THE UNIVERSITY OF CALGARY

HEMISPHERIC ASYMMETRY IN THE RECOGNITION OF MONAURAL, MELODIC, ASCENDING INTERVALS IN GRADE SIX, SEVEN AND EIGHT STUDENTS

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Patricia-Anne Hoag

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Hemispheric Asymmetry in the Recognition of Monaural, Melodic, Ascending Intervals in Grade Six, Seven and Eight Students," submitted by Patricia-Anne Hoag in partial fulfillment of the requirements for the degree of Master of Music

Walter P. Buehning

Chairperson, Dr. Walter Buehning
Department of Music

T. B. Rogers

Dr. Timothy Rogers
Department of Psychology

Nevaida L. Ries

Dr. Nevaida Ries
Department of Music

Malcolm V. Edwards

Professor Malcolm Edwards
Department of Music

Date April 22, 1986

Gregory John Levin

Dr. Gregory J. Levin
Department of Music

ABSTRACT

The purpose of this study was to examine whether there is any hemispheric asymmetry demonstrated in the task of interval recognition. Such asymmetry would be indicated by a left or right ear differential using the criteria of response time and number of correct responses.

The subjects were 32 grade six, seven and eight students from two schools in southwestern Ontario. All subjects were right handed and judged to be free of any form of hearing impairment or learning disability. The students were divided into a Perfect Fourth and a Major Third Group. The subjects listened to the monaurally presented tonal stimuli from a cassette recorder via headphones through one ear and, after a five minute rest, through the opposite ear. This was repeated on four occasions using four different tapes containing 32 intervals. The Perfect Fourth Group tapes contained two practice intervals followed by 10 perfect fourths, 10 perfect fifths and 10 major thirds. The Major Third Group tapes contained two practice intervals followed by 10 major thirds, 10 perfect fourths and 10 major seconds. The order of intervals was randomly assigned and the

range used was from 196 Hz to 523 Hz. Students were asked to push a "Yes" or "No" response key to indicate whether the target interval had been heard. Subjects in both groups were randomly divided so that 50 percent listened with their right ear first and 50 percent listened with their left ear first. Half of the subjects in each of the subgroups were instructed to use their right hand to respond and the other half to use their left hand.

A Commodore 64 computer recorded the responses and clocked the elapsed time from the initiation of the first tone to when the response key was pressed.

Statistical analyses of ear scores consisted of three-way analysis of variance with repeated measures using various combinations of the factors hand, ear, intervals and trials. The extraneous variable of musical background was subjected to a Student t-test.

In conclusion, the results indicated no significant ear advantage in regard to the accuracy or efficiency of recognizing monaural, melodic, ascending intervals.

Recommendations for further research include the study of why some intervals are more difficult to learn than others.

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CHAPTER 1

INTRODUCTION

Numerous studies in the last thirty years have suggested that the left and right cerebral hemispheres for right handed people differ from each other in two ways:

a) The left hemisphere is specialized in language functions and tasks involving abstraction of verbal information from auditory and visual stimuli. The right hemisphere is specialized for perceptual tasks such as those stressing visuospatial processing.

b) The left hemisphere is specialized for an analytic or serial mode of processing while the right hemisphere is specialized for a holistic or parallel mode of processing.

It is a matter of current controversy whether hemispheric specialization is primarily a function of the nature of the stimulus or of the stimulus-processing used. Both visual and auditory stimuli have been used to investigate this question.

Theories concerning hemispheric function originally led some researchers to conclude that certain sections of the brain were devoted to specific subject areas. More recent studies suggest that the different processes of the two hemispheres are neither stimulus nor modality specific. The research indicates that the left hemisphere processes stimuli relationally, analyzing the components of the internal structure of a specific stimulus, while the right hemisphere performs holistic analysis on the overall contours of a stimulus. Therefore, both hemispheres may be used in the total processing, depending upon what information or relationship the subject requires from it.

Other studies indicate that whether relational or holistic processing is performed upon a given stimulus depends, in part, upon the subject's previous experience with the task. There is also evidence that the lateralization of these processes differs according to the handedness of the individual.

The question as to how music is perceived or processed is far from being answered. There have been relatively few investigations of cerebral control of musical behaviours in comparison to those which have been done in language related areas.

Part of the difficulty in arriving at specific conclusions concerning music processing may be in the nature of the stimulus itself. Music is a complex combination of pitch, harmony, intensity, timbre and rhythm. In addition, such extraneous factors as visual imagery or emotional feeling may also contribute to the perceived sound. The importance of each of these components and the manner in which they interact may vary from one stimulus to another (or even within the same stimulus). They may also vary between experienced listeners and nonmusicans and even within a single listener on different occasions. Such fluctuations may account for the discrepant claims on the lateralization of musical function.

The present study examines whether there is any hemispheric asymmetry demonstrated in the task of interval recognition. In the area of auditory perception, listening studies have been used in an attempt to discover ear asymmetry. This is interpreted as an indication of contralateral hemisphere specialization for processing that type of stimuli. It is hypothesized that ear asymmetry effects are the result of the fact that the contralateral connection (ear to the opposite hemisphere) is stronger than the ipsilateral one (ear to the hemisphere on the same side). Hemispheric asymmetry in this study will be indicated by a left or right ear advantage in the factors of response time or number of correct responses.

The intervals were monaural, melodic and ascending in nature. Subjects were grade six, seven and eight students. Children, as opposed to adults were used because the task, at this age, is sufficiently difficult to require a discerning level of processing. Two different intervals were used for recognition in order to determine if any discovered differences were due to the nature of the interval. The element of pitch alone was investigated apart from such factors as timbre, rhythm and harmony. This research seeks to determine whether a single set of stimuli and a single procedure can elicit a significant ear advantage.

Delimitations

The following delimitations were imposed on this study:

1) The study attempted to determine hemispheric asymmetry using only the criteria of number of correct responses and reaction time.

2) The study tested only two different intervals (perfect fourth and major third).

3) The study attempted to assess a limited number of grade six, seven and eight students from two specific schools in southwestern

Ontario. Only those students who completed all aspects of the study were included.

4) Students had to achieve a mastery level of interval recognition prior to testing.

5) Only right handed students were deemed eligible to participate.

6) Students had no known learning deficiencies or hearing impairment.

7) Students with perfect pitch were not used in this study.

Limitations

The investigator had no control over the following limitations in the study:

1) Random selection of subjects was not possible since this study required a specific mastery level of interval identification. However, randomization was utilized in assignment to the various experimental groups.

2) There was no control over individual differences in the musical background of the subjects. Differences were accounted for in randomized assignment to experimental groups. Differences were also surveyed in an investigator-designed musical background questionnaire and examined statistically.

