

EAR PREFERENCE IN THE DICHOTIC PRESENTATION OF
PATTERNED NONVERBAL STIMULI

by

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Abstract

Right ear superiority in the identification and recall of dichotically presented verbal sounds has been frequently demonstrated in right handed persons. This finding has been attributed to left cerebral hemisphere dominance for speech and the assumption that the crossed auditory neural paths are stronger than the ipsilateral ones. An analogous model has been proposed for nonverbal sounds. This model suggests that the left ear, and by implication the right cerebral hemisphere, shows a significant superiority in nonverbal auditory perception. The literature suggests that this conceptualization is too broad since some nonverbal sounds fail to show the expected ear difference.

The left ear superiority has been shown most clearly when music was used as a stimulus. The intent of the present study was to replicate this finding using different experimental methods than have been used previously, to investigate the effect of varying length of the interstimulus interval, and to attempt to isolate those aspects of music which may be critical in demonstrating a right hemisphere functional superiority.

Four types of stimuli were examined: music, rhythm, timbre, and pitch patterns. The latter three stimuli were selected to represent component parts of music. The experimental stimuli were presented one pair at a time. Each dichotic pair was followed by a single identification foil which was either a new sound or one of the members of the experimental pair. The subjects (S) identified the foil by responding yes or no.

Ss were right handed young adults of both sexes who had shown a right ear superiority on a verbal dichotic listening test. Sixty-four Ss were assigned to one of two experimental groups. Group one had a five second interstimulus interval (ISI) separating the dichotic pair from the recognition sound; for group two this interval was twelve seconds. Two dependent variables were examined: number of correct responses and response time.

A left ear superiority in identifying musical stimuli was found for the experimental group with short ISI but not for the group with long ISI. No significant ear difference was demonstrated for the other three stimulus conditions (rhythm, timbre, and pitch) in either time group. There was a significant overall tendency for Ss to make correct responses

more rapidly to stimuli presented to the left ear as compared to the right ear. However, this difference was not statistically significant within any one stimulus condition. Overall performance, i.e., the number of correct identifications, was affected by type of stimulus and length of ISI. Recognition time was significantly affected by the type of stimulus, length of ISI, and sex of S.

These results are interpreted in terms of left ear superiority for nonverbal stimuli under immediate memory conditions. Left ear superiority for nonverbal sounds apparently is subject to rapid decay since it can not be demonstrated under delayed recognition conditions. As predicted, an overall effect of left ear superiority was found for both the number of correct responses as well as response time.

Supplementary analyses of the performance of Ss over time suggest that the phenomenon of left ear dominance is affected by decreasing attention.


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Chapter I

Introduction

The modern history of hemispheric localization of brain function dates back to Broca's report of the association of aphasia with disease of the left cerebral hemisphere (Joynt, 1964). Broca's assertion that people "speak with their left hemispheres" has been widely accepted. The notion of a dominant hemisphere for speech was extended to include other language functions, such as reading and writing. The left hemisphere has also been shown to be "dominant" in the mediation of certain behaviors which are not verbally articulated, e.g., body orientation.

The right cerebral hemisphere, for many years considered a "minor hemisphere", has recently been the subject of considerable study. Patients with right hemisphere lesions have been found to be more severely impaired in certain perceptual and motor abilities than patients with left hemisphere damage. Areas of psychological performance related to right hemisphere function are: impairment of spatial perception and memory, impairment in visuoconstructive activities, defects in visual perception and memory for nonverbal materials, motor impersistence, and impairment in certain aspects of auditory perception

and memory (Benton, 1965).

Specific defects in auditory perception have been demonstrated in patients with unilateral temporal lobe lesions on both sides (Milner, 1962). Damage to the left temporal lobe tends to impair perception and memory for speech. Right temporal lobe damage appears to impair memory and perception for certain nonverbal but meaningful sounds, such as tonal patterns and sounds associated with common objects.

The neural pathways from ear to brain are such that both ears have neural connections with the primary auditory receiving areas in both the right and left temporal lobe (Appendices C and D). This bilateral innervation has made it difficult to study cerebral localization of auditory function in normal subjects since auditory stimuli are received at both hemispheres. The problem has been approached by using the technique of double simultaneous stimulation.

The use of double simultaneous stimulation dates back to animal work done by Loeb (1884). Recent interest in this technique as a clinical and experimental method has been generated by the work of Bender (1952). In the usual application of the double stimulation paradigm, the subject (S) is stimulated at different points on the body surface (Bird, 1964) or in different

visual fields (Teuber et al., 1960). The task of the S is to indicate where or how many stimulations were made. Clinically, brain lesions are presumed to raise thresholds and suppress recognition of the stimulus in the affected area.

Recently, interest in the use of auditory double (dichotic¹) stimulation for the investigation of perceptual processing, verbal learning and cerebral dominance has been growing (Broadbent, 1954; Borkowski et al., 1965; Kimura, 1961a, 1961b).

¹Dichotic stimulation: different stimuli are presented to each ear. Diotic stimulation: identical stimuli are presented to each ear. Monotic stimulation: stimulation of one ear only. Binaural stimulation: the same stimulus is received at both ears but differs in phase and amplitude (Licklider, 1951).

Chapter II

Review of the Literature

I. Dichotic Listening (DLS)

DLS is similar to other double simultaneous stimulation techniques in that the stimuli are presented well above threshold. The S is required to recall or correctly identify the stimuli used. Typically, the sounds used as stimuli carry information beyond that conveyed by simple frequency discrimination. Some of the sounds which have been used in this context are spoken digits (Broadbent, 1954), words (Borkowski et al., 1965), nonsense syllables (Shankweiler, 1967), music (Kimura, 1964), and sonar signals (Chaney, 1966).

Current research using DLS was stimulated by Broadbent's (1954) investigations into the recall of transmitted information in the presence of irrelevant noise. Broadbent presented pairs of spoken digits simultaneously, a different digit to each ear. After this presentation the S was asked to recall the digits. He found that when three pairs of digits were presented at the rate of two pairs per second the typical finding was that the S would report all of the digits presented to one ear before reporting those presented to the other. If, for example, the pairs were 3-5, 9-6, 2-7, the ear order of recall (EOR) would be

392567. Only rarely did his Ss use the temporal order of recall (TOR), e.g., 359627. Broadbent (1958) interpreted this finding to be a result of the S's inability to switch attention between channels rapidly enough to process all of the incoming information under overload conditions. He felt that for this reason S attended to one input channel at a time, the excess input being stored in a temporary storage mechanism which is characterized by rapid decay of memory traces. The greatest deficit in performance occurred in the second half of the recall span (Inglis & Tansey, 1967; Inglis & Ankus, 1965; Inglis, 1965), i.e., the most memory dependent portion of the stimulus.

Satz et al. (1965) investigated the effect of delayed recall of dichotically presented digits under conditions of free choice and instructed order of report. Under the free choice condition Ss showed EOR 76.42 percent of the time. The left channel was the delayed channel 48 percent of the time and the right channel was the delayed channel 52 percent of the time. Disregarding ear order of report, Ss made fewer errors on stimuli presented to the right ear than to the left ($p < .01$).

The error scores for the delayed half spans were calculated as a proportion of the total possible

number of errors. This analysis showed a moderate but nonsignificant right ear superiority ($p < .20$). Satz et al. noted that the high level of efficiency of this task (92 percent total recall) and the lack of systematic control of channels of storage (i.e., delayed channel) may have obscured a real difference.

In a second experiment reported in the same paper Ss were instructed as to the ear that they should report first. Under this instruction EOR occurred 61.69 percent of the time. The criterion for **occurrence** of EOR was that all digits from one channel be reported correctly before any were reported from the other channel. In this experiment ear differences for immediate recall were not significant ($p > .20$). However, the right ear superiority in the delayed recall was very significant ($p < .01$). In the case of EOR the greatest number of errors occurs in the ear recalled last, and more errors are made when this is the left ear than when it is the right one.

Subsequent research investigated various stimulus parameters including words as well as digits. The general findings are in agreement with other investigations of short term memory and verbal learning in that such factors as meaningfulness (e.g., the number of free associations given to a word in a given period

of time) and frequency of English usage (determined by the Thorndike-Lorge (1944) word count; the Howes (1966) count, etc.) affect the accuracy of recall. Single digits, as compared to words, have a higher recall rate in the DLS situation (typically 90 percent or more) presumably because of their high degree of familiarity and the high probability of guessing the correct answer. The EOR was found to be affected by speed of presentation of pairs: slower rates tended to dilute the EOR making it easier for the Ss to report the digits in the actual temporal order of presentation. This is probably due to the verbal rehearsal possible during longer presentation intervals (Bryden, 1962).

II. Perceptual Asymmetry for Verbal Stimuli

Testing patients under treatment for temporal lobe epilepsy, Kimura (1961a, 1961b) made use of DLS for the localization of sensory and perceptual processes in the brain. She noted that patients who had epileptogenic foci in the left temporal lobe showed impairment in the perception of spoken digits presented to either ear when compared with control Ss with lesions in the right temporal or frontal lobes of the brain. Kimura notes further that unilateral temporal lobectomy on either side impaired patients' recognition of the material arriving at the ear contralateral to

the site of removal. Her interpretation was that the temporal lobes are involved in the elaboration of activity at the auditory receiving area of the same side and that the left temporal lobe is particularly important in the perception of verbal material in the auditory modality (Kimura, 1961a). Kimura cites electrophysiological evidence from animal research (Rosenzweig, 1951; Tunturi, 1946) which indicates that the contralateral connections between the ear and the primary auditory receiving areas are stronger than the ipsilateral connections.

Kimura concluded from this evidence that in the dichotic listening situation a strong contralateral signal would be competing with a weaker ipsilateral signal in the auditory cortex of one of the hemispheres. Presumably a stronger stimulus would be more easily perceived and hence more accurately recalled. Since in the large majority of ss language is presumably a process of the left hemisphere this perceptual asymmetry should favor verbal material presented to the right ear (arriving as a stronger signal in the left hemisphere) over verbal stimuli heard in the left ear (arriving as a weaker stimulus at the left, ipsilateral hemisphere). For persons with reversed (right) hemisphere dominance for speech, verbal signals presented to the left ear should be more

accurately perceived than competing signals at the right ear.

With this hypothesis, Kimura (1961b) administered the Broadbent test to 120 Ss with either left or right hemisphere dominance for speech. These Ss, patients with epileptogenic brain lesions, were scheduled for surgical removal of the affected area. Speech dominance was determined by the intracarotid injection of sodium amytal (Wada & Rassmussen, 1960). As predicted, the results for the left hemisphere dominant group showed superior recognition of digits presented to the right ear, and the group representing right hemisphere dominance showed superiority for digits presented to the left ear. However, right hemisphere dominance for speech is fairly rare. Only 13 patients showed this trait and nine of these had extensive lesions in the left hemisphere. Kimura notes that this may have been an influence in the development of right hemisphere dominance since the incidence of long standing left hemisphere damage in patients with left hemisphere speech dominance is low. In these nine cases the right hemisphere is both the dominant hemisphere and the intact one. It could be argued that the left ear superiority for these patients could be due to either of these factors. Kimura

maintains that right hemisphere dominance is not the result of the lesion because all of the four SS without left hemisphere damage and with right hemisphere dominance had a superiority for items presented to the left ear. Two of these patients had lesions of the right (dominant) hemisphere. As a special analysis of this problem, Kimura selected seven left hemisphere dominant SS and seven right hemisphere dominant SS, all with severe left hemisphere damage. Comparing these two groups she found that all SS showed preference for the ear contralateral to the dominant hemisphere for speech. These findings tend to confirm the importance of the speech dominant hemisphere in the perception of spoken digits. However, the small number of subjects and the lack of an adequately constituted control for size and site of left hemisphere lesion make this position less compelling than it could be in regard to right hemisphere speech dominance. A definitive demonstration of reversed EOR with SS having right hemisphere speech dominance as compared to SS with left hemisphere dominance remains to be done.

The finding of right ear dominance in the perception of spoken material has been extended to include normal adults (Kimura, 1964), children of

both sexes as young as age five (Kimura, 1963), and adults as old as 70 years (Inglis & Caird, 1963). It has further been demonstrated to be present in mental retardates (Jones & Spreen, 1967) and to occur with words (Borkowski et al., 1965), consonant vowel nonsense syllables (Shankweiler, 1967), and spoken digits (Satz, 1965). In these studies left hemisphere dominance for speech was assumed on the basis of right handedness (Goodglass & Quadfasel, 1954). Ss with mixed handedness or left handedness were excluded or analyzed separately.

Since the right ear superiority in Ss with presumed left hemisphere dominance has been replicated by a large number of investigators, one may have considerable confidence that the right ear superiority will occur in relatively unselected populations with presumed left hemisphere speech dominance.

III. Perceptual Asymmetry for Nonverbal Stimuli

Milner (1962), investigating the effects of temporal lobectomy, noted that patients with right temporal lobe removal showed a selective impairment when tested with parts of the Seashore Test of Musical Ability (Seashore, Lewis & Saetveit, 1939). These subtests of the Seashore battery are tonal memory, timbre, loudness, pitch, time, and rhythm.

The right temporal lobe patients showed a mean performance one standard deviation (SD) or more below that of normal Ss on every test but pitch. The right temporal lobe group performance was below that of the left temporal lobe group on all of the Seashore tests. The differences were most marked in the tonal memory and timbre subtests. The samples in this group were rather small (N=16 right, N=22 left) and SDs were based on Seashore's original norms for 4,000 healthy adults rather than on a matched control group of brain damaged patients. Milner notes also that the method of administration for the experimental group and for Seashore's normal Ss was not directly comparable.

Since both the tonal memory and the timbre subtest of the Seashore Test require retention of a stimulus and the comparison with a recognition foil, impairment on these subtests may be due to either impairment of memory or perception. Milner's patients were stimulated binaurally and thus received both ipsilateral and contralateral input to the intact left temporal lobe. The finding of an impairment of performance on tonal memory and timbre subtests in patients with right temporal lobectomy implies that an important step in the perception or recall of

musical components, such as timbre and tonal pattern, depends on fibers which pass through the right temporal lobe. It follows that musical sounds presented in this fashion could be expected to show the same selective deficit in patients with right temporal lobectomy.

To test this hypothesis, Milner, Kimura and Taylor (1965) examined groups of SS who had undergone right or left temporal lobectomy and a normal control group on their ability to identify three second excerpts from a recording of bird songs. Both temporal lobectomy groups were inferior to the normals. Unexpectedly, however, the right and left lobectomy groups did not differ from each other.

Shankweiler (1966a) compared right and left temporal lobectomy groups in their ability to name, and to reproduce by humming, selections of well known musical show tunes and musical nursery rhymes. Because of the well established association of verbal defect with left temporal lesions it was hypothesized that the left temporal group would be impaired in the naming but not in the reproducing of melodies. It was predicted that the right temporal lobe group would be impaired with regard to song reproduction but not in the naming of tunes. As predicted, the

right temporal group was inferior to the left temporal group in the reproduction of tunes. However, as in Milner's study with bird songs, the left temporal group's performance was also significantly impaired when compared with the normal control group. The left temporal group performed similarly to the normal group in that both reproduced significantly more tunes than they could name. For the right temporal group this difference between reproduction and naming was not significant.

