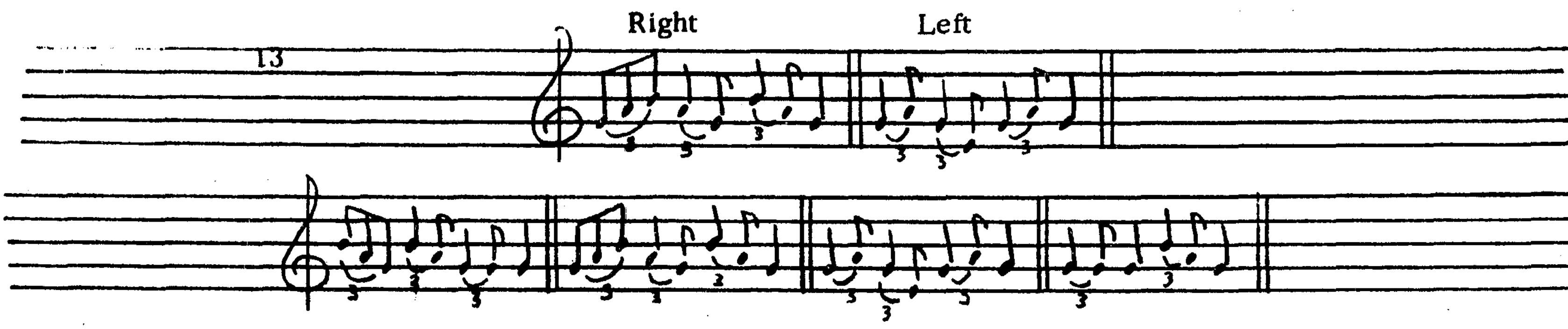
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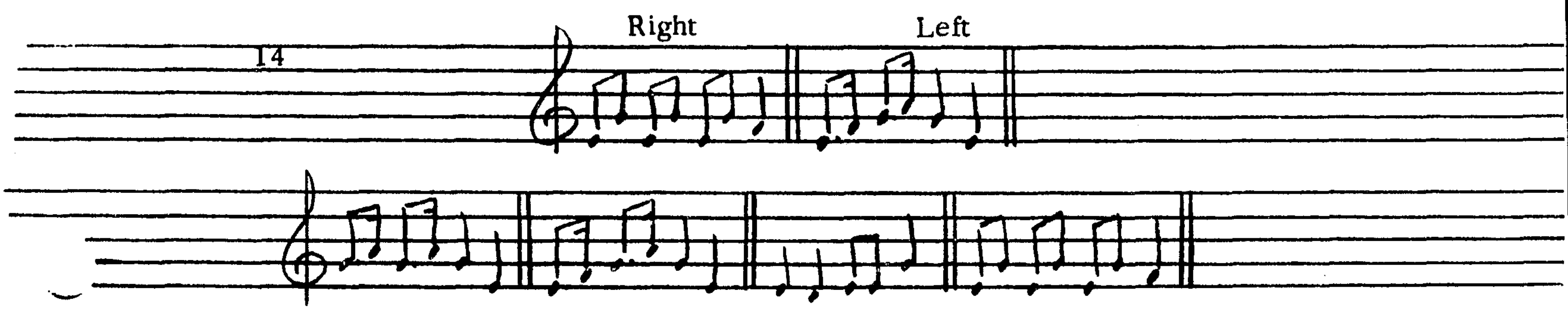
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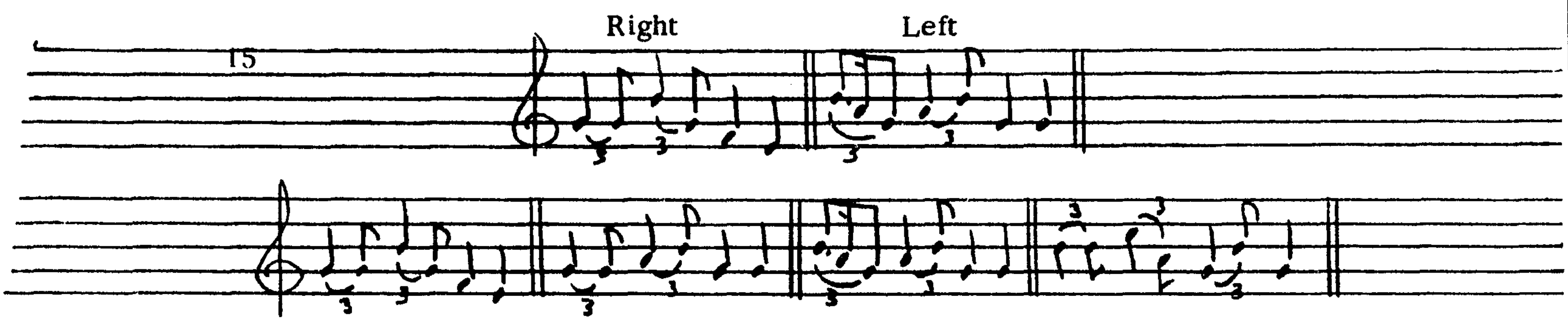
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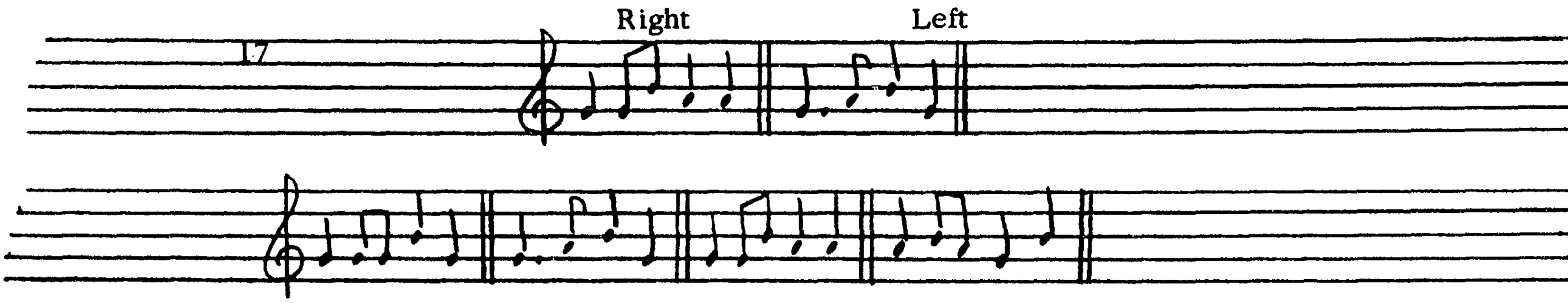