3) Student knowledge of participation in this experiment may have influenced the behaviour. Students were initially given some information regarding their participation in this study but an effort was made to de-emphasize the experimental research aspect during the testing procedures.

4) The educational and environmental differences between the two schools were not controllable. These variants include differences in the physical setting of the schools, the classrooms, administrative policies and the music teachers.

5) There was no control over the factor of handedness in the immediate family of the subjects.

6) The homogeneity of groups in regard to task performance was not controllable.

CHAPTER II

REVIEW OF THE LITERATURE

Until approximately twenty years ago, most of the information regarding brain function and its relation to musical behaviours came from clinical literature. Amusia victims (individuals having disorders of music perception, performance, reading or writing due to brain damage) were studied in an attempt to understand the loss of function associated with the specific area that was injured. Since it is necessary to know the premorbid accomplishment and experience of the patient when considering the loss of musical abilities, it was often difficult to test such impairment following brain injury. There was also uncertainty as to whether any findings or conclusions could be applied to the normal individual.

Recently, more indirect behavioural measures of cerebral lateralization have been developed (dichotic listening, monaural listening, auditory evoked response) making possible controlled studies with both normal and cortically damaged patients.

<u>Dichotic Listening</u>

Since Broadbent (1954) first introduced the dichotic listening paradigm, this technique has become one of the most popular methods used in studying cortical asymmetry. This is a procedure by which the left and right ear simultaneously receive different input.

Kimura (1961a) was one of the first to investigate laterality differences in audition in the normal population. The results of her dichotic listening experiments rely on two assumptions:

a) that under competitive stimulation the contralateral auditory pathways occlude the ipsilateral and

b) that better performance by one ear reflects the greater involvement of the contralateral hemisphere. Her paradigm was a dichotic presentation of two stimuli (one stimulus directed to each ear) followed by binaural presentation of four alternatives from which the subject recognizes the two heard previously.

Kimura (1961a, 1964), in two separate tests, dichotically presented digits and excerpts of melodies to normal right handed subjects. She found a significant right ear superiority for digits and a significant left ear superiority for melodies.

In view of the finding that right handed people are generally considered to be "left hemisphere dominant for speech" (90% in the sample studied by Branch, Milner, & Rasmussen, 1964) and the assumption that the contralateral pathways are more important than the ipsilateral, Kimura (1961a) considers right ear superiority in the recognition of dichotically presented digits to reflect left hemisphere specialization for speech. Conversely, she considers left ear superiority in the recognition of dichotically presented melodies to reflect a right hemisphere superiority for music perception (Kimura, 1964). The picture that Kimura draws from these studies is that one hemisphere, usually the left, is specialized for the perception of linguistic stimuli, while the other is specialized for nonlinguistic stimuli, including music.

The explanation of why the left or right ear should reflect processing of the contralateral hemisphere is not entirely clear. Anatomically, there are both contralateral and ipsilateral projections from the ears to the cerebral cortex. Milner (1962) and Kimura (1961a and b, 1967) argue that the contralateral projections from ear to cortex are stronger or more numerous than the ipsilateral ones. This contention is based on findings from studies involving animals (Rosenzweig, 1951) which have also been confirmed in man (Butler, Keidel, & Spreng, 1969). Milner and Kimura argue that, under conditions of dichotic presentation, stimuli from both ears reach both hemispheres, but the contralateral stimulus will be stronger in each hemisphere, and so, more readily reported or recognized.

The dichotic listening technique has been used by several investigators studying laterality effects in audition; however, their results are not entirely consistent.

Monaural Listening

Dichotic listening was considered for a long time to be the only technique available in auditon to establish the existence of hemispheric asymmetry. The hypothesis of necessary competition between the stimuli to elicit an ear advantage was generally accepted. In 1967, for the first time, Bakker and Simon independently reported an hemispheric asymmetry with monaural (input to one ear) presentation, showing that stimulus competition is not a necessary condition for eliciting ear differences but one of a number of factors that may enhance the degree of difference in the performance of the two ears.

Bakker suggests that dichotic stimulation increases the difficulty of the task sufficiently to elicit a preferential ear performance. The same task under condition of monaural stimulation is not sufficiently difficult to give rise to ear differences. By increasing the length or difficulty of the task an ear superiority emerges. Numerous studies have confirmed these original findings and, in terms of asymmetry of ears, they support the results from dichotic listening studies. Regis Henry (1979) published a bibliography of 74 studies reporting a significant hemispheric difference under monaural stimulation.

It would seem that monaural presentation of stimuli can elicit ear advantages which reflect relative differences in hemispheric activity, provided that the task is of adequate difficulty, or that the response measure (such as reaction time) is sufficiently sensitive. The differences obtained under monaural conditions are smaller than those for comparable tasks under dichotic conditions. However, monaural listening makes possible the use of many experimental designs and tasks which would be either too difficult or impossible for the subject under dichotic conditions.

It has become apparent that demonstrated ear asymmetries are extremely fragile and can be eliminated or shifted from one ear to another through minor manipulation of the stimulus, type of subjects or the instructional restraints placed upon the report strategies. The technique of monaural listening has been adapted to study such acoustic variables as pitch, duration, intensity and temporal sequencing. As was the case with dichotic listening, the results are not entirely consistent.

Processing of Musical Stimuli

A number of research reports on the cerebral processing of music stimuli have implied that the right cerebral hemisphere in most individuals is specialized for the perception of music and other nonverbal input, with the left hemisphere being dominant for verbal functions (Gordon, 1970; Kimura, 1967; Milner, 1962). Other research findings, however, appear to indicate that not all music stimuli are mediated by the right hemisphere. Rhythm, for example, may be processed by one or both hemispheres (Gordon & Bogen, 1974; Gregory, Harriman, & Roberts, 1972). Other results suggest that the functional differentiation of the cerebral hemispheres is dependent upon the kind of processing demanded by a particular task rather than upon the stimulus properties (Bartholomeus, 1974, Gates & Bradshaw, 1977).

Melody

Several investigators have studied laterality effects using melodic stimuli; however, their results are inconsistent.

Kimura (1967) found that the subjects were able to hum more melodies which had been presented to the left ear than to the right. Similarly, a left ear superiority was found for recognition of hummed melodies (Bartholomeus, 1974, King & Kimura, 1972) and melodies sung to letter names (Bartholomeus, 1974) or consonant vowel (CV) syllables (Spellacy & Blumstein, 1970). However, Gordon (1970), Bartholomeus, Doehring, and Freygood (1973), and Cuyler (1974) found no ear differences in melodic recognition.