In these studies the left temporal lobe groups failed to show the expected deficit in naming and instead showed a significant impairment in reproduction or recognition, although this deficit was not as severe as that in the right temporal lobe group. In both of these studies the defective performance of the right temporal lobe group was predicted, but the deficit of the left temporal lobe group remains to be explained if the assumption of a functional specificity of the right temporal lobe is to be maintained.

In the absence of significant differences in the hypothesized direction, a conservative explanation would be that a functional loss is associated with damage to either temporal lobe. In Milner's study a comparison group of patients with frontal lobe

lesions (sparing Broca's area) showed no difference from normal SS. This indicates that the deficit is not a general concomitant of brain damage. Shankweiler's study lacked this brain damage control group and one could argue that the defect in reproduction is a result of brain damage in general rather than being specific to the temporal lobes.

Milner suggests that "...the multidimensional nature of the stimuli used (providing many possible cues for recognition other than melodic pattern) militated against our obtaining either a left right difference or a severe defect" (1965, p. 5).

Shankweiler argues that the defect of the left temporal group in the reproduction of familiar tunes may be due to the fact that in the learning of familiar tunes the melodic line is closely cued to the lyrics. The verbal defect associated with left temporal lobe lesions, then, leads to a loss of memory, and hence, defective reproduction.

Kimura (1964) refers to an unpublished study in which the timbre subtest of the Seashore test was presented monotonically to a group of normal SS, one ear at a time, on two separate occasions. No ear differences were found with this procedure. Milner's (1962) report that SS with right temporal lobectomies

show selective impairment on the timbre and tonal memory subtests of the Seashore battery has been noted.

Right ear superiority in the recognition of verbal stimuli occurs only in the DLS situation (Calearo & Antonelli, 1963; Dirks, 1964) where there is a strong stimulus competition. Analogously, it may be argued that if right hemisphere specificity for the recognition and recall of nonverbal sounds is present in normal Ss, it would appear as a left ear dominance only in the DLS situation. However, Bakker (1967, 1968) indicates that for some sounds competition between ears is not a necessary condition. Using Ss six to thirteen years of age, he presented digits and "morse code like" sound patterns monotically. No significant difference between ears was found in the reproduction of digits. However, a significant left ear dominance was present in the reproduction of sound patterns.

Simon (1967) tested Ss in a simple auditory reaction time task. Ss were stimulated at right, left, or both ears simultaneously. When Ss did not know which ear would be stimulated they responded faster to right ear stimulation than to left. Under this condition of uncertainty binaural stimulation

led to the most rapid response. When Ss knew to which ear the signal would be presented, no differences among the three stimulus conditions were noted. Simon interpreted his results to mean that ear preference can be demonstrated with nonmeaningful stimuli in the absence of competition and that the observed difference may be due to a S's expectations or set regarding ear of stimulation.

Kimura (1964) presented excerpts of commercially recorded music as dichotic stimuli. She used four second excerpts of solo passages drawn from the works of several composers of the Baroque period. The instruments used were primarily strings and woodwinds. She states that the major clue was melodic pattern. Twenty normal female subjects were given the Broadbent test prior to administration of the melodies test. These Ss showed the typical right ear superiority in the recognition of digits while the reverse was found on the melodies test, i.e., musical passages presented to the left ear were identified with significantly greater accuracy than were those presented to the right ear. This asymmetry supports the contention that the right temporal lobe plays a specific and dominant role in the perception and elaboration of certain kinds of nonverbal auditory stimuli.

Kimura (1961a, 1961b, 1964) interpretes her findings in regard to ear asymmetry in DLS to indicate that: (a) the contralateral pathways from each ear to the primary auditory receiving area in the opposite temporal lobe are stronger than the uncrossed pathways, and (b) the brain functions asymmetrically in the processing of verbal and nonverbal auditory stimuli. Verbal perception is mediated primarily by the speech dominant left hemisphere while some kinds of nonverbal stimuli, especially music, are mediated primarily by the right hemisphere.

Shankweiler (1966b) used Kimura's technique and test materials to present the melodies to 45 patients with epileptogenic foci before and following temporal lobectomy. Despite the presence of epileptogenic foci in the temporal lobes the right and left temporal lobe groups did not differ significantly in the accuracy of melody recognition during preoperative testing. Removal of the left temporal lobe made no difference on the overall score on the melodies test. However, as predicted, the group with right temporal lobe removal showed significant postoperative impairment on this test. Like Kimura's normal Ss, the left temporal lobe group was superior in the recognition of melodies presented to the left ear.

Chaney (1966) reported the effects of listener experience in the identification of certain kinds of multidimensional sounds. He noted as an incidental finding that both trained and untrained Ss showed a right ear superiority for perception of speech sounds and a left ear superiority for the perception of sonar sounds. While this was not a planned comparison the difference is in the direction hypothesized by Kimura's conception of nonverbal perceptual asymmetry.

Spreeen et al. (1965) have reported a case of a man with a verified lesion impinging on the temporal-parietal-frontal area of the right cerebral hemisphere who showed an auditory agnosia in the absence of aphasia. The auditory agnosia was demonstrated by means of a sound recognition test (Spreeen & Benton, 1963) in which auditory stimuli are common sounds taken from commercial sound effects recordings. The association of this type of agnosia with a lesion of the right hemisphere in a man with no loss of speech abilities suggests that common nonverbal sounds may be another type of auditory stimulation that is also perceived primarily by the right hemisphere.

IV. Summary

In normal humans each ear is represented by neural connections to both cerebral hemispheres.

There is no difference between ears in the efficiency with which single words are perceived. However, when there is perceptual competition between ears, as in the dichotic listening situation, Ss typically are more effective in recalling those words presented to the right ear. This phenomenon has been noted with both right and left handed samples but the difference is both greater and more reliable with right handed Ss.

Studies performed on Ss who have had their speech dominant hemisphere determined by intracarotid injection of sodium amyotal indicate that superior recognition is obtained at the ear contralateral to the speech dominant hemisphere, i.e., the left cerebral hemisphere in almost all right handed persons and in a majority of left handed persons as well.

There is evidence that lesions of the right cerebral hemisphere may impair the perception of meaningful sounds associated with commonly occurring objects and events (Spreeen et al., 1965). Excision of the right temporal lobe impairs recall and identification of tonal patterns and timbre, and to a lesser degree, other components of music. Excision of either right or left temporal lobe reduces the ability to recognize (Milner et al., 1965) and reproduce (Shankweiler, 1966b) some kinds of melodies.

In normal SS, the left ear and, by implication, the right cerebral hemisphere shows a superiority in the recognition of dichotically presented classical music (Kimura, 1964, 1967). Left ear dominance has also been shown in the recognition of sonar signals (Chaney, 1966). Bakker (1967) has presented evidence that monotically presented code patterns are reproduced better when heard at the right ear than at the left ear.

This evidence suggests that there is a right hemisphere functional specificity in the perception of several kinds of meaningful nonverbal sound.

Chapter III

Present Investigation: Pilot Study

I. Introduction

Kimura (1964) has proposed that the right ear dominance for verbal stimuli and the left ear dominance for music represent an asymmetry of function between the two hemispheres, and that "...the differentiation appears to be along the verbal-nonverbal dimension, and among nonverbal sounds music may be especially effective in eliciting a left ear effect" (p. 357). Ear differences in intensity threshold for a wide range of pure tones are typically absent in SS following either right or left temporal lobectomy (Shankweiler, 1966; Jerger, 1960). This rules out the possibility of ear preference due to selective frequency discrimination associated with one temporal lobe.

If the asymmetry of auditory function does lie on a verbal-nonverbal dimension but does not include the discrimination of pure tones it is reasonable to assume that the difference lies in the perception of more complex, i.e., more meaningful, sounds. The demonstration of a specific defect in the identification of common "social sounds" in a patient with a right hemisphere lesion (Speen, Benton & Fincham,

1965) suggests that the identification of this type of meaningful but nonverbal sound may also, like music, be mediated primarily by the right cerebral hemisphere. If this is the case the competition created by dichotic presentation should tend to favor the identification of those sounds presented to the left ear over those presented to the right one.

To test this hypothesis this study investigated the recognition of dichotically presented nonverbal, nonmusical sounds. The stimuli used in this experiment were common sound effects similar to those used in the Sound Recognition Test (Spreeen & Benton, 1963), e.g., fog horn, airplane engine, siren, etc.

Ss identified the stimulus sounds by making a motor response to three kinds of multiple choice foils representing the stimulus sounds—words, pictures, and sounds. These identification foils represent a continuum ranging from verbal (words) to nonverbal (sounds) with pictures representing a place between the two extreme positions.

A model of bilateral functional asymmetry for verbal and nonverbal sounds suggests the following hypotheses.

A. Hypothesis One

There is an interaction between ear of presentation

and the mode in which the recognition foil is presented. Within the sound and picture response conditions, recognition of sounds presented to the left ear is significantly greater than of those presented to the right ear. Because of the influence of the left cerebral hemisphere in the perception of language, this difference is reversed within the word condition to favor sounds presented to the right ear.

B. Hypothesis Two

Mode of presentation affects the performance, i.e., correct identification of sounds. Specifically, the sound mode of presentation shows the greatest number of correct identifications. The picture and word modes show a smaller number of correct identifications because of the necessity to make a cross-modal comparison. In the case of both words and pictures it is necessary to compare a visual identification foil with the initial auditory stimulation. In addition the word identification requires verbal labeling of a memory trace to make the comparison.

C. Hypothesis Three

Stimuli presented to the left ear will be better

recognized than stimuli presented to the right ear. This hypothesis is only of interest in the absence of a significant interaction between ear of presentation and mode of recognition.

II. Method

A. Subjects

The Ss were 18 students drawn from the Fleet School, Canadian Forces Base, Esquimalt. Ss were male, right handed as determined by a questionnaire, and homogeneous in regard to age, educational background, and intelligence (mean age 19.5, range 18-23; median school grade level 11, range 10-12; median intelligence stanine 7, range 5-9, Applicant Qualification Test). Ss were assigned at random to three groups counterbalanced for order of mode presentation, and to three groups of order within each mode of presentation. All Ss were tested under all conditions and each S completed his testing within one day.

B. Apparatus and Procedure

In a quiet room, each S was examined for normal hearing by a sweep check with a pure tone audiometer. Each ear was tested at a hearing threshold level of 30 db over the range of frequencies from 250 to

6000 cps. The dichotic test stimuli were presented to the S by means of a two channel tape recorder (Ampex 602-2) via stereophonic earphones (Telex St 20). Stimuli were equated for peak loudness at 65 ± 2 db by means of a sound level meter (Scott Type 540). Earphones were reversed for half of the Ss to counter-balance possible artifacts introduced by the sound transmission system.

Each S was seated at a table with two telegraph keys, marked yes and no respectively, directly before him. Each response key activated a signal light on the control panel indicating the response which was recorded by E. Behind the keys was a frosted glass screen 15 inches from S's eyes upon which visual response foils ($5 \frac{1}{2} \times 7$ inches in size) could be projected by a 35 mm. slide projector.

Dichotic stimuli of two seconds duration were presented in groups of three pairs, with one second interpair intervals. Following each set of three pairs there was an interval of five seconds. Twelve response foils of two seconds duration were then presented serially at five second intervals. After each response foil, S indicated by pressing the appropriate key whether or not the foil represented a stimulus that had been part of the preceding

dichotic series.

The sounds used as stimuli and as foils were nonmusical, nonanimate sounds (e.g., fog horn, siren) taken from commercial sound effects recordings. From a pool of 120 sounds, 20 highly familiar sounds were selected. Familiarity was determined by presenting all sounds independently to three judges. For the experiment only those sounds correctly verbally identified by all judges were selected. Ten of these 20 sounds were assigned at random to make up the stimuli used for dichotic presentation and for positive response foils. The remaining 10 were used as neutral response foils. The foils varied according to the three response conditions which were: (a) words, a printed word representing the stimulus was shown on the screen, (b) pictures, a picture of the object making the stimulus sound was shown on the screen, (c) sounds, the stimulus sound or a neutral foil was played binaurally.

All sounds were continuous during the two second presentation. Tapes were prepared by cutting the two channels of continuous sound with an electronic audio gate. The rise time of the audio gate is in the order of micro seconds thus assuring for perceptual purposes simultaneity of stimulus onset and offset.

Stimulus length was measured by a digital time base and counter (Iconix 6255) with an accuracy of 0.1 msec. The audio gate was opened and closed by the timing apparatus.

III. Results

The dependent variable was the number of correctly identified dichotic stimuli. Data were analyzed by a three factor analysis of variance design (Table 1). The factors were ear of presentation (E), response mode (M), and subjects (S).

The hypothesized MxE interaction was not significant. There was no difference noted for ear of presentation either as a main or simple effect (Table 2). The main effect for M was significant. As hypothesized the experimental condition which used sound as an identification foil resulted in significantly more correct identifications. The other two modes did not differ significantly.

IV. Discussion

The superiority of recognition demonstrated under the sound response mode, rather than words or pictures, is of interest for the design of future experiments. This indicates that a higher level of performance can be expected where the S is not

Table 1
Pilot Experiment
Analysis of Variance of Number Correct

Source	df	MS	F
Mode (M)	2	35.90	7.88 ⁺⁺⁺
Ear (E)	1	0.33	<1
Subjects (S)	17	12.17	
MxE	2	1.19	<1
ExS	17	3.55	
MxS	34	4.56	
MxExS	34	2.38	

⁺⁺⁺p<.005

Table 2

Pilot Experiment

Mean Number of Correct Responses per Ear

Within Stimulus Mode

Ear of Presentation ^a	Mode of Response					
	Words		Pictures		Sound	
	Mean	SD	Mean	SD	Mean	SD
Left	8.78	2.49	9.33	1.98	10.88	2.18
Right	8.67	2.84	8.94	2.18	11.06	2.20
$t_{(df=16)}$	.56		-.62		.28	
Mean Number Correct per Mode of Response						
Both Ears ^b	8.73		9.13		10.97	

Note.— The critical difference between any two Mode of Response means at the .05 level of significance is 1.03.

^aStandard Error of Difference (SE_d) = .63

^b SE_d = .503

required to make a crossmodal identification, e.g., auditory—visual—verbal. This superiority is presumably due to the similarity of the response foil to the memory trace since the dichotic perceptual conditions are identical in all three response modes.

Another main finding is the failure to demonstrate a significant difference between ears for this type of nonverbal sound. One explanation for this lack of the expected left ear dominance is that these particular sounds were strong in verbal associations and meaning. This verbal component may have masked a left ear effect that would have been noted had the sounds been purely nonverbal. This possibility is suggested by an operational definition of meaning. In verbal learning research, meaningfulness (m) is defined as the number of words that can be freely associated to a given word in a particular period of time. In this experiment, the selection procedure designed to establish familiarity resulted in the selection of those sounds that are highly verbal in their meaning since only those which could be correctly verbalized by all judges were selected.