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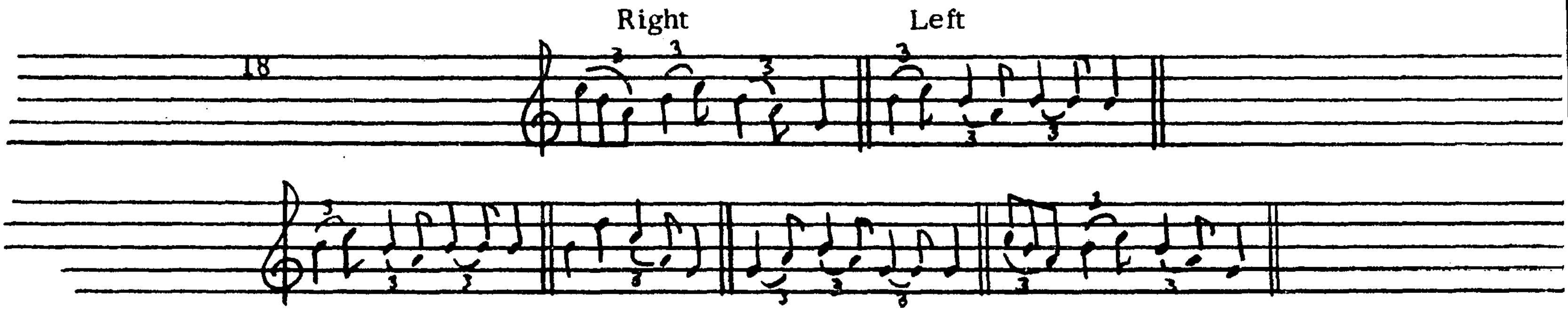
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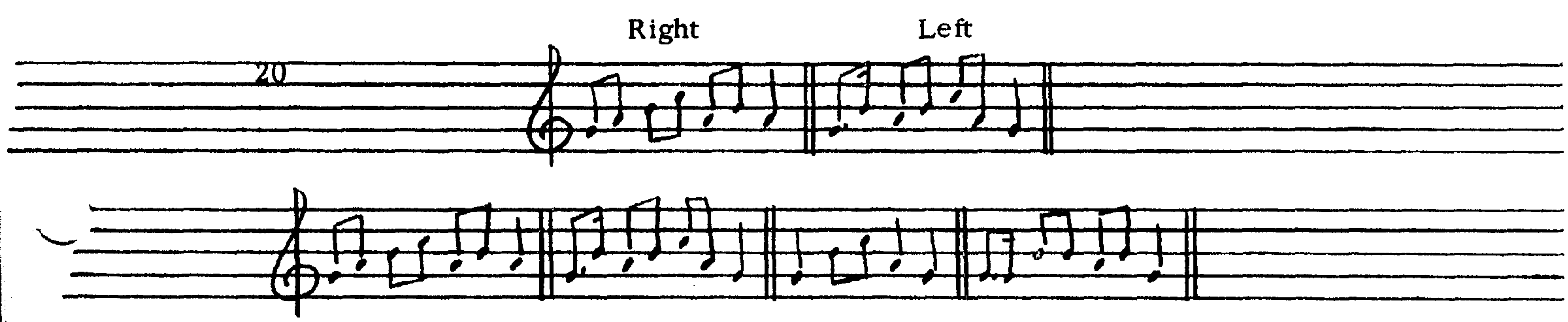
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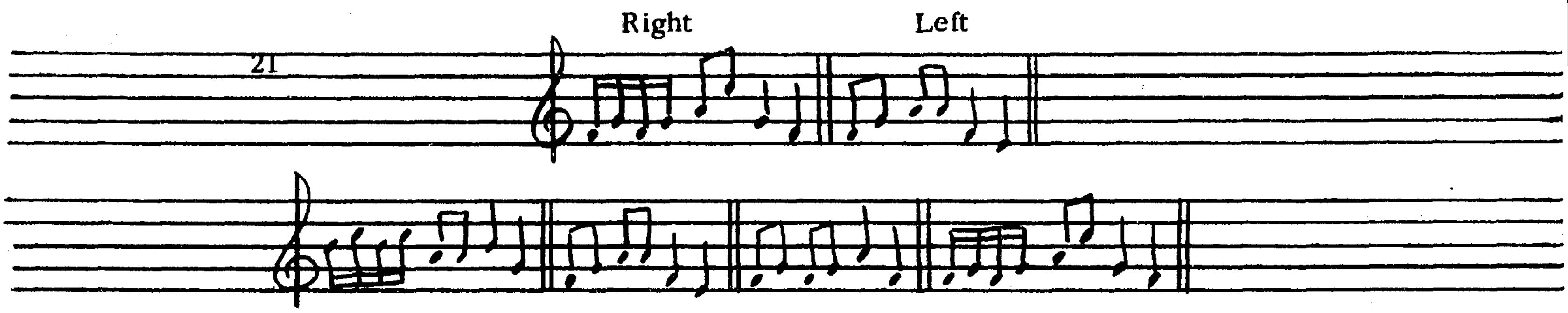