The same melodic stimuli have at different times and under different circumstances yielded varying results:

(a) in a verbal context- no difference reported by Bartholomeus et al. (1973), but left ear superiority reported by Bartholomeus (1974),

(b) the length of time between dichotic presentation and binaural recognition-no difference for 12 sec, reported by Spellacy (1970), but left ear superiority for 1 and 5 sec, reported by Spreen, Spellacy, &

Reid (1970) and Dee (1971),

(c) the experience of the subjects-right ear superiority for experienced listeners, left ear for nonmusician subjects, reported by Bever & Chiarello (1974); left ear superiority for musicians, no ear difference for nonmusicians, reported by Darwin (1969), Doehring & Ling (1971), and McDonough (1973), and

(d) the stimulus attributes to which the subject attends-right ear superiority for digits and left superiority for pitch and loudness, reported by Nachshon (1973). [1]

Pitch

Investigations on the element of pitch have yielded interesting results. In some experiments, simple reaction time data suggested that ear differences were absent with monaurally presented tones (Karp & Birch, 1969; Simon, 1967), although there was some evidence for right ear superiority when the subject was uncertain as to the ear of arrival (Haydon & Spellacy, 1973; Provins & Jeeves, 1975; Simon, 1967). However, when subjects were required to judge whether they heard one tone or two, reaction times tended to be shorter for one tone arriving at the left ear and two at the right (Perl, 1973).

Short pitch sequences have also brought contradictory findings. For two- and three-note sequences, Schulhoff and Goodglass (1969) found no significant ear differences in perception, although the left ear showed a greater over-all performance level. Similarly, Doehring (1971,1972) and Doehring and Ling (1971) found no difference for pitch variations in three-tone sequences presented monaurally. In a series of experiments investigating three-and four-note sequences, Darwin (1969) found the left ear to be superior under most conditions. However, Spellacy (1970) found no ear differences for four-note sequences under similar conditions, except when longer intervals (5 and 12 sec) existed between presentation and recognition stimuli, although left ear superiority was apparent for the same tone patterns with a 1-sec interval (Spreen et al., 1970).

One of the best controlled studies that has been reported for short sequences is that of Berlin and Olroyd (Berlin, 1972). They used five-note sequences with the same temporal pattern, duration, key, and implied harmony within and between dichotic pairs and found no ear differences. Such failure to show any laterality effect may have been due to almost perfect performance for stimuli to both ears. Similarly, pitch discrimination when correct responses were near perfect also revealed no ear differences (pilot study reported in Nachshon, 1973). On the other hand, for the recognition of longer melodic stimuli, the performance level is much lower, ranging from 15% (Spellacy, 1970) to 78% (King & Kimura, 1972). This drop in accuracy from short sequences to longer melodies could possibly be related to memory. The fact that identification of pitch contours showed no ear differences for free report and for precued report, but a left ear superiority for postcued report, suggests that memory plays a role in observed asymmetries (Oscar-Berman et al., 1974). [2]

Role of Experience

A number of studies also suggest that experience relevant to the experimental task influences the way in which subjects process stimuli.

Bever and Chiarello (1974) found a distinct right ear superiority for the recognition of melodies by musicians and a distinct left ear superiority for the recognition of the same stimuli by nonmusicians. They suggest that musical training and experience results in an increased ability among musicians to analyze relationally the melodies' component notes within the overall melodic line and a consequent left hemisphere superiority. Nonmusicians, without this training, are forced to rely on holistic processing of the melodic contour, and so, show a right hemisphere superiority.

The perception of musical intervals also seems to depend upon the musical experience of subjects. Aiello (1978) found a right ear superiority among nonmusicians for arpeggiated chords which differed in their internal structure (e.g., C major vs. C minor). When she used arpeggiated chords which preserved the same internal interval structure but differed in the key in which they were presented (e.g., C major vs. D major), she found no ear differences among nonmusicians. Her musicians showed no ear differences on either type of stimuli. Presumably, nonmusicians needed to analyze the internal relation of the notes in the former case, but not the latter.

It can be seen that testing of melodic stimuli up to this point has not demonstrated an invariant pattern of cerebral asymmetry, although either left ear superiority or an absence of ear differences is found more often than right ear superiority, particularly in non-language situations.

Gates and Bradshaw (1977) in a review of the related literature, indicate that neither hemisphere seems to be dominant for music. Rather, both hemispheres are involved in music perception, each operating according to its own specialization and task requirement.

The purpose of this research was to study ear asymmetry in the recognition of intervals in grade six, seven and eight students. The following null hypothesis was investigated: There is no left ear superiority in the recognition of monaural, melodic, ascending intervals.

CHAPTER III

DEVELOPMENT OF THE STUDY

Introduction

This chapter records the procedures followed during the course of the study. The purpose of this research was to investigate whether the task of monaural interval recognition in grade six, seven and eight students would elicit an ear asymmetry using the criteria of response time and number of correct responses.

Pilot Test

A pilot test was conducted with a grade eight class during the school year prior to the one used for this research. As a result of this, a new set of tapes was made in an attempt to eliminate a slight echo. Revisions were also made in the computer programming.

It was also decided that the students should be divided into Group A or B prior to the learning of the determined interval. Students in the pilot test were taught both the perfect fourth and major third intervals and, sometimes, showed temporary difficulty in remembering which interval they were to identify. More practice in the specific interval, assigned at an earlier stage, seemed to eliminate this confusion and allowed mastery level to be achieved earlier in the pre-test instruction.

PRE-TEST PROCEDURES

Permission

Prior to the actual testing, permission to carry out experimental research within the School Boards was requested. Written consent was obtained from the Research Liaison Committee in one Board and from the Superintendent of Education in the other Board. The principals involved also gave their verbal approval. An informal session was given for the teachers in the schools so that they would be aware of the research and the student involvement. A formal seminar was held for the parents of possible subjects to inform them of the details of the experiment and to answer any questions which they might have. Consent and explanation forms were sent home with all prospective subjects (Appendices 1 and 2).

Interval Identification Instruction

Three months prior to the beginning of testing, 55 right handed students (32 girls, 23 boys) from grades six, seven and eight volunteered to take part in this experiment. Due to limited school population, the students were taken from two different schools. The potential subjects were given a brief description of the research but great detail was avoided in an attempt not to bias student test response. Exact information concerning the time commitment was discussed and students were told that they would not be reimbursed for their participation in this experiment.

All students were randomly assigned to the Perfect Fourth or Major Third Interval Group. Twenty-four students were designated Group A (perfect fourth) and thirty-one students Group B (major third). A larger number of students was assigned to the Major Third Group because the pilot test had indicated that fewer people from this group qualified for the mastery level.

Students were coached on the average of twice a week for twenty minutes at each session. The subjects were first taught to associate the determined interval with the beginning of a well known song and, later, were encouraged to sing the interval on various pitches from the piano.