Another possibility is that the right hemisphere is responsive primarily to the type of tonal patterning found in music but not in other nonverbal mean-

ingful sounds. Shankweiler (1967), using spoken vowel sounds with Ss who had shown right ear superiority for consonant vowel combinations, failed to obtain a difference between ears. This was, he suggested, because this type of nonpatterned, nonverbal sound lies midway between words and music. What this might mean is not clear. One interpretation is that the vowel sound is equally verbal and nonverbal. Another possibility is that a vowel sound by itself, like a steady tone, is devoid of meaning and not subject to cortical analysis.

A third explanation is that the time from the presentation of the dichotic stimuli to the last foil (96 sec.) was so great that the final half of the foils were responded to in a chance fashion. This might conceal any effect that may have been present during the first half of the recognition foils.

To examine this last possibility only those six stimuli that appear in the first half of the recognition foil series were analyzed. This analysis showed the same pattern as above with the exception that the main effect for mode only reached the .05 level of significance (Table 3).

A further interpretation of the pilot study

Table 3
Pilot Experiment
Analysis of Variance
of First Six Response Foils in Each Mode

Source	df	MS	F
Mode (M)	2	8.04	4.30 ⁺
Ear (E)	1	1.33	<1
Subjects (S)	17	4.15	
MxE	2	0.78	<1
ExS	17	1.76	
MxS	34	1.87	
MxExS	34	3.47	

⁺p<.05

concerns the fact that the same stimulus sounds recurred in different combinations but were not used as neutral foils. It might be argued that after several exposures S learned which were stimulus sounds and which were neutral foils. If this were the case the second and third response modes in the order of presentation would show a high degree of accuracy in identification of sounds presented to both ears. This would also conceal any ear preference that may have been present during the first mode of response tested. This question was examined by considering only the first series presented to each S. These data were analyzed by analysis of variance (Table 4). As in the previous analysis the main effect for mode of presentation was significant. The ExM interaction and the main effect for ear of presentation were not significant.

Shortly after the completion of this pilot study, Curry (1967) published the results of an experiment with stimuli similar to those used in this pilot study. His Ss received three different dichotic tests: words, nonsense words, and environmental sounds. This last test was composed of 27 pairs of sounds taken from sound effects recordings. Stimulus durations were approximately two seconds.

Table 4

Pilot Experiment

Analysis of Variance: Initial Response Mode

Source	df	MS	F
Mode (M)	2	33.36	4.19 ⁺
error (b)	15	7.96	
Ear (E)	1	0.69	<1
ExM	2	1.36	<1
error (w)	15	3.34	

⁺ $p < .05$

Curry used groups of both right and left handed Ss. The right handed group, which had previously shown significant right ear superiority on the tests employing words and nonsense words, showed a significant left ear superiority ($p < .05$) in the identification of the nonverbal sounds.

Prior to testing, each of Curry's Ss were familiarized with the sounds in the experiment. Ss were assisted in the identification of these sounds and corrected when this was necessary. Ss were told that these were the sounds they would be hearing in the experimental conditions. Ss responded immediately following the presentation of one pair of sounds and attempted to verbally identify the sounds which they had heard.

By contrast, in the study reported here, Ss were given three pairs of sounds before being allowed to identify them. Identification was by motor response to a set of multiple choice foils rather than by verbal report. The Ss had not heard the sounds before but sounds were presumed to be familiar because of their identification by judges.

The technique used by Curry of giving Ss the names of the stimuli was specifically avoided on the assumption that this would introduce a degree of

verbal association that might dilute a possible left ear effect for supposedly nonverbal stimuli. However, the fact that his study obtained a difference in spite of the technique suggests that it is not necessarily an important factor. It might be argued that the different means of responding, i.e., verbal and motor, were influential in causing the difference between these two studies. However, Curry showed a left ear superiority in a situation where the Ss respond verbally. This weakens the argument that a verbalized response may show a right ear superiority because of the method of report rather than because of functional differences in perception (Inglis, 1965). Mode of response does not appear to be as significant a factor as originally assumed.

The key to the difference between Curry's experiment and the present study may lie in the different time intervals between stimulus presentation and response and the discriminability of the stimuli in the two studies. Curry's Ss were able to respond at once whereas the Ss in this pilot study had to wait as long as 60 seconds before responding to some foils. The fact that Curry's Ss knew in advance the range of stimuli that they would be receiving probably increased the salience of small stimulus

differences thus enhancing discrimination.

There remains the possibility that Curry's results are due to statistical error. The ear difference just reached the .05 level of significance for his right handed Ss and failed to reach significance for his left handed Ss. This latter group is of importance because they had previously demonstrated a significant right ear preference ($p < .01$) in a dichotic words test. The classification of handedness was based on the coincidence of Ss' statement of handedness to two of three questions relating to handedness. If these groups are pooled on the basis of their demonstrated right ear dominance the margin of left ear superiority on the Dichotic Environmental Sounds Test fails to reach statistical significance ($t=1.36$ $df=48$ $p < .40$). The status of a left ear dominance in the perception of common environmental sounds remains equivocal.

V. Conclusion

The hypothesized left ear dominance for nonverbal sounds was not demonstrated in this study. The ear differences were slight and not consistently in the direction predicted by the hypotheses. The absence of a significant difference requires that the null hypothesis be retained. The obtained ear differences

in this study were so small that there ordinarily would be little reason to pursue the possibility of ear differences using this type of stimuli. However, the demonstration of a left ear dominance by Curry using very similar stimuli and the literature on musical stimuli raises the possibility that failure to find a left ear preference in this study may be due, not to the absence of an effect, but rather to procedural differences between the two experiments.

In Curry's study, the increased discriminability of the stimuli due to instruction and the opportunity to respond immediately appear to be factors that may influence the production of an ear difference.

Evidence suggests that the hypothesis that the right hemisphere mediates meaningful nonverbal sounds is too broad. A conservative interpretation, based on current research, would be that the right hemisphere is involved in the perception of patterns or melodies, especially those which, like chamber music and unlike popular music, are relatively free of verbal content or association.

Chapter IV

Present Investigation: Main Experiment

I. Introduction

The auditory asymmetry for dichotically presented verbal sounds, in which words presented to the right ear are better recognized and recalled than those presented to the left ear, is well established. The existence of a left ear dominance for nonverbal but meaningful sounds is still rather speculative. The previously reported pilot research using sound effects failed to show any ear preference while a study using similar stimuli but a different method did show a significant difference favoring the left ear. Vowel sounds too have failed to show a left ear superiority even though they are meaningful and, it might be argued, nonverbal. If the effect exists it appears to be a smaller effect than that shown for verbal stimuli and almost certainly does not apply to all meaningful sounds that could be classed as nonverbal.

The best evidence for the phenomenon of left ear dominance has been found with music stimuli (Kimura, 1964, 1967; Shankweiler, 1966b). The intention of the present study was to examine the phenomenon of left ear dominance using music stimuli under experi-

mental conditions different from those used in previous studies and to examine, with regard to ear preference, the effects of various musical components.

Seashore (1947) lists four physical variables of sound that have significance for music: frequency, intensity, duration, and form. The psychological equivalents of these dimensions are pitch, loudness, time, and timbre. According to Seashore, rhythm, harmony, volume, and tone quality are compounds of these psychological variables. The discrimination of pitch and intensity have been shown to be relatively insensitive to cortical injury in man (Shankweiler, 1966; Milner, 1962) and animal (Neff, 1961). This suggests that an attempt to isolate those components of music which are responsible for a left ear effect in DLS might best be directed toward those components for which some evidence of specificity exists, i.e., timbre, rhythm, and tonal pattern. This choice of musical components represents commonly accepted elements of music which are discriminably different. Previous research suggests that these components may show a functional specificity of the right cerebral hemisphere.

A. Hypothesis One

Musical excerpts, when presented dichotically.

are recognized more frequently at the left ear than at the right ear.

The phenomenon of left ear dominance in the perception of music has been tentatively established in some studies. However, replication with new music under different experimental circumstances is desirable.

B. Hypothesis Two

In a DLS situation, tonal patterns presented to the left ear are more frequently recognized than those presented to the right ear.

Two previous studies employing musical stimuli (nondichotic presentation) failed to support the hypothesis of specificity associated with the right temporal lobe. This suggests that only some aspects of music are important. To determine what the critical variables may be it is necessary to analyze the complex stimulus represented by music into its component parts.

The use of tonal patterns is a first step in singling out aspects of music which may result in right hemisphere specificity. This hypothesis follows from Milner's demonstration of selective deficit on this type of test following right temporal lobectomy.

C. Hypothesis Three

In a situation where simultaneous stimuli differ only in timbre, those stimuli presented to the left ear are correctly identified more frequently than those stimuli presented to the right ear.

Timbre is the other stimulus which is reported by Milner as showing selective deficit in patients with right temporal lobectomies. Kimura (1964) refers to an unpublished study in which this test was given to normal Ss, one ear at a time. In her study no differences were found between ears. This negative finding may be due to lack of rivalry between the ears. The increased difficulty of the DLS situation may be enough to demonstrate an ear difference in normal Ss.

D. Hypothesis Four

Rhythm patterns show no differences in performance between ears in the DLS situation.

This hypothesis is suggested by Milner's finding of equal performance levels on the Rhythm subtest of the Seashore battery by lobectomy patients, both pre- and postoperatively.

E. Hypothesis Five

Differences in performance between ears are greater

following a 12 second interval of recall than following a 5 second interval.

This hypothesis is suggested by Broadbent's theory which suggests that ear differences in DL are due to the inability of S to shift his attention rapidly enough to attend to both stimuli. The stimulus that does not receive primary attention is shunted into an emergency holding system which is characterized by rapid memory decay. Thus it is expected that the discrepancy between the memory decay rates of the normal perceptual system and the temporary system will result in different levels of performance for each ear. These differences will be greater the longer the time interval between the presentation of the stimulus and the occurrence of the recognition foil.

F. Hypothesis Six

The use of response latency as a dependent variable will give results which are parallel to those obtained in hypotheses one to five in which number of correct identifications is the dependent variable. Specifically, the hypotheses predict that there is a left ear superiority for music, tone patterns, and timbre, and that there is no ear difference for rhythm. Hypothesis five predicted

that such differences as were found would be greater in the long ISI group.

This measure is not a motor reaction time measure. S is given no instructions to respond rapidly. Response latency is assumed to reflect speed of recognition rather than speed of reaction.

This is an exploratory hypothesis. Response latencies are notoriously variable and have not always proved to be efficient dependent variables.

II. Method

A. Subjects

Ss were drawn from two Victoria public high schools, the Victoria Adult Education Institute, a Canadian Forces school, a school of nursing, and the University of Victoria. Ss were unpaid and provided their own transportation with the exception of two for whom transportation was arranged. Each S was required to take part in four experimental sessions on separate days. Most of the experiments were done in the late afternoon or early evening. The Ss willingness to be inconvenienced is taken as presumptive evidence that they were both motivated and cooperative.

Ss were preselected according to the following

four criteria: age between 17 and 20 years, right handedness, normal hearing thresholds bilaterally, and right ear superiority on dichotic presentation of words. Age, sex, and handedness were determined by a questionnaire (Appendix A) distributed to interested persons in the appropriate age ranges.

1. Handedness. Handedness was assessed by ten questions relating to manual preference in varying situations (Spreeen & Benton, 1967). The questions are answered by the S indicating that he habitually uses either his right or left, or both hands equally, for a given task. A response indicating a right hand preference is given a score of ten, both hands five, and a left hand preference zero. Right handedness is defined by a score of 65 or greater. This initial screening yielded a subject pool of 56 males and 49 females.

2. Hearing threshold. Ss were tested individually in a quiet room (ambient noise level between 40-45 db) for hearing threshold of each ear using a pure tone audiometer (Maico, MA-2B). A sweep test through the frequencies of 500, 750, 1000, 1500, and 2000 Hz was made at a level of 20 db (ISO, 1964). One male and one female S were dropped from the subject pool because of high frequency hearing loss.

3. Ear preference. The remaining Ss were tested for right ear preference in the recall of dichotically presented words. This test consists of words matched for frequency of use, abstractness, and initial phoneme. It has been shown to produce right ear preference in a variety of right handed samples (Jones & Spreen, 1967; Borkowski et al., 1965). Word pairs are presented three at a time with an interpair interval of .5 seconds. After each series of three pairs S recalls as many of the words as possible. The score is the number of correctly recalled words presented to the right ear minus the number of correctly recalled words presented to the left ear. Right ear dominance is defined by a score of one or greater.

Nine of the 55 males and four of the 49 females failed to show this effect. This between sex difference is not statistically significant (16.3 percent vs. 8 percent, $z=1.23$ $p<.22$).

From the remaining subject pool 32 experimental Ss of each sex were selected at random. Three females were dropped from the study after one experimental session. One of these was excluded because of failure to correctly follow the experimental instructions and two because of commitments which did not allow

them to complete the full experimental series. Two males withdrew from the study with no reason given. These Ss were replaced by Ss from the pool of eligible volunteers.

The 64 Ss who took part in the experiment are described in Table 5. Sex differences in criterion performance were not significant.

The .05 level of significance was adopted for testing statistical hypotheses.²

B. Apparatus

S was seated in one of two experimental rooms at a table with two telegraph keys, marked yes and no. These two rooms were separated by an observational and equipment room which allowed E to observe Ss through a one way mirror while monitoring the test equipment. Prior to testing Ss were shown the observation room. It was demonstrated to them that E would be able to observe them during the course of testing. The test rooms were divided into two cubicles by a room divider so that two Ss could be

²The ExS mean square from the pilot study was used to estimate between ear variability in the design of this experiment. Using this estimate, a two tailed t test of the between ear difference in the smallest homogenous cell ($N=16$) has power $>.95$ when a .05 level of significance is adopted.

Table 5
Main Experiment
Subject Description

N	Age		Right Ear Dominance ^a		Handedness	
	Mean	SD	Mean	SD	Median	Range
Male 32	18.1	.99	7.2	4.7	89.5	65-100
Female 32	18.3	.70	6.6	4.2	89.7	65-100

^aNumber of words correctly recalled after presentation to the right ear minus number of words correctly recalled after presentation to the left ear.

tested in each of the two experimental rooms at the same time. There was no visual contact between Ss. They were instructed not to talk to each other during the experiment. Ss were told that their responses would be recorded but no mention was made of the fact that response times would be measured. Each experimental session lasted approximately 21 minutes for group one Ss and 32 minutes for group two Ss.

The dichotic stimuli, recognition foils, and identification numbers for each of the stimuli were recorded on magnetic recording tape and presented by a two channel tape recorder (Ampex 606-2). Each channel was separately amplified by an Ampex 620 speaker-amplifier and presented to S via a pair of stereophonic earphones (Telex St-20). Earphones were balanced for sound intensity by calibrating with a sound level meter pressed flush against the earphone cushions. The stimuli were presented at an intensity level between 58 and 64 db. The difference between peak loudness of dichotic stimulus pairs was 2 db or less. In the musical pairs this difference was exceeded in some portions of a musical passage. However, as the stimulus duration was relatively brief, intensity variations were

kept at a minimum.