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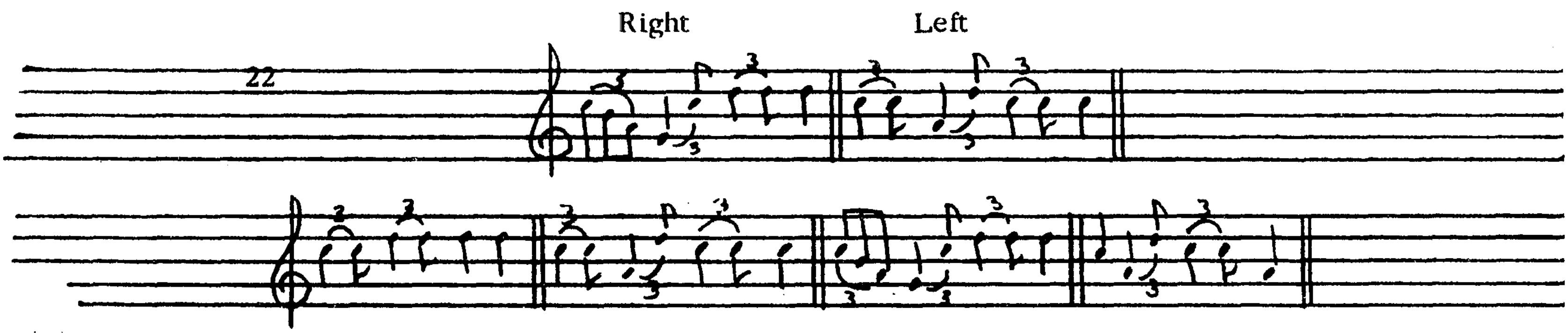
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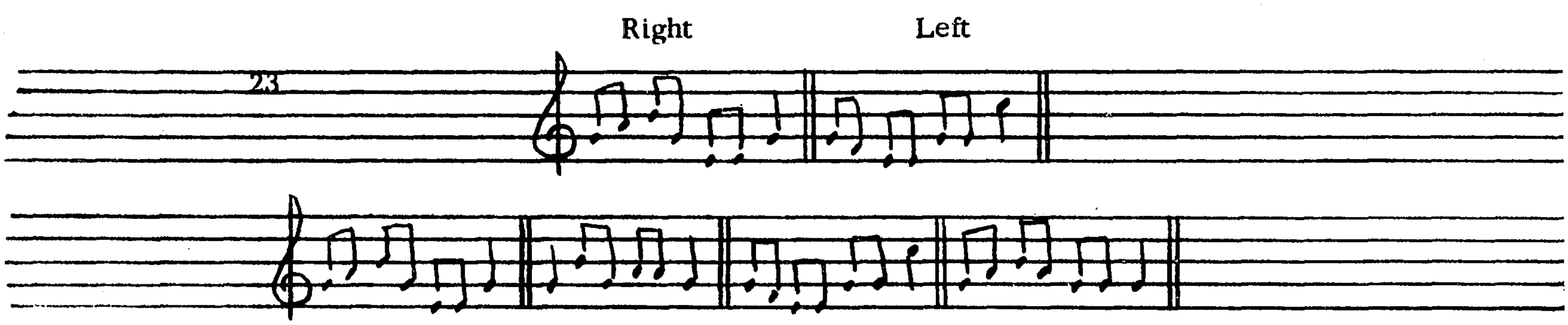
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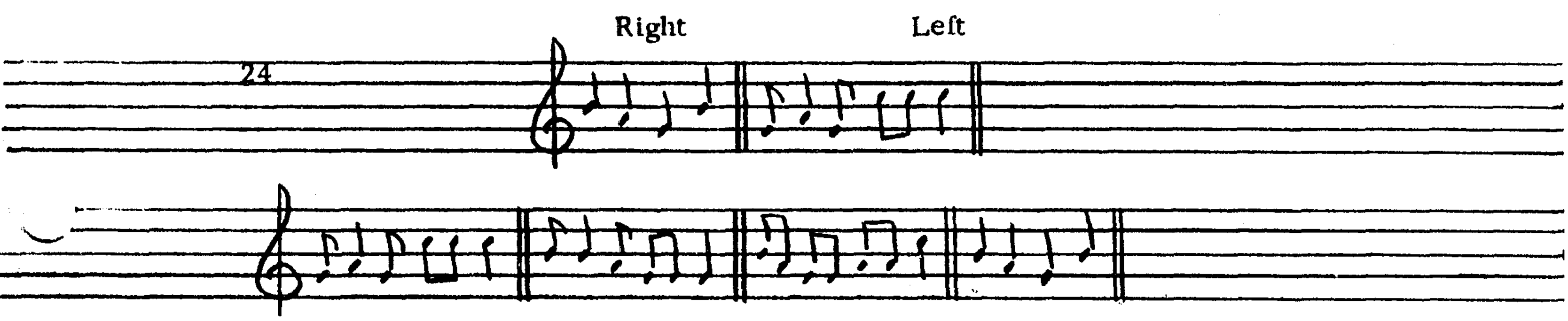