After two weeks of practice, the potential subjects were required to do a paper and pencil test. The perfect fourth test consisted of a random order of perfect fourths, major thirds and perfect fifths. The proximity of the intervals was to encourage a higher level of cerebral processing. The major third test consisted of a random order of major thirds, perfect fourths and major seconds. Ten intervals were given and the student was required to write P4 (or M3 depending on the assigned group) beside the appropriate number whenever he heard his determined interval. All tones were played on a piano and the duration of the interval was approximately one second with a four second response time. This was purposely faster than the time used in the actual testing to ensure that the subject was capable of performing the task.

In the following week, two trial tests of ten intervals were given with a three minute rest separating the tests. This procedure was practised for three weeks. The next stage of instruction consisted of three trial tests of ten intervals with a four minute rest between them. In the next week, students were given one test of thirty intervals. After two instruction sessions using this format, subjects were given two tests of thirty intervals with a five minute rest between them. The forms used are found in Appendices 3 and 4.

Following this process, the student was then considered eligible to attempt mastery level. This consisted of receiving 90 percent (27 out of 30) on two separate tests. If he achieved this standard but his scores prior to the 90 percent were sufficiently below this level (e.g., 21 out of 30), he was asked to take another week of instruction and achieve the mastery level on one more test. It was hoped that this procedure would eliminate the possibility of the subject accomplishing the mastery level due to the element of chance. Thirty-two of the original fifty-five subjects achieved this standard and were retained for the actual testing procedure. These students were then tested individually for vocal range, the average of which was used in determining the range of the taped auditory stimuli. Appendix 7 shows the chart that was completed during the ten minute session with the student. Subjects were also asked to complete a Handedness Chart, a Family Handedness Questionnaire and a Musical Background Questionnaire (Appendices 6, 8 and 9).

Each subject was given three practice series prior to the actual experiment to familiarize himself with the sound of the tapes and the use of the equipment.

METHOD

Subjects

There were 32 students involved in this experiment. Fourteen were male and eighteen were female. These participants came from a rural elementary school and a junior high school in southwestern Ontario. There were 7 grade six students, 9 grade seven students and 16 grade eight students. The ages ranged from 11.1 to 14.1 years with a mean age of 12.68 years. All students reported no neurological or sensory abnormalities. Their teachers reported no history of cognitive or learning disabilities.

Auditory screening was performed by an audiologist from the County Health Unit, prior to and after the completion of the experiment, to ensure normal hearing in both ears. Two tests were performed at each of the sessions: a flexibility of eardrum test indicated whether any infections or allergies were present; an audiometric threshold hearing test indicated the decibel level that each child was capable of hearing.

None of the subjects showed any evidence of perfect pitch. All subjects were right handed according to a modified version of the Edinburgh Inventory Handedness Test (Oldfield, 1971). A strength of +0.80 was required to participate in this research. The mean handedness score was +0.8829. The range of handedness was +0.80 to +1.0.

Stimuli

The monaural-listening tapes were produced in the Digital Sound Lab at the University of Western Ontario. The recordings were prepared using both channels of a Sony TC K 81 dual channel stereo cassette tape deck. The tones were generated using a Synclavier II synthesizer reproducing the sound of a piano; therefore, equal tempered tuning was used. Stimuli were presented in pairs with an inter-stimulus time of 400 msec separating the tones in each pair. All tones were 600 msec in duration. Thus, the duration of each pair was 1600 msec. Each sound began with a 10 msec attack time and ended with a 100 msec decay period. The time from the onset of one pair to the next was 7.5 sec. (See Figure 1.)

The range of notes used extended from G (196 Hz) below middle C

Figure 1

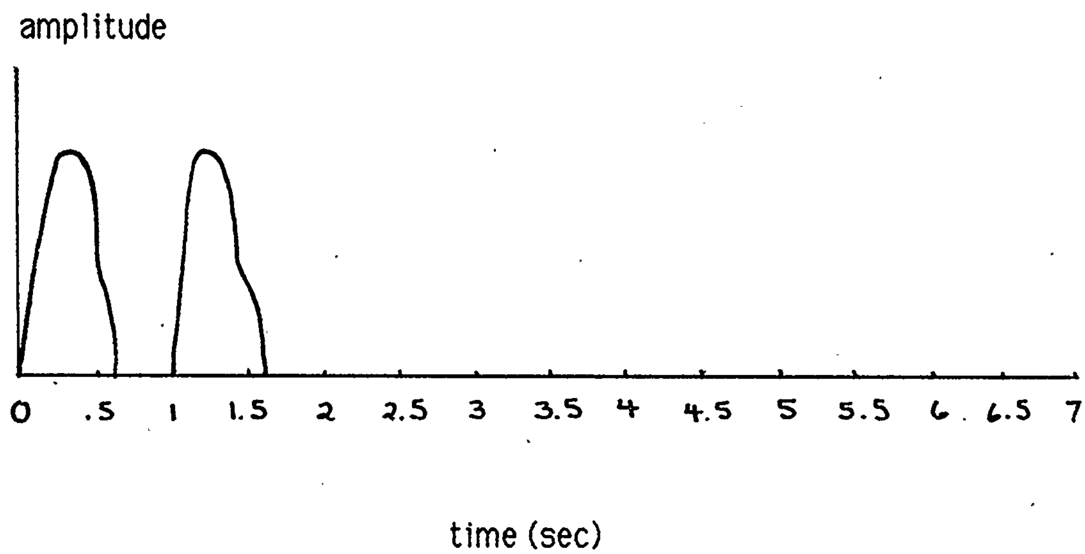


Figure 2

Tone One (600 msec) Initiation of First Pair
400 msec Pause
Tone Two (600 msec)
5.9 sec Pause between Interval Pairs
Tone Three (600 msec) Initiation of Second Pair
400 msec Pause
Tone Four (600 msec)
5.9 sec Pause between Interval Pairs

This process is continued for a total of 32 interval pairs.

to C one octave above middle C (523 Hz). A total of eight tapes was made, four for each group, to prevent the subjects from memorizing a specific interval order. Each tape consisted of 32 interval pairs. The first two intervals were for practice only and were not tabulated in the calculations.

Tapes 1-4 were designed for the group recognizing the interval of a perfect fourth. The first interval was always a perfect fourth and the second a perfect fifth. These were included to remind the subject of the interval for which he was listening. The next 30 intervals included 10 perfect fourths, 10 major thirds and 10 perfect fifths. Intervals were a diatonic second above or below the perfect fourth to encourage a discerning level of processing. Four separate interval orders, one for each tape, were obtained by allowing an independent observer to draw a series of intervals from a hat four different times. The actual pitches used for each interval were randomly assigned.

Tapes 5-8 were designed for the group recognizing the major third interval. The first interval was always a major third and the second a perfect fourth. The next 30 intervals included 10 major thirds, 10 major seconds and 10 perfect fourths. To control as many factors as possible, the same order of intervals was used in tapes 5-8 as had been established for tapes 1-4. Wherever a perfect fourth had occurred, it was replaced by a major third. A perfect fifth was replaced by a perfect fourth and a major third was replaced by a major second. This is illustrated in Table 1.