Ss responses were recorded by separate pens of a six pen paper tape recorder. The stimulus onset and offset was simultaneously recorded on the same tape by a pen driven by a sound activated relay (Grayson Stadler A 7300a-1).

C. Procedure

Ss were randomly assigned to one of two experimental groups, Time One (T_1) in which the ISI was 5 seconds or Time Two (T_2) in which the interval was 12 seconds. Within these two groups Ss were randomly assigned to one of four orders of presentation to counterbalance possible learning effects between test sessions. Within each order, half of the Ss had their earphones reversed, to control possible bias introduced by the sound transmission system.

Ss were presented with dichotic stimuli in each of the four stimulus conditions: music (M), tonal pattern (P), rhythm (R), and timbre (T_m). Within any one test session only one type of stimulus was used. The dichotic pairs were preceded by a spoken number, heard diotically. This number ended the preceding response interval, acted as a ready signal, and identified the pair. The dichotic pairs of 2

seconds duration were followed by an ISI appropriate for the experimental group. The ISI ended with the onset of an identification foil presented diotically. This foil was a sound which was either one of the members of the preceding dichotic pair or a new but similar stimulus. The S's task was to indicate, by pressing one of the two response keys, whether or not the foil was one of the dichotic pair.

D. Stimulus Material

In each of the four stimulus conditions S received 96 dichotic pairs, each followed by a diotic foil. The pair and the foil were separated by an ISI according to experimental group. Half of the recognition foils were drawn from the dichotic stimulus pair and half were new foils not present in the dichotic pair. Pairs 1-48 were repeated to make up the pairs 49-96. However, the channels of presentation were reversed so that each S received every dichotic pair twice. Each member of a stimulus pair appeared once at each ear in different halves of the test. The stimulus tape in each session was played through without pause.

1. Music. Twenty-four diotic foils were made up from one member of each of the dichotic stimulus pairs. The foil was recorded on both channels of the

experimental tape. Thus the foil was an exact diotic replica of the stimulus.

Musical passages were paired randomly for the dichotic stimuli. No attempt was made to match selections for such variables as tempo, rhythm, etc. In all instances the melodies were continuous within the 2 second stimulus interval.

Simultaneity of onset and offset of stimulus pairs was achieved by recording dichotic and diotic signals passed through an electrically driven audio gate. The dichotic stimuli were cut from the middle of the recorded passages. The method is the same as that described in the pilot study reported above (p. 27).

2. Tone pattern. The patterns in this subtest were composed of four pure tones of 500 msec. duration each, presented contiguously to make up a 2 second stimulus. The eight pure tones, comprising the octave from A_4 to A_5 on the chromatic scale, with frequencies of 440, 494, 522, 586, 660, 700, 784, and 880 Hz were produced by a sine wave generator. Phase was not controlled for the dichotic pairs.

The dichotic pairs were unique combinations of four tone patterns, produced in such a way that each ear received a different tone at any one time, and each of the tones in any one ear pattern was different

from the one which preceded it, e.g., right ear received 440, 784, 660, 494 Hz and left ear received 494, 522, 586, and 880 Hz.

A program was prepared for a digital computer (IBM 360) that would enumerate the very large (greater than 500,000) number of such unique patterns. A printout of every five hundredth such combination was obtained. From this sample, patterns for both dichotic pairs and recognition foils were selected randomly with the restriction that a neutral foil did not match a member of a dichotic pair.

3. Rhythm. This test consisted of signals similar to Morse Code. However, instead of the conventional dot and dash pattern the signals were made of pure tone pulses of 100, 200, 300, or 400 msec. duration. The interpulse interval was 200, 300, or 400 msec. long. Each ear received a different frequency (1000 Hz and 1500 Hz) to maximize discrimination. The frequency presented to each ear and the frequency of the recognition foil were randomized. To prevent frequency discrimination acting as a cue a recognition foil drawn from a dichotic pair had the same frequency as the original stimulus. All pulses were simultaneous in onset. The pattern differences were created by the difference in offset

and hence in the interpulse interval.

4. Timbre. The stimuli in this instance were single notes played on a pipe organ. The fundamental frequency was the same for both members of the pair but the overtones differed according to the combination of pipes used (Appendix B).. Each stimulus was 2 seconds in length. Foils were of the same fundamental frequency.

E. Scoring

Two dependent variables were used in this study. The first dependent variable was the number of correct responses made by the S, i.e., responding yes when the foil was one of the dichotic pair. Thus for each S in each condition a score could range from 0 to 24 for each ear. The second dependent variable was recognition time, the time from onset of response foil to S's pressing of the response key. The duration of the response foil was 2 seconds for all stimulus conditions. In most instances S did not respond until after the foil was completed. Response time was measured from foil onset to allow the S to make a scorable response prior to the end of the 2 second foil duration. This measure was recorded on paper tape moving at a velocity of 12 mm. per second. Measurements were made to the nearest mm., i.e., .083 sec. For purposes of analysis

the distribution of these data was normalized by a natural logarithm transformation. In a few cases a S would respond both yes and no within the same response interval. In this instance the following scoring convention was adopted: the last response in the interval was assumed to be S's corrected preference and the initial response was ignored. If no accurate determination could be made regarding the priority of onset the response was scored as no.

III. Results

A. Dependent Variable One (Number of Correct Responses)

1. Sex. The first analysis of the data was performed by a four factor analysis of variance with two independent measures, sex (S) and time (T), and two repeated measures, ear of presentation (E) and stimulus condition (C). The sex main effect and the interactions with E, T, and C were not significant (Table 6). Therefore, the data were collapsed for sex and a three factor analysis of variance (Type VI, Lindquist, 1953) performed. This analysis (Table 7) showed significant main effects for T and C, and a significant ExC interaction (Figure 1).

2. Time. A significant main effect was obtained. The main effect for T shows that the overall level of performance decreased from T_1 to T_2 . The ExT inter-

Table 6
Main Experiment
Analysis of Variance:
Number of Correct Responses

Source	df	MS	F
Time (T)	1	817.59	17.70 ⁺⁺⁺
Sex (S)	1	43.36	<1
TxS	1	45.72	<1
error (b)	60	46.17	
Ear (E)	1	1.64	<1
ExT	1	48.14	3.90
ExS	1	43.36	3.90
ExTxS	1	12.19	<1
error ₁	60	12.35	
Stimulus Condition (C)	3	445.35	30.92 ⁺⁺⁺
CxT	3	11.29	<1
CxS	3	9.43	<1
CxTxS	3	10.17	<1
error ₂	180	14.40	
ExC	3	23.46	2.95 ⁺
ExCxT	3	16.05	2.02
ExCxS	3	12.69	1.59
ExCxSxT	3	10.14	1.29
error ₃	180	7.94	

⁺ $p < .05$

⁺⁺⁺ $p < .001$

Table 7
Main Experiment
Analysis of Variance:
Number Correct Responses with Sexes Pooled

Source	df	MS	F
Time (T)	1	817.60	17.73 ⁺⁺⁺
error (b)	62	46.12	
Ear (E)	1	1.64	<1
Condition (C)	3	445.35	31.24 ⁺⁺⁺
ExC	3	23.46	2.90 ⁺
ExT	1	48.14	3.72
CxT	3	11.29	<1
ExCxT	3	16.05	1.99
error ₁	62	12.93	
error ₂	186	14.26	
error ₃	186	8.05	

⁺ $p < .05$

⁺⁺⁺ $p < .001$

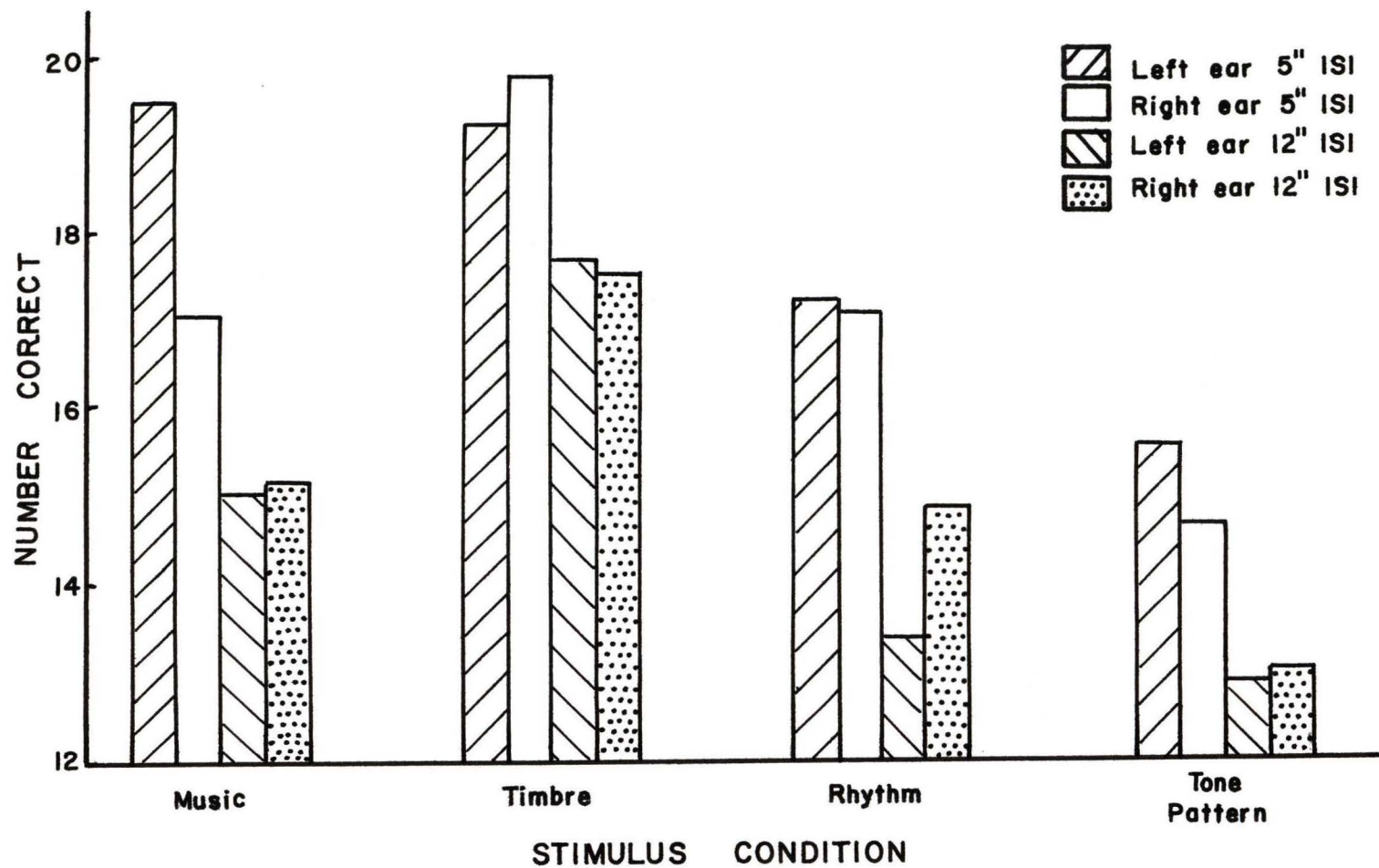


FIGURE 1

action was large ($F=3.72$ $p<.10$) but fell short of the adopted level of significance. Inspection of the data suggested that the variances in the two experimental groups were not equal. This was tested by a two tailed F test (Pearson & Hartley, 1966). The hypothesis of equal variance was rejected ($F=2.57$ $p<.05$). Following Lindquist (1953) a separate analysis was done for each experimental group.

3. Stimulus condition. A significant main effect was obtained in the overall analysis. Separate two factor analyses of variance with repeated measures on each factor were performed on each experimental group for the reason noted above. Group one (Table 8) showed significant main effects for C and E. The ExC interaction was also significant.

In group two (Table 9) only the main effect for C was significant.

4. Ear of presentation. No overall main effect for ears was obtained. However, because of the ear effect found in the analysis of experimental group one, the ear effects within each stimulus condition were examined separately by two tailed t tests. In group one (short ISI) the left ear was significantly superior to the right ear (Table 10). There was no significant ear difference demonstrated in any of the

Table 8
Main Experiment
Five Second ISI Group
Analysis of Variance:
Number of Correct Responses

Source	df	MS	F
Ear (E)	1	33.78	5.12 ⁺
Condition (C)	3	216.71	17.79 ⁺⁺⁺
ExC	3	28.66	4.46 ⁺⁺
Subjects (S)	31	36.18	
ExS	31	6.59	
CxS	93	12.18	
ExCxS	93	6.42	

⁺ $p < .05$

⁺⁺ $p < .01$

⁺⁺⁺ $p < .001$

Table 9
Main Experiment
Twelve Second ISI Group
Analysis of Variance:
Number of Correct Responses

Source	df	MS	F
Ear (E)	1	16.00	<1
Stimulus Condition (C)	3	239.93	14.69 ⁺⁺⁺
ExC	3	10.85	1.12
Subjects (S)	31	56.07	
ExS	31	19.26	
CxS	93	16.33	
ExCxS	93	9.69	

⁺⁺⁺ $p < .001$

Table 10

Main Experiment

Five Second ISI Group (N=32)

Summary Table: Mean Number Correct per Ear

Within Stimulus Condition

Ear of Presentation ^a	Stimulus Condition			
	Music	Timbre	Rhythm	Tone Pattern
Left	19.5	19.2	17.2	15.6
Right	17.0	19.8	17.1	14.7
$t_{(df=30)}$	3.90 ⁺⁺⁺	-.92	.97	1.46

^a $SE_d = .64$ ⁺⁺⁺ $p < .001$

other three stimulus conditions. In group two (long ISI) no ear differences could be demonstrated within any stimulus condition (Table 11).

The results supported hypotheses one and four. Hypotheses two and three were not supported. The left ear superiority within the tone pattern condition was in the direction proposed by hypothesis two and this observed difference was moderately large ($t=1.46$ $p<.10$). Hypothesis five was rejected. This hypothesis predicted greater ear differences in the group with long ISIs. There was a significant ear difference for M in group one and no difference in group two. This result was directly opposite to hypothesis five.

B. Dependent Variable Two (Response Time)

The data for this analysis are the natural logarithms of mean response times for trials with a left or right ear foil.

The first analysis was a four factor analysis of variance with two independent factors and two repeated measure factors (Table 12). The four factors, i.e., S, E, C, and T, were the same as in the analysis of dependent variable one. All four main effects were significant. None of the interactions were significant.