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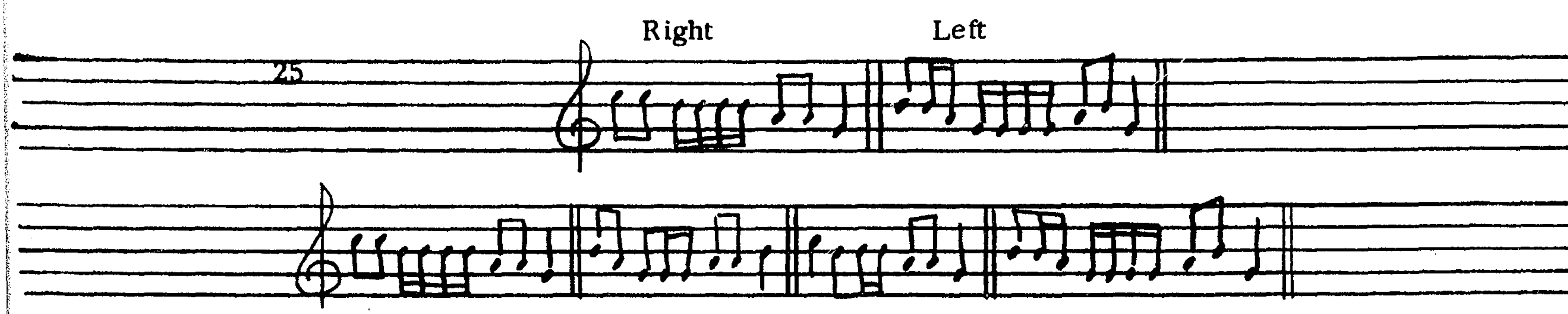
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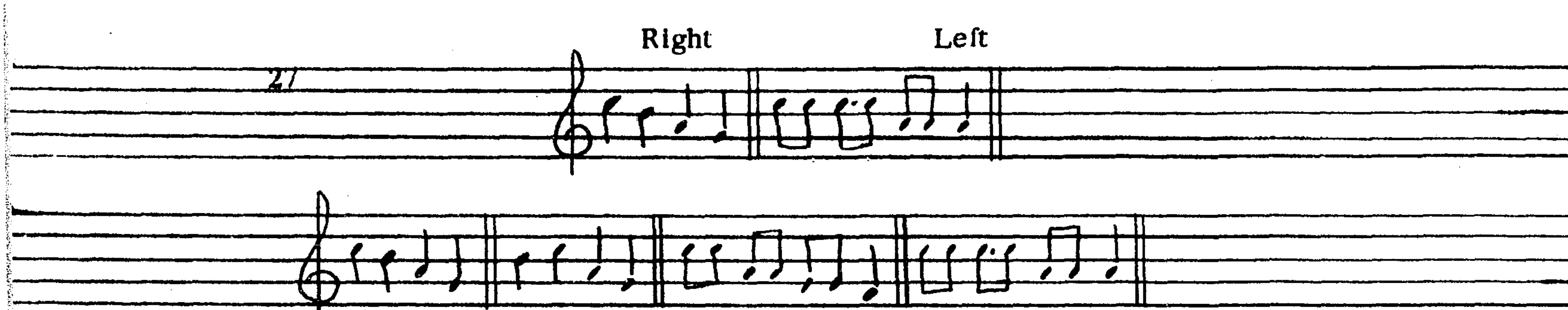
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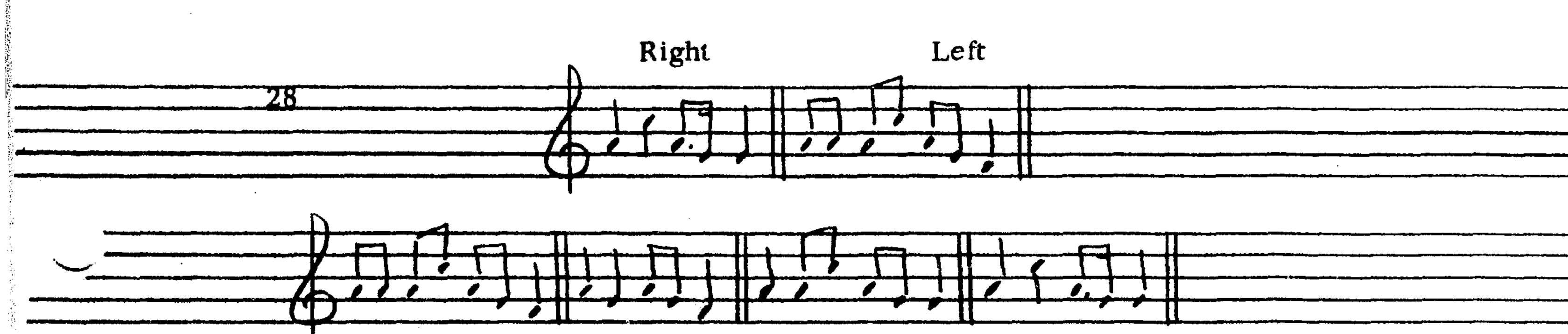