Table 1

Tapes 1-4	Tapes 5-8
Perfect Fourth	Major Third
Major Third	Major Second
Perfect Fifth	Perfect Fourth

The actual pitches of the intervals were randomly assigned.

Instrumentation

The stimuli were recorded on TDK 60 SA tapes. These were chosen for their high intensity sound production. The tapes were played on an Alpage AL 40 stereo cassette deck. This four track, two channel stereo system has a frequency response of 20 Hz to 17 KHz. An independent output dial allowed the headphones to be individually controlled without touching the main volume control of the amplifier.

The subject listened to the tapes with Sennheiser HD 400 HiFi stereo headphones. These were chosen for their light weight, a factor important in mimimizing subject fatigue. The headphones were plugged directly into the cassette deck.

An Akai stereo receiver AA-1175 supplied the power to drive the tape deck. The headphone jack accommodates 8 ohm low impedance stereo headphones which allowed the examiner to listen to the same stimuli as the subject and ensure that all the mechanisms were correctly co-ordinated. The speaker system terminals were used to attach the amplifier to a box containing a pulse detector. A schematic of this unit may be seen in Figure 3. This box was connected to a response board which mounted a "Yes" and "No" key that the student pushed to indicate his decision concerning the interval heard. Each key was 4 X 5 cm in size. When pressed and released, the keys gave a clicking sound which indicated to the subject that his response had been registered. The board was marked with masking tape located 3 cm from the base of the keys to ensure that the subject returned his hand to the same point after each response. The box was also connected to Port 2 of a Commodore 64 computer. This meant that when a tape was played an auditory signal was sent to the computer which activated its own clocking mechanism at the onset of each pair. The timer was stopped by a signal from either response key when the subject pressed it. The computer would then record the student's yes or no response and time its duration to the nearest 0.01 sec. If the subject did not respond within the 7.5 sec period, the computer would record an invalid response and start the clocking mechanism again at the onset of the next interval pair.

The computer was connected to a Panasonic monitor which provided a visual output of the stimuli and student response. This also enabled the examiner to make sure that the computer was receiving adequate electronic signals from both the stereo receiver and the response board.

At the end of each day's testing, the computer was connected through its serial port to a Commodore printer which provided a record of the results.

A schematic of the complete equipment used in this study can be seen in Figure 4.

Figure 3

PULSE DETECTOR SCHEMATIC

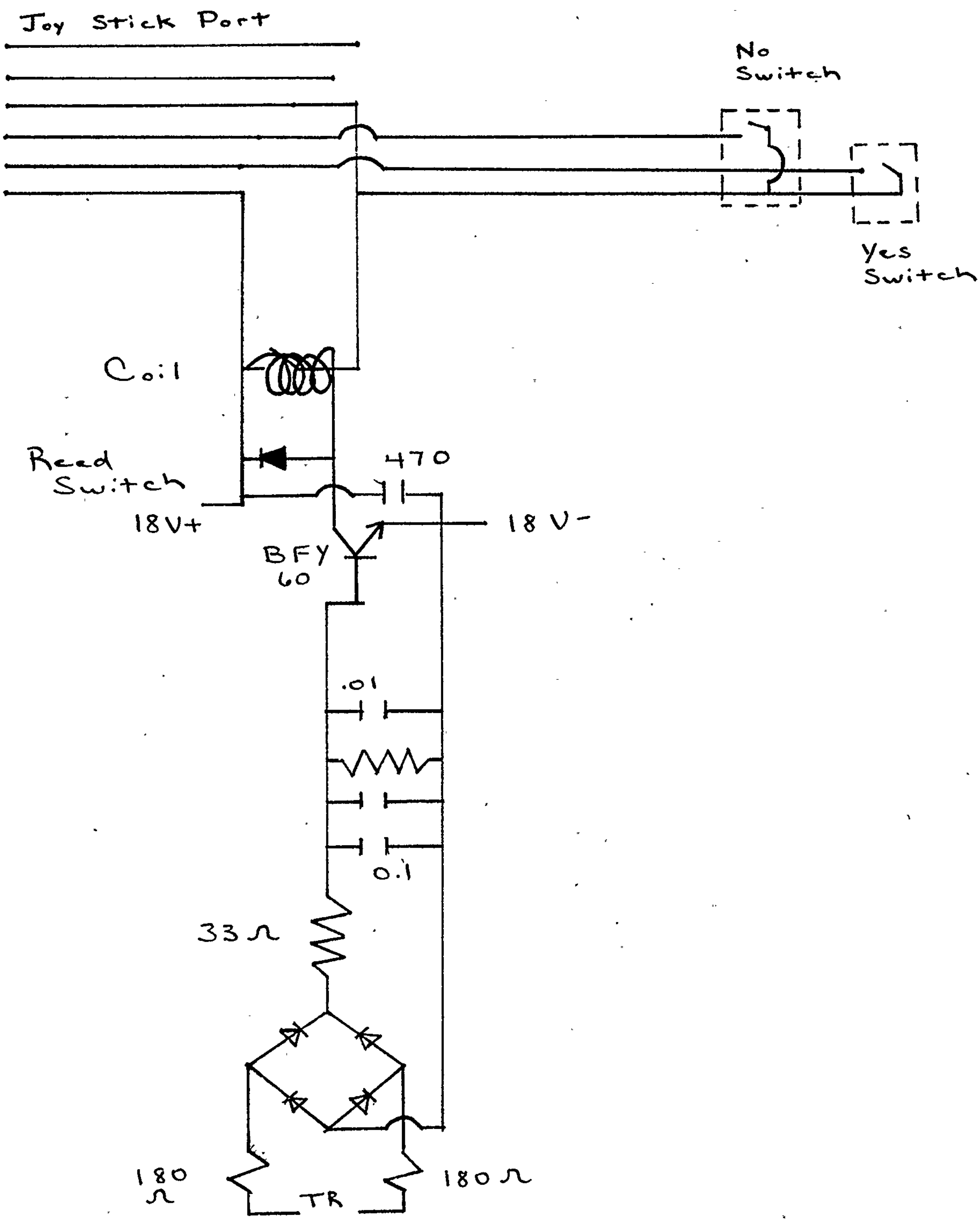
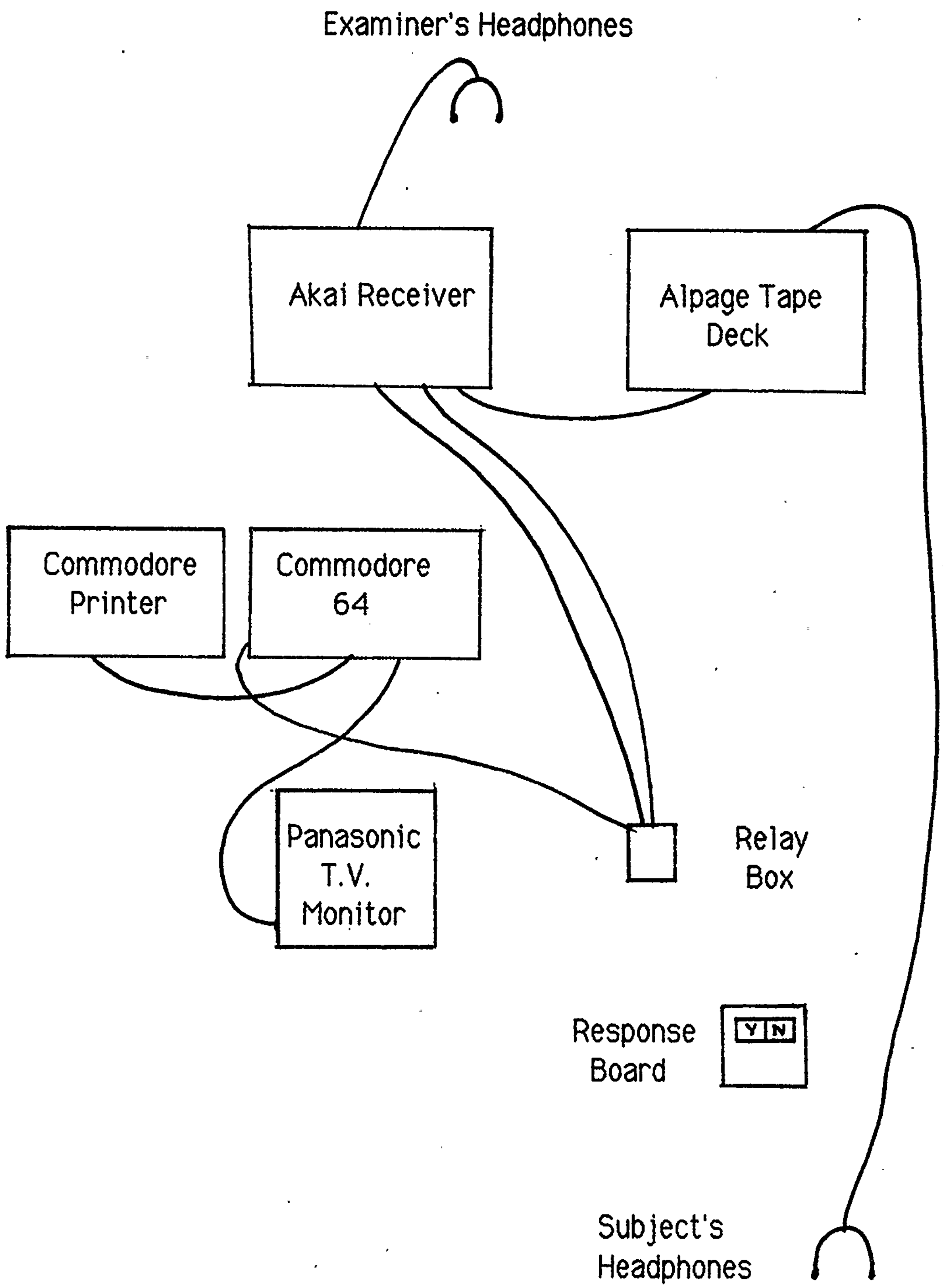