1. Sex. Males responded significantly faster than females.

Table 11

Main Experiment

Twelve Second ISI Group (N=32)

Summary Table: Mean Number Correct Responses
per Ear Within Stimulus Condition

Ear of Presentation ^a	Stimulus Condition			
	Music	Timbre	Rhythm	Tone Pattern
Left	15.00	17.66	13.44	12.91
Right	15.16	17.56	15.15	13.12
$t_{(df=30)}$	.17	.20	-1.57	-.08

^a $SE_d = 1.10$

Table 12

Main Experiment

Analysis of Variance:

Mean Response Times (Log Seconds)

Source	df	MS	F
Time (T)	1	1.1580	11.70 ⁺⁺
Sex (S)	1	1.6133	15.42 ⁺⁺⁺
TxS	1	.0362	<1
error (b)	60	.1046	
Ear (E)	1	.0189	4.20 ⁺
ExT	1	.0030	<1
ExS	1	.0005	<1
ExTxS	1	.0053	<1
error ₁	60	.0045	
Stimulus Condition (C)	3	1.7695	63.64 ⁺⁺⁺
ExT	3	.0203	<1
CxS	3	.0075	<1
CxTxS	3	.0442	1.59
error ₂	180	.0278	
ExC	3	.0169	2.31
ExCxT	3	.0054	<1
ExCxS	3	.0121	1.64
ExCxTxS	3	.0087	1.19
error ₃	180	.0073	

⁺ p < .05
⁺⁺ p < .01
⁺⁺⁺ p < .001

2. Time. Recognition time was slower in the second (long ISI) experimental group.

3. Stimulus condition. The order of the conditions from most rapid to slowest recognition time was timbre, music, tonal pattern, and rhythm (Figure 2, Figure 3).

4. Ear of presentation. Ss responded significantly faster to stimuli presented to the left ear than to those presented to the right ear. Ear differences within individual conditions were not significant (Table 13).

These results support the notion of a left ear superiority suggested in hypotheses one to three. However, the individual hypotheses are not supported. Hypothesis four cannot be rejected. Hypothesis five is not supported since the magnitude of the ear difference is the same within each time group.

C. Supplementary Analysis

The stimulus tapes were designed so that the first and the second half were composed of the same items balanced with regard to the number of right and left ear presentations. This made it possible to analyse separate halves of the experiment. Within each experimental group a two factor repeated measures analysis of variance was performed on the data in each

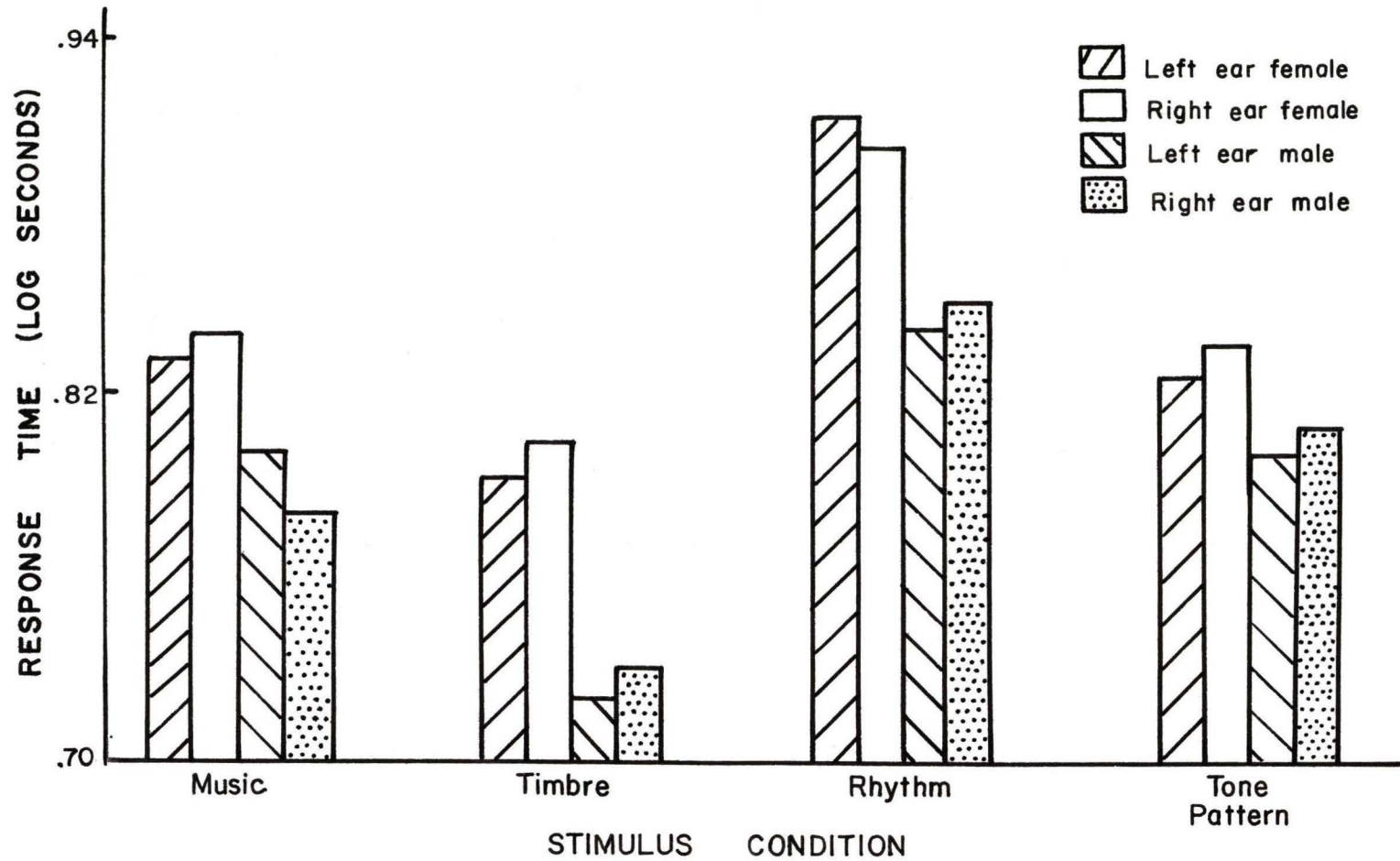


FIGURE 2
5 SECOND ISI

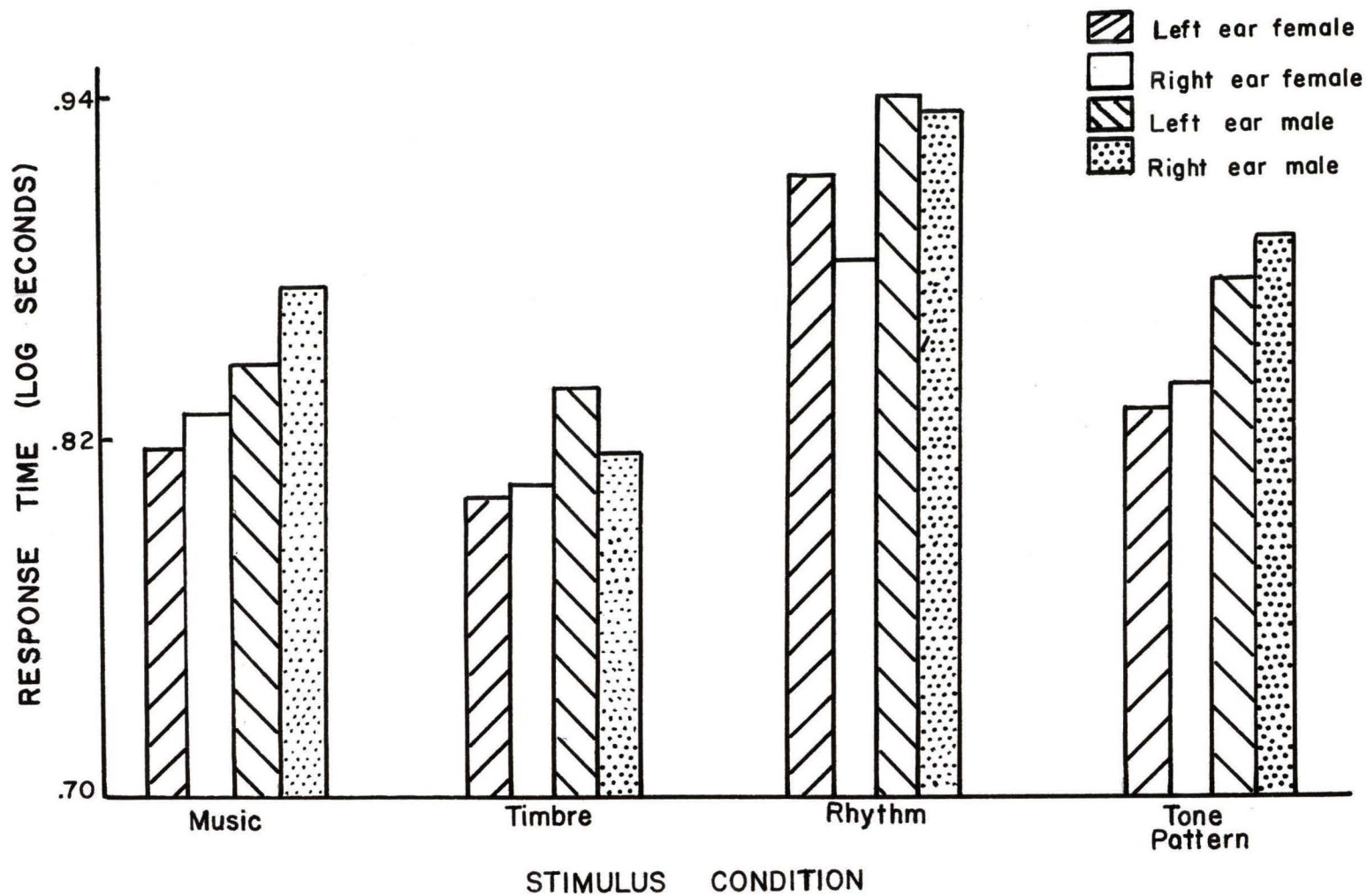


FIGURE 3
12 SECOND ISI

Table 13

Main Experiment

Summary Table:

Mean Response Time (Log Seconds) per Ear

Within Stimulus Condition

Ear of Presentation ^a	Stimulus Condition			
	Music	Timbre	Rhythm	Tone Pattern
Left	.8233	.7856	.9100	.8333
Right	.8375	.7830	.9063	.8468
$t_{(df=62)}$	-1.20	.22	.31	-1.14
Mean Response Time per Stimulus Condition				
Both Ears ^b	.8314	.7843	.9082	.8468

Note.— The critical difference between any two stimulus condition means which is significant at .05=.1864.

^a $SE_d = .012$

^b $SE_d = .0932$

half of the experiment.

1. Number correct. In group one (short ISI) the analysis of the number of correct responses obtained on the first half of the experiment (items 1-48) showed significant main effects for E and C, and a significant ExC interaction (Table 14). The analysis of the second half of the data (items 49-96) showed a significant main effect for C only (Table 15).

In group two (long ISI) the analysis of the two halves of the test showed significant main effects for C only (Table 16, Table 17).

2. Response time. Separate analyses of response times for first and second halves of the experiment showed significant main effects for C, T, and S in both halves. The F ratio for E is less in the second half of the experiment (Table 18, Table 19).

3. Sign test. A different way of examining ear dominance is to class each S as to whether he shows a right or left ear dominance. Ss who show no difference in either direction are disregarded by the analysis. A sign test was performed within ear stimulus conditions (Table 20). The results of this analysis were essentially the same as those obtained in the analysis by t test. The only significant ear difference was found within the musical stimulus

Table 14

Main Experiment

Five Second ISI Group

Analysis of Variance:

Number Correct in First Half of Experiment

Source	df	MS	F
Ear (E)	1	25.0	4.85 ⁺
Stimulus Condition (C)	3	74.9	21.05 ⁺⁺⁺
ExC	3	12.38	3.72 ⁺⁺
Subjects (S)	31	7.68	
ExS	31	5.12	
CxS	93	3.54	
ExCxS	93	3.30	

⁺ p<.05
⁺⁺ p<.025
⁺⁺⁺ p<.001

Table 15

Main Experiment

Five Second ISI Group

Analysis of Variance:

Number Correct in Second Half of Experiment

Source	df	MS	F
Ear (E)	1	0.66	<1
Stimulus Condition (C)	3	39.04	8.85 ⁺⁺⁺
ExC	3	4.48	1.37
Subjects (S)	31	13.59	
ExS	31	2.05	
CxS	93	4.40	
ExCxS	93	3.27	

⁺⁺⁺ $p < .001$

Table 16

Main Experiment

Twelve Second ISI Group

Analysis of Variance:

Number Correct in First Half of Experiment

Source	df	MS	F
Ear (E)	1	1.40	<1
Stimulus Condition (C)	3	66.42	14.34 ⁺⁺⁺
ExC	3	3.38	<1
Subjects (S)	31	13.47	
ExS	31	7.83	
CxS	93	4.63	
ExCxS	93	4.02	

⁺⁺⁺ $p < .001$

Table 17

Main Experiment

Twelve Second ISI Group

Analysis of Variance:

Number Correct in Second Half of Experiment

Source	df	MS	F
Ear (E)	1	7.91	1.67
Stimulus Condition (C)	3	55.64	10.21 ⁺⁺⁺
ExC	3	3.64	<1
Subjects (S)	31	16.60	
ExS	31	4.75	
CxS	93	5.45	
ExCxS	93	3.90	

⁺⁺⁺ $p < .001$

Table 18

Main Experiment: First Half

Analysis of Variance:

Mean Response Times (Log Seconds)

Source	df	MS	F
Time (T)	1	.9193	11.34 ⁺⁺
Sex (S)	1	1.0132	12.49 ⁺⁺⁺
TxS	1	.0002	<1
error (b)	60	.0811	
Ear (E)	1	.0168	2.59
ExT	1	.0000	<1
ExS	1	.0010	<1
ExTxS	1	.0045	<1
error ₁	60	.0065	
Stimulus Condition (C)	3	1.3911	68.96 ⁺⁺⁺
CxT	3	.0245	1.21
CxS	3	.0162	<1
CxTxS	3	.0180	<1
error ₂	180	.0202	
ExC	3	.0093	1.04
ExCxT	3	.0020	<1
ExCxS	3	.0113	1.27
ExCxTxS	3	.0061	<1
error ₃	180	.0089	

⁺⁺ $p < .01$
⁺⁺⁺ $p < .001$

Table 19

Main Experiment: Second Half

Analysis of Variance:

Mean Response Times (Log Seconds)

Source	df	MS	F
Time (T)	1	.7324	7.64 ⁺⁺
Sex (S)	1	1.3873	14.48 ⁺⁺⁺
TxS	1	.0983	1.02
error (b)	60	.0958	
Ear (E)	1	.0231	1.47
ExT	1	.0012	<1
ExS	1	.0061	<1
ExTxS	1	.0054	<1
error ₁	60	.0157	
Stimulus Condition (C)	3	1.3182	35.96 ⁺⁺⁺
CxT	3	.0177	<1
CxS	3	.0149	<1
CxTxS	3	.0636	1.73
error ₂	180	.0366	
ExC	3	.0256	1.52
ExCxT	3	.0281	1.67
ExCxS	3	.0137	<1
ExCxTxS	3	.0188	1.12
error ₃	180	.0168	

⁺⁺ $p < .01$
⁺⁺⁺ $p < .001$

Table 20

Main Experiment

Sign Test: Ss with Left Ear Dominance^a

	Stimulus Condition			
	Music	Timbre	Rhythm	Tone Pattern
Proportion	.68	.42	.43	.61
N ^b	60	55	58	56
z ^c	2.71	1.08	-.92	1.47
p<	.003	.15	.82	.07

^a Dominance defined by left ear minus right score of one or more.