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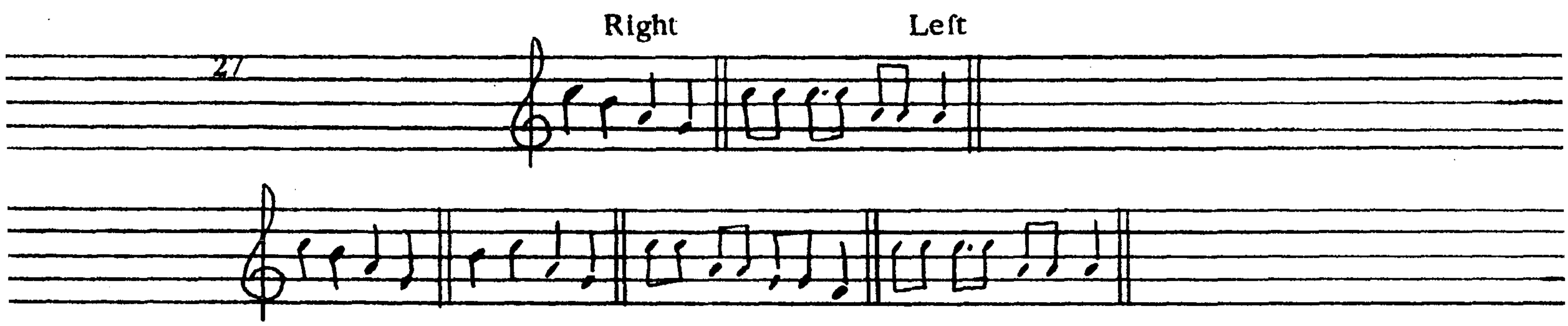
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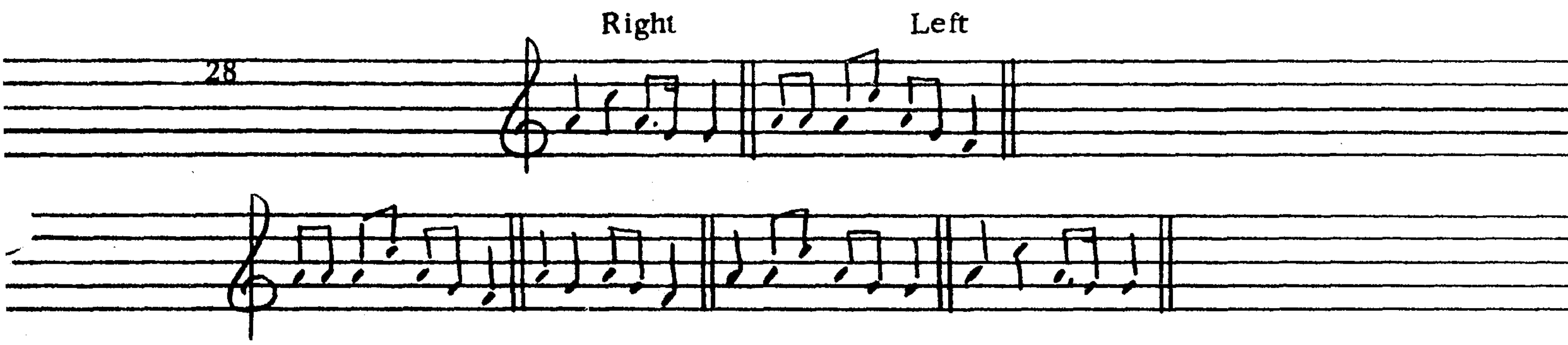
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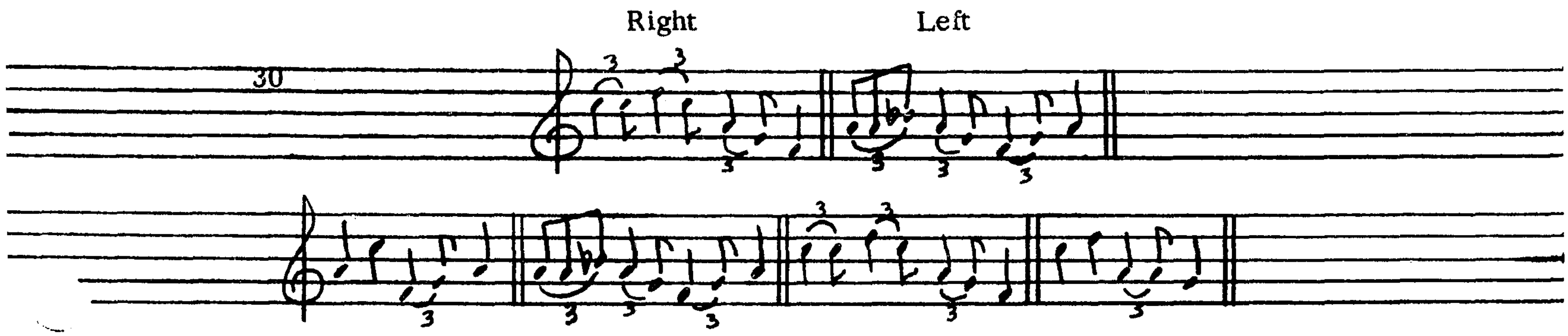