Figure 4

TECHNICAL DESIGN



Procedure

At the onset of the testing, each person in Group A (perfect fourth) and Group B (major third) was randomly assigned to one of the sub-groups. Section 1 students used only their right hand to respond and had their right ear tested first. Section 2 students used only their right hand to respond and had their left ear tested first. Section 3 students used only their left hand to respond and had their right ear tested first. Section 4 students used only their left hand to respond and had their left ear tested first. Table 2 illustrates these groupings.

Table 2

	Group A (P4)	Group B (M3)
Section 1	Right Hand Right Ear (first)	Right Hand Right Ear (first)
Section 2	Right Hand Left Ear (first)	Right Hand Left Ear (first)
Section 3	Left Hand Right Ear (first)	Left Hand Right Ear (first)
Section 4	Left Hand Left Ear (first)	Left Hand Left Ear (first)

Each sectional ear-hand combination had 4 subjects. The hand used to start the testing was maintained throughout the experiment, regardless of the later shift to the opposite ear. The purpose of having students start with different ears was to balance the factor of ear fatigue. Different hands were used in case a slight superiority in reaction time might be lost due to the necessary crossing of hemispheres to inititate motor response to the opposite hand. The design format had the potential to indicate whether the hand used is a significant factor.

Each student was tested individually in a quiet, dimly lit room away from the active area of the school. Subjects were seated at a desk facing a wall to ensure minimal visual distraction. Each test took approximately 15 minutes to administer. Students were familiar with the examiner and appeared quite eager to perform.

The examiner explained the procedures for the listening task. Students were asked to relax and sit comfortably. Each subject was assigned a specific ear on which to put the marked side of the headphones. The other side was disconnected to ensure that the subject was only hearing with one ear. The student was told that he would hear a tape with 32 pairs of intervals. The first interval was the kind for which he was listening and, therefore, he should respond by pressing the "Yes" response key. The second interval was not the determined interval and, therefore, the "No" response key should be pressed. The subject was instructed that, following these, he would hear 30 more sets of intervals and that his task was to decide whether the target interval had been played and to push the appropriate key. The student was also assigned a specific hand to use when touching the response keys. The subject was told that this hand would be used for all the sessions in which he participated. A piece of masking tape was pointed out as the line behind which his hand must return each time after touching the reponse key.

Another person was stationed in the room behind the subject to ensure that the hand was returned to its original position behind the tape and on the board between each pair of intervals. This individual also timed the break between the separate right and left ear tests of each student.

After listening to the first tape, the student was given a five minute rest period. The examiner then instructed the subject to switch the orientation of the headphones to the opposite ear. Another cassette tape, using a different random order of intervals, was played through this ear. The volume of the stimuli was kept constant for all subjects and sessions.

A total of eight stimuli tapes were made. Tapes 1-4 were for the Perfect Fourth Group and 5-8 for the Major Third Group. Two different tapes were played at each session, one for each ear. This was designed to prevent students from memorizing the interval order. Table 3 shows the sequence in which the tapes were presented.

Table 3

	GROUP A		GROUP B	
	First Ear	Second Ear	First Ear	Second Ear
Session 1	Tape 1	Tape 2	Tape 5	Tape 6
Session 2	Tape 3	Tape 4	Tape 7	Tape 8
Session 3	Tape 2	Tape 1	Tape 6	Tape 5
Session 4	Tape 4	Tape 3	Tape 8	Tape 7

This design ensures that both ears hear all four tapes.