^b Ss with left minus right=0 were not included in the analysis.

^c 1 tailed

condition, where most Ss showed left ear dominance ($p < .005$). A majority of Ss (61 percent) showed left ear dominance in the tone pattern condition but this falls short of statistical significance (1 tailed $z = 1.47$ $p < .07$).

IV. Discussion

The first purpose of this study was to replicate the finding of a left ear dominance for dichotically presented music and to investigate the generality of the phenomenon under experimental conditions not previously used. A second purpose of the study was to indicate what components of music, if any, are critical in producing the finding of a left ear superiority. The effect of memory on the differences in recall between right and left ears was also examined. Finally, response time was investigated as a potentially useful indicator of ear difference.

A. Dependent Variable One (Number Correct)

1. Stimulus conditions. No specific predictions were made with regard to the effect of experimental conditions on overall level of performance. The differences between various stimulus conditions in level of performance may be taken as an index of their difficulty. Considered in this way the stimuli in the order from least to most difficult are: timbre, music,

rhythm, and tone pattern. This ordering is found both under long and short ISI conditions. In the absence of a priori reasons for predicting different levels of difficulty for the different stimulus conditions, statistical tests between individual mean scores were not performed.

The relationships between the stimulus conditions in the two experimental groups are shown graphically in Figure 1. This relationship indicates that the conditions are ordered according to degree of familiarity, with music and timbre being more familiar than pattern and rhythm. This explanation assumes that even though the melodies themselves have not been heard before they appear familiar to the Ss since they are composed in traditional style and performed on a commonly heard musical instrument. In a similar fashion the pipe organ can be considered as a familiar sound to most Ss even though the experience of judging continuous tones on this instrument is not. By comparison, rhythm and tone patterns are quite unique. The stimuli for the tone patterning experiment were selected randomly and as a result many of the "melodies" constructed were not musical in the sense of being commonly heard combinations of notes. For example, one S described a tone pattern as "atonal electric music". The rhythmic patterns in this experiment were

quite unique and unfamiliar to the Ss. Even if a S were familiar with Morse code the experimental stimuli would not be recognized as a familiar pattern since stimuli were made up of tone and pulse intervals that varied in four rather than two time dimensions. It appears then that level of difficulty is related to stimulus familiarity, with music and timbre the most familiar stimuli and tone pattern and rhythm the least familiar.

Another explanation for the obtained order of stimulus difficulty could be found according to the amount of information contained in them. Miller (1951) states that the amount of information in a sound wave is proportional to the duration of the signal, the range of the frequency components involved, and the logarithm of discriminable steps in amplitude.³

In this experiment music contains the greatest number of discriminable steps in amplitude and has the greatest range of frequency components. The timbre stimuli have few amplitude changes but comprise many discriminable overtones. The tone patterns have no amplitude changes and contain a maximum of eight

³Amount of Information = $2 TW \log \frac{S+N}{N}$, where
 T = duration of signal, W = width of band of frequencies,
 S = maximum amplitude of the signal, N = the size of a
 discriminable difference in amplitude (Miller, 1951, p. 45).

frequencies, and the rhythm stimuli contain only two frequencies but have several on-off amplitude changes. All stimulus conditions have the same duration with the possible exception of rhythm which, unlike the other conditions, is not continuous. Following Miller's definition of information, music and timbre would be expected to be the most discriminable stimuli and tone pattern and rhythm the least.

The nature of scoring used in this experiment could have allowed Ss to get spuriously high scores if a strategy of yes guessing had been adopted. The degree of yes guessing was estimated by calculating the mean number of false positive responses within each condition. The number of false positive responses varied widely from condition to condition and was always less than would be expected by random guessing⁴. The fact that false positives varied widely and were based on repeated measures on the same Ss in each condition discounts the possibility that Ss used a systematic strategy that would maximize their scores.

2. Time. The overall difference in performance level between the long and short ISI groups is consistent

⁴Mean number of false positive responses per ear are: music 4.7, timbre 8, rhythm 10, tone pattern 8.5. Means which fall below 11.9 are significantly less than chance at the .05 level of confidence.

with other experiments which find a decrement in performance following longer memory intervals (Woodworth & Schlosberg, 1955).

The major difference of interest between the two time groups lies in the fact that the predicted left ear dominance for music is found only in the group with the short ISI. This result is in the opposite direction from the prediction made in hypothesis five and will be discussed in conjunction with other findings regarding ear of presentation.

3. Ear of presentation. For ear of presentation a main effect favoring the left ear across all conditions in the short ISI group was obtained. However, because of the specific predictions made and because of the significant ExC interaction the differences between ears will be discussed separately within each stimulus condition.

a. Hypothesis one. A statistically significant difference obtained in the short ISI group supports the prediction of a left ear superiority in the recognition of dichotically presented music. This finding replicates Kimura (1964) and demonstrates that in normal right handed ss opposite ear preference exists for the identification of verbal and musical stimuli. The demonstration of an ear difference using a motor rather than a spoken or sung response

discounts the likelihood of the ear asymmetry being response related and validates an experimental technique that provides more control over experimental variables than has been available in previous experiments. No such difference was obtained with long ISIs.

This hypothesis is concerned with whether or not there is a right hemisphere superiority in the identification of musical stimuli. It also pertains to the question of whether or not such a difference is due primarily to perceptual or memory processes. Kimura (1961b) maintained that right ear dominance for words in a DLS situation was due to enhanced perception caused by the strong contralateral signal arriving at the speech dominant hemisphere. Inglis (1965) suggested that the difference was not one of perception but rather one of selective retrieval from memory storage. The distinction between differences due to perception and those due to memory is somewhat artificial in an experimental situation since any identification response necessarily involves some memory component, albeit a brief one. However, perceptual influences can be usefully defined as differences occurring following very short ISIs.

In this experiment the left ear preference effect is demonstrated after an ISI of 5 seconds but not after an ISI of 12 seconds. This suggests that if memory

processes are involved in producing ear differences under dichotic conditions of presentation they are most effective under relatively short spans of memory and are no longer operating with longer ISIs. However, without knowing the degree of ear difference that occurs following still shorter ISIs (e.g., less than 1 second) the question of perceptual differences remains rather speculative. The question of memory process is examined more fully in the discussion of hypothesis five.

b. Hypothesis two. The prediction that tone patterns would evoke left ear preference followed from the evidence that right hemisphere damage creates a specific deficit in the recall of this type of stimulus (Milner, 1962).

This hypothesis cannot be supported by the data in this experiment. It should be noted, however, that there is a moderately large observed ear difference in the predicted direction (one tailed t test $p < .10$; one tailed sign test $p < .07$). The overall level of performance on this test and the guessing rate as indicated by false positive responses show this to be a difficult test. This raises the possibility that a real ear difference has been obscured by task difficulty.

Alternatively, for this particular stimulus a 5 second interval may be too long to retain a memory trace. Egeth (1967) has called attention to the lack of data on auditory trace decay. He noted that visual trace decay is very rapid within the first half second. The Seashore tonal memory test used by Milner has an interval of less than 1 second between the stimulus patterns and the matching foils. In light of the possibility of a rapid memory trace decay for musical stimuli, it might be possible that dichotic tone patterns of the type used in this experiment would show the hypothesized left ear dominance had the recognition foils followed the dichotic stimuli by a much shorter interval (i.e., less than 1 second).

c. Hypothesis three. The predicted left ear superiority for the recognition of timbre was not demonstrated. This hypothesis was suggested by the deficit shown by Ss with right hemisphere damage (Milner, 1962). The observed differences, while not significant, are opposite in direction to the hypothesis.

Simon (1967) suggested that under conditions of uncertainty Ss responded to pure tones more rapidly at the right ear than the left. He attributed this to an habitual expectancy favoring the right ear. It might be argued that, like pure tones, timbre stimuli are relatively devoid of meaning and that Ss respond

with similar expectancies.

Neither Milner's nor Simon's study is directly comparable to the present one and under the circumstances the observed difference is best attributed to random variability.

d. Hypothesis four. This hypothesis predicted there would be no significant difference between right and left ears in the identification of rhythmical patterns. This hypothesis cannot be rejected.

The dichotic stimulus pairs in this test are not completely dichotic in the sense that they are both simultaneous and different. Although the onset of the pulses was simultaneous, offset of one member occurred before the other. Thus the difference in rhythmical patterning results in the fact that for brief periods one ear is receiving stimulation while the other is not. This difference may lessen the stimulus competition that the DLS technique attempts to achieve, since the signal from the ear still receiving a pulse will be represented bilaterally.

Recently, Bakker (1967, 1968) has shown that Ss asked to reproduce monotonically presented Morse code like stimuli demonstrate a left ear superiority. The apparent conflict in results between the Bakker studies and the rhythm test in this study may be due in part to differences in ISI. Bakker's Ss responded immediately.

In light of Bakker's results this lack of competition, due to differences in offset time, is probably not critical. However, even if the stimuli are not conceived of as being in competition, the S must make and recall a discrimination between two patterns rather than one, as in monotic presentation. The greater difficulty of this task may in part account for differences between Bakker's results and those reported here.

e. Hypothesis five. This hypothesis predicted greater performance differences between ears for the experimental group with the long ISIs. The hypothesis is not supported by this experiment. Instead just the opposite appears to be the case. These results are pertinent to the question of whether ear superiority is primarily a result of perceptual or memory processes.

Broadbent (1958) held that the S could only attend to one stimulus at a time. When two simultaneous stimuli were presented, the stimulus attended passed directly into the usual sound processing system for short term memory and recall (p-system) and the unattended stimulus was shunted into an emergency storage system (s-system) where it was subject to rapid memory trace decay. Broadbent held that Ss could not switch attention rapidly between input channels. Consequently, when pairs of stimuli were

presented rapidly (one pair per half second) the S did not switch attention between ears but maintained attention to one ear. This accounted for the EOR.

Rather than EOR, Kimura has emphasized the lateral dominance shown by the superior recall of verbal stimuli presented to the right ear over those presented to the left ear. Satz et al. (1965) have shown that both EOR and right ear preference occur and that these two models for DLS are compatible. Satz' experiments show that ear differences in performance are not usually present in the first half span of recalled digits. The appearance of ear dominance in the most memory dependent part of the test suggests that the stimuli which were presented to the right ear are in some way retained better than those presented at the left ear.

Hypothesis five was derived from Broadbent's conceptualization of separate memory processes for simultaneous stimuli. The nonattended, i.e., non-dominant, ear was expected to show more rapid decay and hence a greater ear difference following the long ISI.

There are two possible explanations for the failure of this experiment to support this hypothesis. The first explanation assumes that the Broadbent memory model is essentially correct but that the choice of

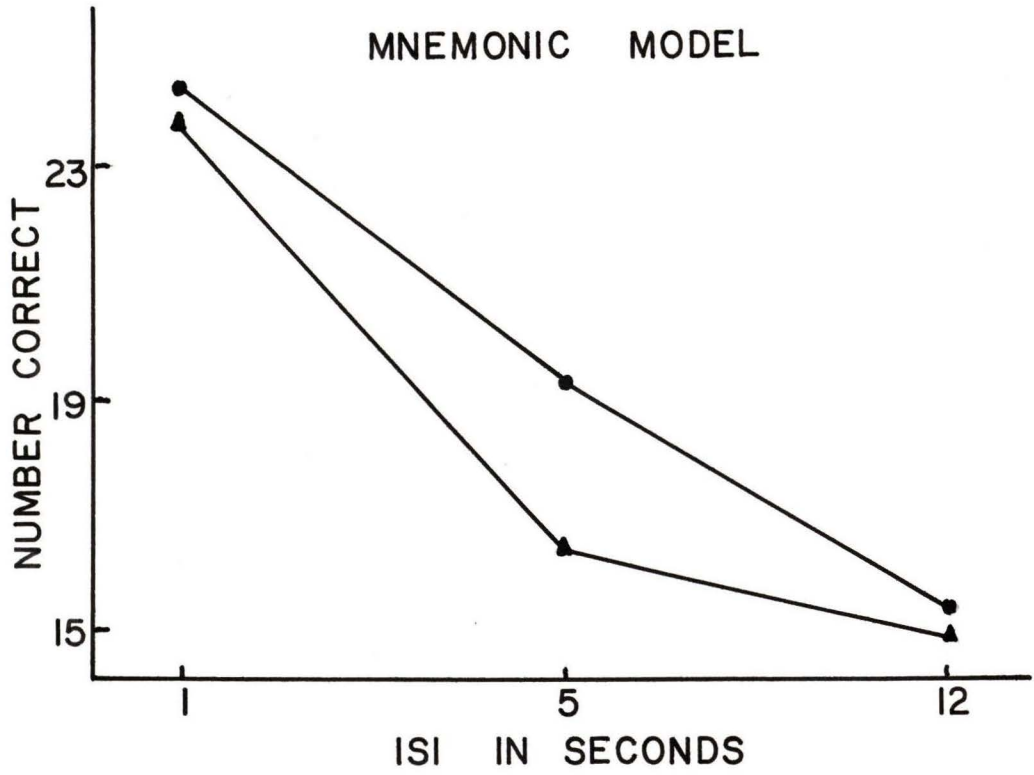
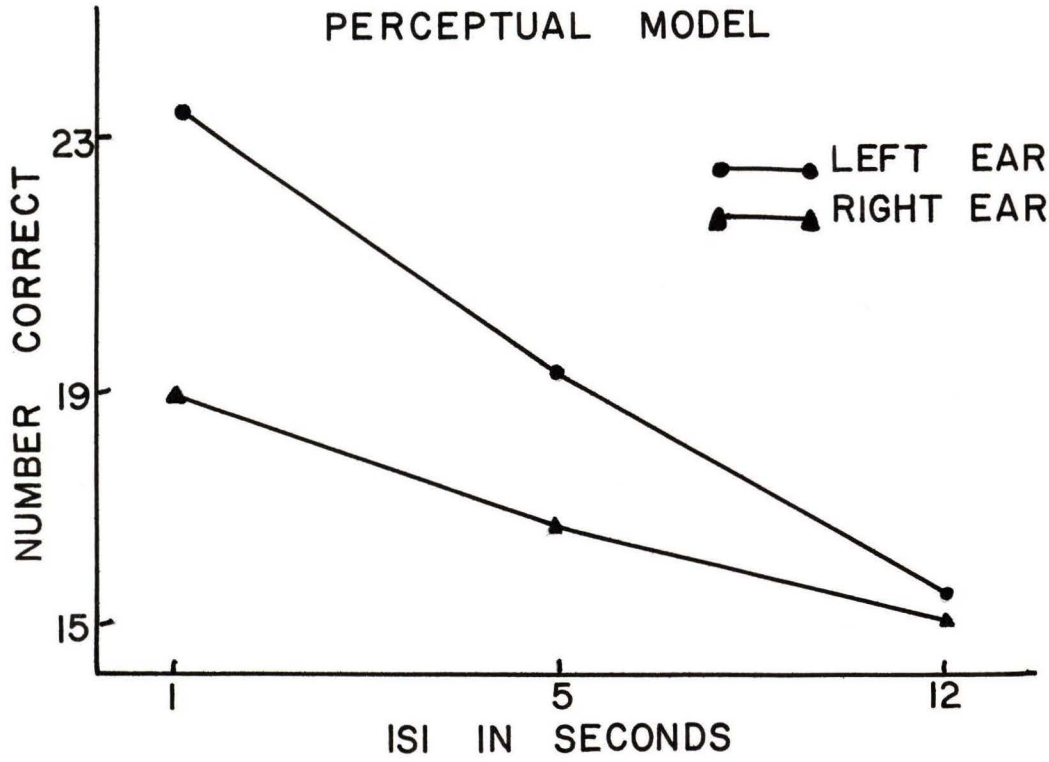
ISIs in this experiment was not an appropriate one. It may be the case that 5 seconds is a long interval for the retention of unfamiliar stimuli. By 12 seconds the immediate memory traces from both ears have completely decayed. This mnemonic process model would predict that at 1 second or less the ear differences would be very slight. This would be consistent with the evidence from verbal DLS studies which show little ear difference in the first digits recalled.