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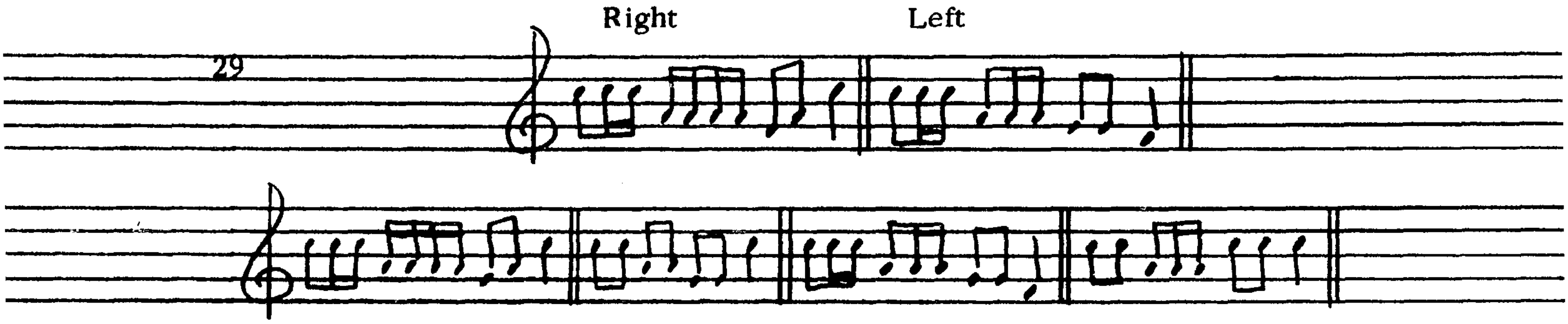
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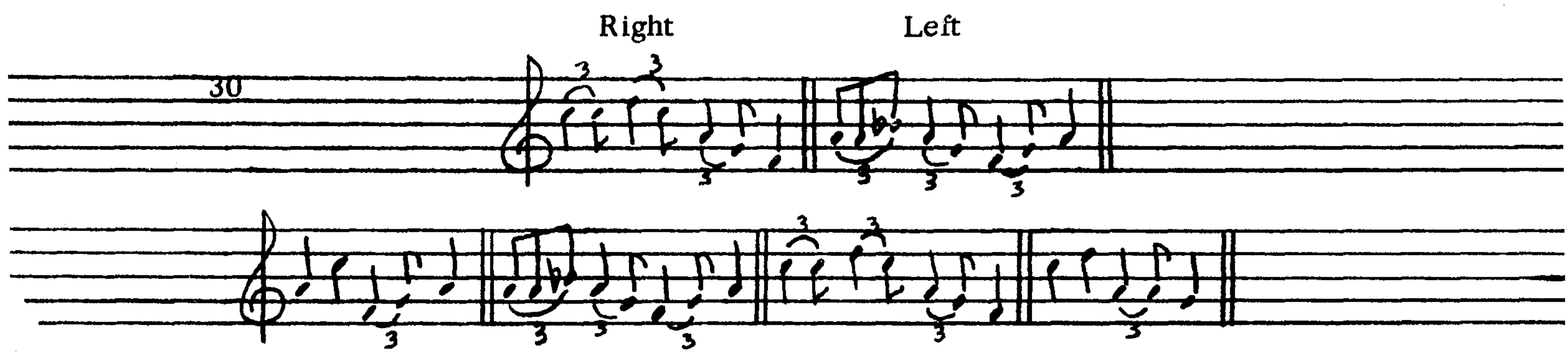
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Answer Sheet--Verbal Test I