The four trial periods in which each student participated extended over a period of no more than seven days. This allowed for weekends on which the students could not come in for testing, special school activities and possible illness or absence. Students were not tested more than once a day.

After completing all the sessions, the students filled out a Research Questionnaire (Appendix 10). This was done after the testing was finished to ensure that personal bias or preference would not interfere or influence performance.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Introduction

This chapter presents an analysis of the data obtained from the four individual testing sessions in which each subject participated. As a result, there were four right ear scores and four left ear scores from the 32 participants.

Data collection began the second week of December, 1985 and was completed by the third week of January, 1986. The computer printed results of the testing daily but no tabulation was done until all of the experiment was completed. Thus, the investigator had no knowledge of any results during the course of the study. Any student who was interested in his personal results was allowed to view these after all the testing was finished.

Data were also organized and tabulated from the Musical Background, Family Handedness and Research Questionnaires.

Statistical Procedures

The statistical analyses were completed on an Apple IIc computer using a program developed specifically for this experimental research. Raw data ear scores were analyzed to compare the various subject treatments. For this analysis, subjects were classififed into one of eight different groups according to the interval, hand and ear combination which had been used:

1) Perfect Fourth	Right Hand	Right Ear First
2) Perfect Fourth	Right Hand	Left Ear First
3) Perfect Fourth	Left Hand	Right Ear First
4) Perfect Fourth	Left Hand	Left Ear First
5) Major Third	Right Hand	Right Ear First
6) Major Third	Right Hand	Left Ear First
7) Major Third	Left Hand	Right Ear First
8) Major Third	Left Hand	Left Ear First

The experimental data were subjected to a three-way analysis of variance using various combinations of the factors hand, ear, intervals and trials. Time and accuracy were treated as two separate entities during the course of the analysis. The level of significance was set at .05.

There was a deliberate decision on the part of the investigator to avoid a four-way analysis due to the difficulties of explaining possible interactions.

The results from the Musical Background Questionnaire were subjected to a Student t-test. Due to the limited number of subjects, the Family Handedness and Research Questionnaires were not subjected to statistical analysis.

Results

Two different analyses were performed on the research data in an attempt to answer the question of whether there is a difference in the number of correct responses depending on the hand used to respond and ear to which the signal was presented.

a) Perfect Fourth: Number Correct

Data from this interval group were subjected to a three-way analysis of variance wth repeated measures on the last two factors. Factor A referred to the hand used to respond (Right or Left). Factor B referred to the ear used (Right or Left) which had been counterbalanced in order of presentation. Factor C represented the number of trials (4). The results indicated no significant major effects or interactions (Table 4).

b) Major Third: Number Correct

Data from this interval group were subjected to a three-way analysis of variance with repeated measures on the last two factors. The factors were identical to those used in the Perfect Fourth analysis. The results indicated no significant major effects or interactions (Table 5).

Two different analyses were performed on the research data in an attempt to answer the question of whether there is a difference in the speed of response depending on the hand used and the ear to which the signal is presented.

c) Perfect Fourth: Time

In this analysis the variable of time to respond was considered. The score for each student was the average response time for correct choices per trial. The factors employed were identical to those used in the Perfect Fourth: Number Correct analysis. No significant major effects or interactions were found (Table 6).

d) Major Third: Time

Time to respond was also considered for this interval group. The factors used were identical to those employed in the Major Third: Number Correct analysis. No significant effects or interactions were found (Table 7).

Observations

Examination of the scores in Tables 4, 5, 6 and 7 revealed large error terms both within and among the individual subjects. Variances existed in regard to individual performances from one trial to another and also between the various ear-hand group combinations. This was evident in both the analyses of number correct and response time. As a result, any significant hand-ear interaction could be masked by the group variance.

In the Perfect Fourth: Number Correct analysis the ear x hand interaction approached significance ($F=3.075, \alpha 0.10=3.14$). Simple

Table 4

Interval-P4
No. Correct

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	1030.	15		
Factor A (Hand)	38.28	1	38.28	.540
Subjects within Groups	991.72	14	70.84	
Within Subjects	311.5	112		
Factor B (Ear)	.28	1	.28	.085
AB	10.13	1	10.13	3.075
B x Subjects within Groups	46.09	14	3.29	
Factor C (Trials)	17.94	3	5.98	2.417
AC	20.66	3	6.89	2.783
C x Subjects within Groups	103.91	42	2.47	
BC	4.78	3	1.59	.666
ABC	7.19	3	2.40	1.001
BC x Subjects within Groups	100.53	42	2.39	

Table 5

Interval-M3 THREE-WAY ANALYSIS OF VARIANCE
No. Correct WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	2493.30	15		
Factor A (Hand)	297.07	1	297.07	1.894
Subjects within Groups	2196.23	14	156.87	
Within Subjects	377.88	112		
Factor B (Ear)	.95	1	.95	.248
AB	1.32	1	1.32	.346
B x Subjects within Groups	53.36	14	3.81	
Factor C (Trials)	13.21	3	4.40	1.235
AC	7.46	3	2.49	.698
C x Subjects within Groups	149.70	42	3.56	
BC	1.71	3	.57	.178
ABC	15.34	3	5.11	1.592
BC x Subjects within Groups	134.83	42	3.21	

Table 6

Interval-P4 Time

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	18.58	15		
Factor A (Hand)	.63	1	.63	.495
Subjects within Groups	17.95	14	1.28	
Within Subjects	8.65	112		
Factor B (Ear)	1.88E	1	1.88E	.018
AB	.15	1	.15	1.485
B x Subjects within Groups	1.43	14	.10	
Factor C (Trials)	.19	3	.06	.939
AC	.17	3	.06	.814
C x Subjects within Groups	.285	42	.07	
BC	.37	3	.12	1.558
ABC	.20	3	.07	.867
BC x Subjects within Groups	3.28	42	.08	

Table 7

Interval-M3 Time

THREE-WAY ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	45.21	15		
Factor A (Hand)	2.13	1	2.13	6.94
Subjects within Groups	43.07	14	3.08	
Within Subjects	22.34	112		
Factor B (Ear)	.04	1	.04	.231
AB	.18	1	.18	1.089
B x Subjects within Groups	2.27	14	.16	
Factor C (Trials)	1.93	3	.64	2.457
AC	.56	3	.19	.719
C x Subjects within Groups	10.97	42	.26	
BC	.20	3	.07	.476
ABC	.42	3	.14	1.015
BC x Subjects within Groups	5.78	42	.14	

effects, although not statistically significant, showed that, in this group, there were more correct responses when there was a match between the ear to which the signal was presented and the hand used for responding.