A second explanation is provided by Kimura's (1961b) argument that ear differences are primarily a perceptual phenomenon. This position implies a significant difference between the ears at short ISIs. Presumably this difference would lessen rather than increase as the ISI grows longer. With this model it is not necessary to make the assumption of two types of memory. These models are compared graphically in Figure 4.

It can be seen that either of these models can account for the results obtained in the present experiment and that they make different and testable predictions about size of ear difference that would be obtained following an ISI of 1 second or less.

The question of perception versus memory cannot be determined from the available literature since ISI has not been controlled in previous studies. In Kimura's

FIGURE 4



(1964) study using musical stimuli, the Ss task was to identify the two of four multiple choice foils which were the same as the members of the dichotic pair. These stimuli were 4 seconds in length and separated by a 3 second interval. The first of the foils was presented 4 seconds after the dichotic pair. It can be seen that her Ss were responding to a last foil that began 29 seconds after initial stimulation. The midpoint of the response foil sequence occurs 15.5 seconds after the dichotic stimuli. The demonstration of a left ear preference under these circumstances led to the selection of 5 and 12 second ISIs as the short and long recall intervals for this experiment.

Following the present experiment's failure to demonstrate an ear difference at a 12 second ISI, a re-examination of Kimura's study suggests that the critical interval of recall in the Kimura study may be less than it initially appeared. In each set of four multiple choice foils, the S knew that two of the foils were a repetition of the dichotic stimuli and two were neutral foils. If the S correctly identified the first of the four foils, the remaining three could be determined with a probability of .67. Thus it can be argued that the left ear superiority was due primarily to correct identification of the first foil presented and that the remaining foils were identified

at a better than .5 probability. If this is the case the critical responses in the Kimura study follow a 4 second interval which is comparable to the results obtained in the present experiment. Unfortunately Kimura does not present an analysis of her Ss' responses on a per foil basis.

Milner's (1962) demonstration of a deficit on the tonal memory test, by patients after right temporal lobectomy, occurred following an ISI of less than 1 second. Bakker showed a left ear superiority in immediate reproduction of code messages; however, the time between stimulus and response was not measured. Neither of these two studies employed DLS and so generalizations to dichotic music are tentative. They do suggest, however, that a significant ear preference for music may be found following short ISIs.

B. Dependent Variable Two (Response Time)

In the analysis of dependent variable two, the length of time required for the S to respond to the foil was taken as an index of the time necessary to recognize the stimulus foil.

1. Hypothesis six. It was hypothesized that response time would show results parallel to those hypothesized for dependent variable one in hypothesis one through five. This hypothesis received only partial support.

2. Sex, time, and stimulus condition. In this analysis males responded significantly more quickly than females. Even though this measure was not a motor reaction time measure in the traditional sense, this finding is consistent with studies of reaction time (Woodworth & Schlosberg, 1955) which characteristically find males responding faster than females.

Overall speed of response indicates the degree of difficulty inherent in individual stimulus conditions. The order of conditions corresponds closely to that obtained with the number correct responses as dependent variable one. Timbre and music are identified more quickly, tone pattern and rhythm more slowly.

The superiority of time one over time two parallels the findings of dependent variable one.

The above results support the proposition that dependent variable two is primarily an index of speed of recognition rather than motor reaction time, although the sex difference may in part be accounted by motor reaction time differences.

3. Ear of presentation. The overall difference between ears is significant and in the predicted direction. The stimuli presented to the left ear were responded to more rapidly than those presented to the right. This supports the hypothesis of left ear dominance. Failure to detect significant differences

within individual stimulus conditions does not allow more specific statements with regard to the ear effect within each of the stimulus conditions.

In this experiment response time did not prove to be as useful a variable in detecting possible ear differences as did the number of correct identifications. However, the fact that a main effect for the ear factor was obtained suggests that recognition time is a potentially useful variable. The significant ear difference is in the opposite direction from that obtained by Simon (1967). This suggests that the time variable is not reflecting auditory-motor reaction time. Since Ss were given no instructions to respond rapidly, it seems likely that the experimental precision of response time as a variable was reduced due to an increase in subject variability.

C. Attention

First and second half analysis of the number of correct responses shows that left ear preference in group one (short ISI) is present only in the first half of the experiment. However, there is still a significant effect on level of performance attributable to the different stimulus conditions in the second half of group one. No ear effect is present in either half of group two (long ISI).

The two halves of the test represent the performance of the same persons on identical test items. The disappearance of the ear effect in the second half of the experiment suggests that attention is related to the production of ear dominance in dichotic listening experiments.

Treisman (1968) has discussed the role of selective attention in the perception of dichotic speech. Her Ss were required to verbally shadow (i.e., repeat) a speech message being presented to one ear and, at the same time, to respond, by tapping, to certain key words in a speech message being presented to the opposite ear. Treisman found that Ss' tapping to target words presented at the right ear was better than at the left ear when these words were in the nonshadowed message. She further notes that Ss made more errors mainly for nontarget words in the left ear message. Treisman (1968) interprets her findings in the following manner: "The ear asymmetry was shown only when Ss attention was focused on some other aspect of the task." She concludes "...right ear dominance is primarily a quantitative difference in the distribution of attention to left and right ear inputs (p. 139)."

Simon (1967) has also indicated that attention plays a part in the efficiency of auditory perception. Under conditions of uncertainty as to which ear would

be stimulated, Ss characteristically showed a right ear superiority in motor reaction time to a monotonically presented tone. This superiority disappeared when Ss were informed in advance of the ear to be stimulated. Simon postulates an ear expectancy to explain this finding. He suggests that Ss tend to "tune in" with their right ear and therefore react faster on trials where the stimulus source corresponds to their expectancy. The implication of an habitual set or tendency to attend to the right ear advanced by Simon is not consistent with the left ear dominance obtained in the present experiment unless one assumes with Treisman that an ear preference in the recognition of complex sounds occurs at the nonattended ear.

These two studies are not directly comparable in as much as Treisman's Ss had to respond to meaningful stimuli (words) which requires cortical analyses whereas Simon's Ss were involved in nonmeaningful signal detection, which is a much simpler, and primarily subcortical, task (Shankweiler, 1966).

The experiments of Treisman and Simon indicate, however, that selective attention is involved in producing an ear difference in response to auditory stimuli. It is not possible from the available evidence to say what part attention plays in the production of an ear preference in DLS. However,

attention appears to be a necessary if not sufficient conditions for the demonstration of left ear dominance for music.

Chapter V

Implications for Future Research

The present study raises questions concerning the parts played by attention and memory in the production of left ear superiority in the recognition of musical stimuli.

A. Interstimulus Interval

In previous studies employing DLS, the length of the interval between stimulus and response has not been controlled. The usual experimental method requires S to verbally identify the stimuli when he is ready. This length of time has not been measured. Verbal DLS experiments indicate that the ear difference appears in the most memory dependent portion of the stimulus recall (Satz et al., 1965). The stimuli used (spoken digits) have a high degree of familiarity and are presented in groups of three pairs or more. This stimulus paradigm typically produces an ear order effect. Thus with verbal stimuli it appears that ear differences increase with length of recall interval.

It was pointed out in the previous chapter that the ear differences obtained following the short ISIs could be equally well explained by either of two theoretical models which generate opposite predications

for intervals shorter than 5 seconds.

The results of the present study considered with the findings of Milner (1962) and Bakker (1967, 1968) indicate that for music the shorter ISI may produce greater ear difference. If this hypothesis were confirmed it would indicate that the different ear preference for verbal and musical stimuli was related to different mnemonic and perceptual processes as well. The solution to the question of whether ear superiority is due primarily to perceptual or mnemonic processes or to an interaction of the processes can be approached by systematically varying the length of the ISI from less than 1 second to more than 5 seconds.

This experimental manipulation of ISI should be done with musical stimuli such as used in the present experiment in order to establish the nature of the interval of recall on this particular stimulus. In addition it would be reasonable to use tone patterns and social sounds as dichotic stimuli. With both of these stimuli there is reason to believe that the failure to obtain significant ear differences in the experiments reported above was due to ISIs which were too long.

B. Attention

The failure to find significant ear differences in the second half of the experiment in the short ISI

group indicates that attention is a factor that influences ear dominance. The classical study of Hernandez-Peon (1956) with unanesthetized cats has demonstrated that increased attention to another sense mode, i.e., tactile, visual or olfactory, can inhibit evoked electrical potentials to auditory stimuli. A similar phenomenon has been demonstrated with human ss. Hernandez-Peon and Donoso (1957) found that evoked potentials to visual stimuli were inhibited by requiring the s to perform mental arithmetic and that the more difficult the problem the greater the inhibition. Grossman (1967) notes that the finding of suppression of auditory input by attention is typically present only under conditions of arousal as indicated by EEG.

In considering the effect of attention upon the production of ear preference in DLS it might be speculated that there is a selective suppression of auditory input from one ear. If this were the case it could be argued that the ear differences in DLS experiments are in part due to differences in perceived loudness. This hypothesis could be readily tested using standard psychophysical methods for matching the intensities of two stimuli.

C. Methodology

The present study has shown that the ear difference in DLS can be obtained in the absence of an articulated response, and in a way offering exact control over the time of the recall interval. This technique could be usefully employed in DLS studies using verbal stimuli. In comparing the lateral asymmetries in the perception of words and music, very different experimental methods have been used and the stimuli involved have differed greatly in familiarity. To eliminate differences in discriminability between words and music it would be possible to create a set of stimuli which were equally discriminable, e.g., 50 percent of the time. This could be done by manipulating the background noise level for words or by selectively cutting speech frequencies out of the stimuli.

The notion of a bilateral functional asymmetry for words and music would be more compelling if the phenomenon were demonstrated under identical experimental conditions, with familiarity and discriminability controlled.

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Appendix A

University of Victoria
Neuropsychology Laboratory

Research Subject Information

Name:

Age:

Sex:

- A. Do you have normal hearing in both ears so far as you know? Yes No
- B. 1 With which hand do you write? Right Left Both
- 2 With which hand do you use a scissors? Right Left Both
- 3 With which hand do you use a screwdriver? Right Left Both
- 4 With which hand do you throw a ball? Right Left Both
- 5 In baseball, do you bat right-handed or left-handed? Right Left Both
- 6 With which hand do you use a hammer? Right Left Both
- 7 With which hand do you use a needle in sewing? Right Left Both
- 8 With which hand do you usually carry books? Right Left Both
- 9 With which hand do you usually carry a suitcase? Right Left Both
- 10 With which hand do you hold the toothbrush when brushing your teeth? Right Left Both
- C. This research will take about 30 minutes of your time on each of four different days.
1. Would you be willing to come to the University Psychology Laboratories during the following times:
- | | | |
|-------------|-----|----|
| 9 - 12 a.m. | Yes | No |
| 1 - 5 p.m. | Yes | No |
| 5 - 10 p.m. | Yes | No |
2. Do you have your own transportation for later afternoon or evening when school is out:
(If not, transportation will be provided)
- Yes No

Appendix B

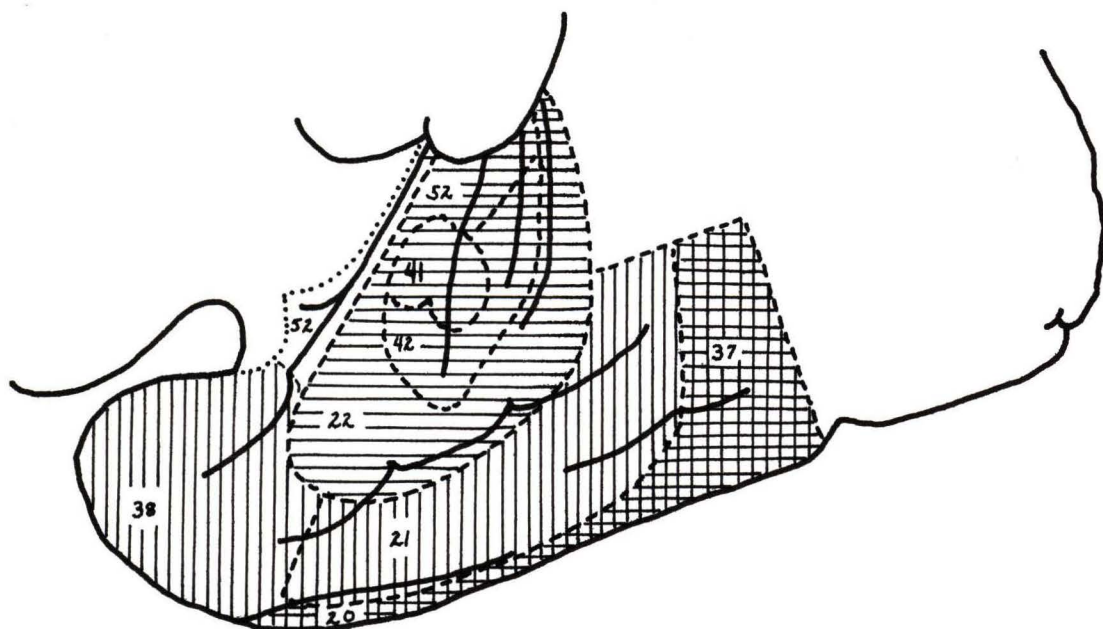
The timbre selections were made up of the following combinations of stops.