DIGITS TEST NAME________________________

Instructions: This test is an auditory perception test composed of thirty test items preceded by two practice trials. Please answer all items to the best of your ability. Each test item will be presented by tape according to the diagram below:

Right Ear:		"723"
Both Ears:	"Practice Trial 1"	"473 723 134 124"
Left Ear:		"124"

On the answer sheet below please indicate with a check ( ) the serial position(s) of the set(s) of digits you were able to hear.

Example:

1____ 2____ 3____ 4____

or

1____ 2____ 3____ 4____ if you were able to distinguish both sets of digits.

ONCE THE TAPE HAS BEEN STARTED IT WILL NOT BE STOPPED UNTIL THE END OF THE TEST. PLEASE ASK ANY QUESTIONS YOU MAY HAVE BEFORE THE TAPE STARTS.

ANSWER SHEET

Practice Trials:

1\. 1____ 2____ 3____ 4____

2\. 1____ 2____ 3____ 4____

Test:

1\. 1____ 2____ 3____ 4____

2\. 1____ 2____ 3____ 4____

3\. 1____ 2____ 3____ 4____

4. 1____ 2____ 3____ 4____

5. 1____ 2____ 3____ 4____

6. 1____ 2____ 3____ 4____

7. 1____ 2____ 3____ 4____

8. 1____ 2____ 3____ 4____

9. 1____ 2____ 3____ 4____

10. 1____ 2____ 3____ 4____

11. 1____ 2____ 3____ 4____

12. 1____ 2____ 3____ 4____

13. 1____ 2____ 3____ 4____

14. 1____ 2____ 3____ 4____

15. 1____ 2____ 3____ 4____

16. 1____ 2____ 3____ 4____

17. 1____ 2____ 3____ 4____

18. 1____ 2____ 3____ 4____

19. 1____ 2____ 3____ 4____

20. 1____ 2____ 3____ 4____

21. 1____ 2____ 3____ 4____

22. 1____ 2____ 3____ 4____

23. 1____ 2____ 3____ 4____

24. 1____ 2____ 3____ 4____

25. 1____ 2____ 3____ 4____

26. 1____ 2____ 3____ 4____

27. 1____ 2____ 3____ 4____

28. 1____ 2____ 3____ 4____

29. 1____ 2____ 3____ 4____

30. 1____ 2____ 3____ 4____

Answer Sheet--Verbal Test IV--Pilot Experiment

VERBAL TEST

Instructions: Thirty test items and three practice trials will be presented by tape according to the diagram below:

Right Ear:		"SGB"	
Both Ears:	"Number 1"		(five seconds of silence)
Left Ear:		"XRD"	

During the five seconds of silence, write down all the letters you can remember in the order that you can best recall them. At the end of fifteen test items (*), signal the examiner so that the earphones may be switched.

Practice Trials:

1.

2.

3.

Test:

1.	10.	19.	28.
2.	11.	20.	29.
3.	12.	21.	30.
4.	13.	22.	
5.	14.	23.	
6.	15.*	24.	
7.	16.	25.	
8.	17.	26.	
9.	18.	27.	

Melodies Test Answer Sheet--Pilot Experiment

Instructions: This test is composed of thirty test items preceded by three practice trials. Please answer all items to the best of your ability. Each test item will be presented on tape according to the diagram below:

<u>Right Ear:</u>	Melodic fragment A	
<u>Both Ears:</u> "Number 1"		Choices: 1, 2, 3, 4
<u>Left Ear:</u>	Melodic fragment B	

On the answer sheet below please indicate with a check ( ) the serial position(s) of the melodic fragment(s) you were able to hear.

Example: 1____ 2____ 3____ 4____

<u>or</u>

1____ 2____ 3____ 4____ if you were able to distinguish both melodies.

At the end of fifteen test items (*), signal the examiner so that the earphones may be switched.

Practice Trials:

1. 1____ 2____ 3____ 4____
2. 1____ 2____ 3____ 4____
3. 1____ 2____ 3____ 4____

Test:

1. 1____ 2____ 3____ 4____
2. 1____ 2____ 3____ 4____
3. 1____ 2____ 3____ 4____

4. 1____ 2____ 3____ 4____

5. 1____ 2____ 3____ 4____

6. 1____ 2____ 3____ 4____

7. 1____ 2____ 3____ 4____

8. 1____ 2____ 3____ 4____

9. 1____ 2____ 3____ 4____

10. 1____ 2____ 3____ 4____

11. 1____ 2____ 3____ 4____

12. 1____ 2____ 3____ 4____

13. 1____ 2____ 3____ 4____

14. 1____ 2____ 3____ 4____

*15. 1____ 2____ 3____ 4____

16. 1____ 2____ 3____ 4____

17. 1____ 2____ 3____ 4____

18. 1____ 2____ 3____ 4____

19. 1____ 2____ 3____ 4____

20. 1____ 2____ 3____ 4____

21. 1____ 2____ 3____ 4____

22. 1____ 2____ 3____ 4____

23. 1____ 2____ 3____ 4____

24. 1____ 2____ 3____ 4____

25. 1____ 2____ 3____ 4____

26. 1____ 2____ 3____ 4____

27. 1____ 2____ 3____ 4____

28. 1____ 2____ 3____ 4____

29. 1____ 2____ 3____ 4____

30. 1____ 2____ 3____ 4____

VERBAL TEST ANSWER SHEET
(Main Experiment)

Name ______________________________

Instructions: Thirty test items plus three practice trials will be presented on tape according to the diagram below:

Right Ear:	"SGB"	
Both Ears: "Number 1"		(five seconds of silence)
Left Ear:	"NXP"	

Although letters will be given in both ears, you should attend to only one ear and write down as many letters as you can remember from that ear. For the three practice trials and the first 15 test items attend only to those letters given to the _________ ear. We will then pause briefly before proceeding to the last 15 test items. On these trials, attend only to those letters given to the _________ ear.

Practice Trials:

1.

2.

3.

Test Items:	8.	16.	24.
1.	9.	17.	25.
2.	10.	18.	26.
3.	11.	19.	27.
4.	12.	20.	28.
5.	13.	21.	29.
6.	14.	22.	30.
7.	15. (Raise your hand)	23.	

MELODIES TEST ANSWER SHEET
(Main Experiment)

Name ____________________________

Instructions: This test is composed of thirty test items preceded by three practice trials. Each test item will be presented on tape according to the diagram below:

Right Ear:		Melodic fragment A	
Both Ears:	"Number 1"		Choices: 1, 2, 3, 4
Left Ear:		Melodic fragment B	

Although melodies will be given to both ears, you should attend to and remember the melody given only to one ear so that you can pick it out of the four choices given at the end of each test item. Indicate your choice with a check mark in the correct serial position (Choice 1, 2, 3, or 4). For the three practice trials and the first 15 test items attend only to that melody given to the ________ ear. We will then pause briefly before proceeding to the last 15 items. On these items, attend only to those melodies given to the ________ ear.

Practice Trials:

1. 1____ 2____ 3____ 4____

2. 1____ 2____ 3____ 4____

3. 1____ 2____ 3____ 4____

Test Items:

1. 1____ 2____ 3____ 4____

2. 1____ 2____ 3____ 4____

3. 1____ 2____ 3____ 4____

4. 1____ 2____ 3____ 4____

5. 1____ 2____ 3____ 4____

6. 1____ 2____ 3____ 4____

7. 1____ 2____ 3____ 4____

8. 1____ 2____ 3____ 4____

9. 1____ 2____ 3____ 4____

10. 1____ 2____ 3____ 4____

11. 1____ 2____ 3____ 4____

12. 1____ 2____ 3____ 4____

13. 1____ 2____ 3____ 4____

14. 1____ 2____ 3____ 4____

15. 1____ 2____ 3____ 4____

Raise your hand

16. 1____ 2____ 3____ 4____

17. 1____ 2____ 3____ 4____

18. 1____ 2____ 3____ 4____

19. 1____ 2____ 3____ 4____

20. 1____ 2____ 3____ 4____

21. 1____ 2____ 3____ 4____

22. 1____ 2____ 3____ 4____

23. 1____ 2____ 3____ 4____

24. 1____ 2____ 3____ 4____

25. 1____ 2____ 3____ 4____

26. 1____ 2____ 3____ 4____

27. 1____ 2____ 3____ 4____

28. 1____ 2____ 3____ 4____

29. 1____ 2____ 3____ 4____

30. 1____ 2____ 3____ 4____

APPENDIX B

QUESTIONNAIRES

QUESTIONNAIRE--MUSICIANS

Name____________________________ Age_____ Class: Fr. Soph. Jr. Sr. Grad.

Address____ Phone_____________

Instrument____________________________ Number of years study__________

Secondary instrument____________________ Number of years study__________

What performing musical organizations do you participate in at the present?

1.

2.

3.

4.

Have you presented or are you preparing to present a public recital?__________

Are you: right handed____ left handed____ ambidexterous____

Do you have or have you had any known hearing problems?__________________

Does anyone in your immediate family sing or play an instrument?____________

At what age did you begin musical training?_____________

List any other formal or informal (i.e., church choir) musical experiences you have had.

1.

2.

3.

4.

If chosen to participate in this study, will you agree to do so?____________

If the answer to the previous question is "yes," please list the free time you have during the week between the hours of 9:00 A. M. to 4:00 P. M.

QUESTIONNAIRE--NONMUSICIANS

Name_____________________________ Age______ Class: Fr. Soph. Jr. Sr. Grad.

Address____ Phone_________________

Do you have any background of formal music study?______ Number of years_____

Do you read music?____________

What informal experiences have you had with music? (For example, singing in church choir, playing guitar or piano by ear, etc.) Please list.

1.

2.

3.

4.

Are you: right handed____ left handed____ ambidexterous____

Do you have or have you had any known hearing problems?____________________

Does anyone in your immediate family sing or play an instrument?_____________

If chosen to participate in this study, will you agree to do so?_________

If the answer to the previous question is "yes," please list the free time you have during the week between the hours of 9:00 A.M. to 4:00 P.M.

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