1. Trumpet 8'
2. Rohrflöte 8'
3. Gemshorn 8' and Quintaton 16'
4. Diapason 8' and Spitzflöte 4'
5. Diapason 8', Octave 4', and IV Fourniture 1 1/3'
6. Gemshorn 8', Spitzflöte 4', and Superoctave 2'
7. Choir 16', Blockflöte 4', and Krummhorn 8'
8. Hautbois 8' and Octavin 4'
9. Swell 16', Cor de Nuit 8', and Octave 4'
10. Viole de Gambe 8', Plein Jeu 4', and Nazard 2 2/3'
11. Schalmei 4' and IV Mixture 2 2/3'
12. Choral bass 8', Principal 4', and IV Mixture 2 2/3'
13. Nachthorn 8' and Schalmei 4'
14. Nachthorn 8', Schalmei 4', and IV Mixture 2 2/3'
15. Oboe 8' and Echo 4'
16. Erzähler 8', Sesqui Altera 2 2/3', and
III Cymbal 1/2'
17. Erzähler 8', Koppelflöte 4', Quintflöte 1 1/3'
18. Erzähler 8', II Sesqui Altera 2 2/3', Quintflöte
1 1/3', and III Cymbal 1/2'
19. Choir 16', Erzähler 8', II Sesqui Altera 2 2/3',
Quintflöte 1 1/3', and III Cymbal 1/2'
20. Trumpet 8', Spitzflöte 4', and IV Fourniture 1 1/3'

21. Trumpet 8', Superoctave 2', and IV Fourniture 1 1/3'
22. Hautbois 8', Octave 4', Nazare 2 2/3', IV Plein Jeu 1'
23. Swell to Great 8', Trumpet 8', Trompette 8',
Gemshorn 8', Nazard 2 2/3', IV Fourniture 1 1/3',
IV Plein Jeu 1'
24. Trompette 8', Gemshorn 8', Nazard 2 2/3',
IV Fourniture 1 1/3', IV Plein Jeu 1', (Swell to
Great 8')
25. Hautbois 8', Basson 16', Flute Harmonique 4'

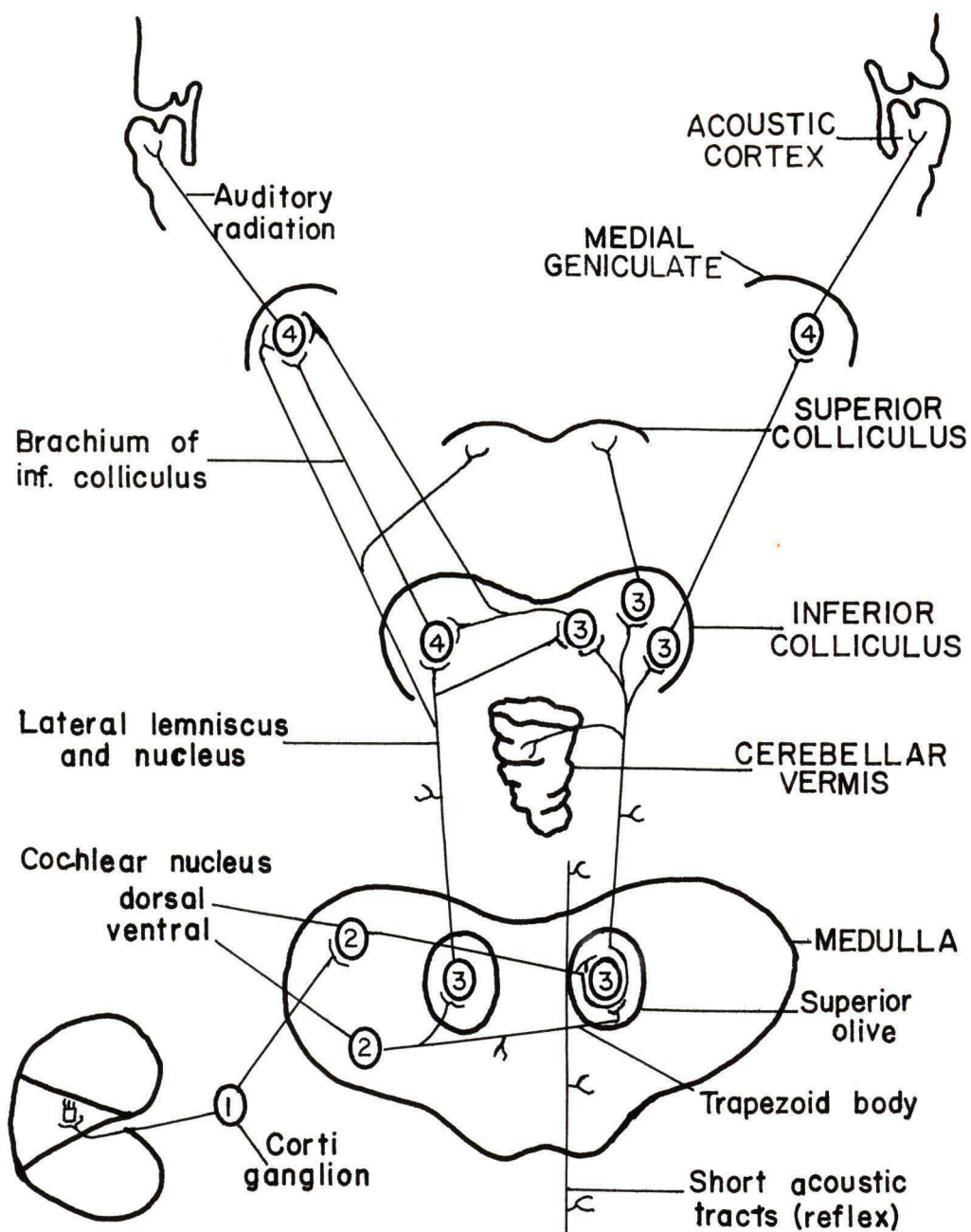
APPENDIX C

- ==== SENSORY-ACOUSTIC AREA
||||| MOTOR-ACOUSTIC AREA
||||| PSYCHO-ACOUSTIC AREA



Kleist's (1928) auditory cortical areas. Area numbering according to Brodmann (1914). Taken from Spreen et al. (1965).

APPENDIX D



The afferent acoustic pathways. The "order" of each neuron is identified by a number. Taken from Davis (1951).

APPENDIX E

Pilot Experiment: Number Correct

Response Mode

Subject Number	Words		Pictures		Sounds	
	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear
1	8	4	6	9	9	7
2	7	9	8	10	10	14
3	10	11	10	9	12	11
4	12	11	11	13	14	11
5	6	7	8	12	10	12
6	11	12	11	10	13	12
7	11	8	7	9	10	10
8	10	8	12	8	10	11
9	13	13	10	9	14	14
10	11	10	8	11	8	11
11	10	10	11	10	13	12
12	6	7	8	8	13	9
13	3	8	7	10	10	11
14	7	7	11	11	13	11
15	12	11	11	9	13	8
16	5	8	6	4	8	13
17	9	10	11	9	12	10
18	5	4	5	7	7	5

Appendix F

Main Experiment: Number Correct

5 Second ISI

S	Music		Timbre		Rhythm		Tone Pattern	
	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear
1	20	15	17	20	16	18	14	15
2	22	12	22	22	18	18	20	14
3	24	18	20	16	15	17	23	15
4	21	17	16	22	14	9	16	17
5	21	24	21	23	22	23	17	20
6	24	14	19	20	20	18	19	15
7	15	17	21	19	18	19	15	15
8	21	15	21	18	8	13	19	16
9	21	19	22	21	20	20	16	18
10	16	15	17	13	19	14	17	17
11	22	18	20	20	16	15	9	8
12	11	19	15	17	12	9	8	11
13	21	18	16	19	17	16	12	8
14	18	7	20	21	14	16	9	14
15	15	15	22	22	22	19	15	21
16	14	7	13	21	13	11	16	8
17	16	7	19	23	13	11	11	14
18	21	20	20	22	17	19	19	18
19	24	22	22	19	20	16	21	17
20	23	19	22	24	18	19	20	16
21	21	21	24	24	15	19	18	17
22	21	20	20	19	18	21	10	15
23	23	21	18	17	16	19	17	15
24	15	17	24	22	16	21	15	12
25	14	20	18	16	24	22	15	14
26	20	22	24	24	14	19	15	19

27	21	14	15	18	21	17	10	10
28	20	15	17	14	16	18	13	13
29	23	21	17	19	20	20	18	18
30	20	15	16	19	20	15	22	16
31	15	17	16	17	17	17	16	15
32	22	24	21	23	20	19	16	10

12 Second ISI

33	21	19	23	23	13	19	17	13
34	21	18	20	20	15	14	16	8
35	20	13	22	18	20	22	18	15
36	21	17	18	20	16	16	19	18
37	15	15	20	23	9	11	8	5
38	6	8	12	12	14	17	22	22
39	14	12	10	12	5	9	6	9
40	15	17	13	16	12	19	12	11
41	22	20	16	20	14	17	11	14
42	15	13	10	15	12	15	7	8
43	19	22	22	18	19	15	20	16
44	16	11	16	19	12	16	15	14
45	2	4	14	10	12	8	13	8
46	13	12	21	16	12	18	16	15
47	21	19	23	21	16	15	18	15
48	14	13	14	11	13	8	13	10
49	18	15	20	20	12	20	18	18
50	13	13	13	15	14	12	19	14
51	20	12	20	22	18	15	13	15
52	8	14	16	17	14	10	8	15
53	18	17	21	18	13	19	11	14
54	14	20	18	8	11	17	2	13
55	5	13	22	23	9	13	12	12
56	22	15	18	20	12	18	6	12

57	20	19	12	19	16	12	14	13
58	24	18	20	19	19	21	19	13
59	21	17	22	19	14	16	14	16
60	3	24	23	19	9	18	1	20
61	16	12	18	16	18	11	14	9
62	5	19	16	18	10	20	9	10
63	11	14	14	16	12	9	11	10
64	7	10	18	19	15	15	11	15

Note- Ss 1-16 and 33-48 are female.

Ss 17-32 and 49-64 are male.

Appendix G

Main Experiment: 5 Second ISI

Response Time (Log Seconds)

S	Music		Timbre		Rhythm		Tone Pattern	
	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear
1	1.864	1.867	1.924	1.959	1.902	1.896	2.072	2.079
2	1.912	1.905	1.933	1.937	2.000	1.949	1.906	1.929
3	1.810	1.963	1.915	1.777	2.213	2.233	1.812	1.920
4	1.824	1.953	1.760	1.852	2.296	2.184	1.710	1.929
5	1.957	1.839	1.813	1.816	2.035	2.108	1.909	1.880
6	1.904	2.039	1.887	1.829	2.187	2.219	2.032	2.050
7	1.867	1.944	1.808	1.892	2.177	2.189	2.028	2.133
8	1.957	1.926	1.832	1.826	2.258	2.151	1.454	1.482
9	2.055	1.978	1.900	1.977	2.100	2.140	2.203	2.117
10	1.876	1.911	1.783	1.823	1.980	2.046	2.104	1.912
11	1.775	1.940	1.472	1.435	2.126	2.184	2.088	1.963
12	2.111	1.984	1.772	1.785	2.168	2.220	1.901	2.040
13	1.753	1.816	1.954	1.954	2.171	2.116	1.844	1.839
14	1.963	1.999	1.778	1.756	2.059	2.041	1.815	1.878
15	2.088	1.985	1.795	1.821	1.986	1.905	1.942	1.914
16	2.027	2.088	1.957	1.908	2.135	2.253	2.087	2.128
17	1.867	2.123	1.166	1.227	1.952	1.884	1.836	1.898
18	1.797	1.984	1.848	1.746	2.119	2.166	1.936	1.906
19	1.748	1.831	1.753	1.677	2.009	2.045	1.688	1.887
20	1.732	1.950	1.221	1.200	1.744	1.847	1.603	1.732
21	1.411	1.401	1.256	1.272	1.855	1.829	1.641	1.717
22	1.800	1.690	1.532	1.595	1.930	2.011	1.892	1.845
23	1.821	1.850	1.893	1.836	2.001	1.959	1.456	1.597
24	1.803	1.785	1.754	1.782	1.904	1.930	1.850	1.883
25	1.930	1.911	1.956	2.128	2.135	2.159	2.115	2.106
26	1.845	1.836	1.466	1.511	2.031	1.995	1.878	1.751

27	2.111	1.960	1.787	1.803	1.968	2.043	2.109	2.202
28	1.652	1.739	1.571	1.541	1.975	1.905	1.985	1.855
29	1.780	1.845	1.946	1.905	2.001	1.962	1.673	1.692
30	1.673	1.703	1.621	1.732	1.802	1.917	1.735	1.775
31	1.957	2.060	1.765	1.920	2.097	2.125	1.967	1.884
32	1.936	1.852	1.923	1.939	1.826	1.861	1.995	1.926

Main Experiment: 12 Second ISI

33	1.641	1.813	1.660	1.575	2.050	2.048	1.962	1.934
34	1.775	1.714	1.867	1.766	2.087	2.168	1.866	2.097
35	1.939	2.086	1.688	1.615	2.172	2.158	2.071	2.029
36	1.861	1.995	2.036	1.982	2.204	2.270	2.048	2.057
37	2.046	1.923	1.904	1.690	2.283	2.245	2.037	2.233
38	2.395	2.204	2.381	2.401	2.371	2.371	2.018	1.924
39	1.917	2.103	1.848	1.611	2.063	2.123	2.201	2.226
40	2.033	1.986	2.041	1.929	1.966	2.106	2.199	2.166
41	1.879	1.904	2.099	1.842	2.230	2.037	1.912	2.062
42	1.906	2.003	2.067	1.833	2.273	2.146	1.896	2.032
43	1.906	1.927	1.759	1.873	2.236	2.281	2.033	1.920
44	2.086	2.026	1.643	1.782	2.189	2.029	1.918	2.040
45	1.514	2.237	1.946	1.797	2.283	2.271	2.059	2.202
46	2.967	2.284	1.873	1.899	2.171	2.176	2.066	2.003
47	1.970	1.929	1.812	1.836	2.087	2.179	1.950	1.942
48	2.370	2.288	2.379	2.480	2.199	2.514	2.159	2.089
49	1.823	1.870	1.493	1.591	2.235	1.963	1.861	1.805
50	2.018	2.185	1.556	1.669	2.091	1.963	1.912	1.930
51	1.923	1.964	1.819	1.896	2.263	2.166	2.126	1.957
52	2.406	2.312	2.337	2.166	2.373	2.407	2.251	2.235
53	1.826	1.733	1.541	1.649	1.908	1.855	1.679	1.742
54	1.756	1.579	1.686	1.635	1.985	1.928	1.705	1.724
55	1.924	1.950	1.869	1.888	2.277	2.151	2.006	2.020
56	1.832	2.084	1.780	1.869	2.122	2.097	1.981	2.020
57	1.732	1.826	1.783	1.818	2.001	2.044	1.831	1.856

58	1.797	1.805	1.772	1.721	2.041	2.004	1.761	1.887
59	1.730	1.820	1.940	1.908	2.063	2.123	1.967	1.982
60	1.946	1.787	1.852	1.881	2.217	1.995	1.428	1.924
61	1.890	1.944	1.918	1.855	1.988	1.926	2.049	2.037
62	1.912	1.853	1.973	1.875	1.936	1.949	2.108	2.036
63	1.966	1.942	1.970	2.129	2.274	2.304	2.032	1.805
64	1.898	1.902	2.000	1.986	2.046	2.084	1.785	1.890

Note- Ss 1-16 and 33-48 are female.
Ss 17-32 and 49-64 are male.

Surname: Spellacy Given Names: Frank Jared

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<u>Univ. of Hawaii, Honolulu</u>	<u>1963</u>	to	<u>1964</u>
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Publications:

<u>With Crowell, Davis, & Chunn, Galvanic Skin Reflex in</u>
<u>Newborn Humans, <u>Science</u>, 1965, 148, 1108-1111.</u>
<u> </u>
<u> </u>

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