POST HOC ANALYSES

For these analyses significance was set at the .01 level. One way of reducing error is to increase the number of subjects. This would be possible if the 2 tone groups could be collapsed. The following analyses were computed to see if there were any tone x ear or tone x trial interactions for either number correct or response time.

e) Right Hand: Number Correct

A three-way analysis of variance with repeated measures on the last two factors was used. Factor A represented the interval (Perfect Fourth or Major Third). Factor B indicated the ear to which the stimuli was directed (Right or Left) and Factor C showed the trials (4). There were no significant major effects or interactions (Table 8).

Table 8

Right Hand
No. Correct

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	1515.74	15		
Factor A (Interval)	.38	1	.38	3.537E
Subjects within Groups	1515.36	14	108.24	
Within Subjects	311.13	112		
Factor B (Ear)	.63	1	.63	.130
AB	8.51	1	8.51	1.746
B x Subjects within Groups	68.23	14	4.87	
Factor C (Trials)	12.02	3	4.01	1.414
AC	9.52	3	3.17	1.120
C x Subjects within Groups	119.08	42	2.84	
BC	11.15	3	3.72	2.035
ABC	5.27	3	1.76	.963
BC x Subjects within Groups	76.70	42	1.83	

f) Left Hand: Number Correct

A three-way analysis of variance with repeated measures on the last two factors was used. The factors were identical to those employed in the right hand analysis. No significant major effects or interactions occurred (Table 9).

g) Right Hand: Time

In this analysis the factor of time was considered. Time for each ear was the average response time for correct choices. The factors used were ear, interval and trials. No significant major effects or interactions were found (Table 10).

h) Left Hand: Time

The factors used were ear, interval and trials. No significant effects or interactions were found (Table 11).

Observations

Factor A (tone) approached the level of significance in the Left Hand: Number Correct analysis ($F=4.35, \alpha.05=4.60$). This suggested that the number of correct responses did depend to a certain

Table 9

Left Hand
No. Correct

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	2192.63	15		
Factor A (Interval)	520.03	1	520.03	4.353
Subjects within Groups	1672.59	14	119.47	
Within Subjects	378.25	112		
Factor B (Ear)	1.53	1	1.53	.687
AB	2	1	2	.897
B x Subjects within Groups	31.22	14	2.23	
Factor C (Trials)	11.69	3	3.90	1.216
AC	26.03	3	8.68	2.709
C x Subjects within Groups	134.53	42	3.20	
BC	8.03	3	2.68	.709
ABC	4.56	3	1.52	.403
BC x Subjects within Groups	158.66	42	3.78	

Table 10

Right Hand
Time

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	38.81	15		
Factor A (Interval)	1.08	1	1.08	.401
Subjects within Groups	37.73	14	2.70	
Within Subjects	10.46	112		
Factor B (Ear)	.08	1	.08	.758
AB	3.61E	1	3.61E	.033
B x Subjects within Groups	1.52	14	.11	
Factor C (Trials)	.31	3	.10	.930
AC	.11	3	.04	.339
C x Subjects within Groups	4.64	42	.11	
BC	.10	3	.03	.391
ABC	.26	3	.09	1.065
BC x Subjects within Groups	3.44	42	.08	

Table 11

Left Hand
Time

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	26.19	15		
Factor A (Interval)	2.90	1	2.90	1.746
Subjects within Groups	23.29	14	1.66	
Within Subjects	20.52	112		
Factor B (Ear)	.27	1	.27	1.756
AB	8.13E	1	8.13E	.052
B x Subjects within Groups	2.18	14	.16	
Factor C (Trials)	1.72	3	.57	2.618
AC	.71	3	.24	1.081
C x Subjects within Groups	9.18	42	.22	
BC	.29	3	.10	.728
ABC	.53	3	.18	1.329
BC x Subjects within Groups	5.63	42	.13	

degree on the tone being presented. Since there was no significant interaction between tone and ear or trials for the analysis of time, data were collapsed over the two intervals.

i) Both Intervals: Time

A three-way analysis of variance was used with repeated measures on the last two factors. Factor A represented hand (Right or Left). Factor B indicated the ear used (Right or Left). Factor C represented the trials (4). The data from both tone groups were used which increased the subject number to 16. No significant major effects or interactions were found (Table 12).

A second attempt to reduce intersubject variability was used. Subjects were divided into good or poor performers based on data from trial 1. Analyses were then compiled for trials 2, 3 and 4.

j) Perfect Fourth (Top Group): Number Correct

A three-way analysis of variance with repeated measures on the last two factors was used. Factor A represented hand (Right or Left). Factor B represented the ear (Right or Left). Factor C indicated the number of trials (3). This factor was one less than the previous

Table 12

Interval-Both Time

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	67.60	31		
Factor A (Hand)	2.57	1	2.57	1.185
Subjects within Groups	65.03	30	2.17	
Within Subjects	31.01	224		
Factor B (Ear)	.03	1	.03	.244
AB	.32	1	.32	2.594
B x Subjects within Groups	3.71	30	.12	
Factor C (Trials)	1.67	3	.56	3.415
AC	.36	3	.12	.737
C x Subjects within Groups	14.65	90	.16	
BC	.32	3	.11	.969
ABC	.07	3	.02	.209
BC x Subjects within Groups	9.89	90	.11	

analyses since the first trial had been used to determine the subject's assignment to the top or bottom group.

In this analysis Factor A (hand) showed a significance better than the .05 level but not at the .01 level ($F=10.505; \alpha.05=5.99, \alpha.01=13.7$). This indicated that, for the top students, those responding with their left hand made more correct responses than those using their right hand regardless of the ear to which the stimuli was given (Table 13).

k) Perfect Fourth (Bottom Group): Number Correct

This duplicated the above analysis except that it used the bottom students. A hand x trial interaction was evident in the examination of the data ($F=5.059, \alpha.05=3.89, \alpha.01=6.93$). The right hand group got worse with subsequent trials while the left hand group improved with subsequent trials (Table 14).

l) Perfect Fourth (Top Group): Time

This duplicated the Perfect Fourth (Top Group): Number Correct analysis except that the criterion of time was investigated. No significant factors or interactions were seen (Table 15).

Table 13

Interval-P4
No. Correct
Top Students

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	35.65	7		
Factor A (Hand)	22.69	1	22.69	10.505*
Subjects within Groups	12.96	6	2.16	
Within Subjects	48.17	40		
Factor B (Ear)	2.52	1	2.52	2.404
AB	.02	1	.02	.020
B x Subjects within Groups	6.29	6	1.05	
Factor C (Trials)	2.38	2	1.19	.725
AC	2.63	2	1.31	.801
C x Subjects within Groups	19.67	12	1.64	
BC	.29	2	.15	.127
ABC	.54	2	.27	.235
BC x Subjects within Groups	13.83	12	1.15	

* .05 level of significance

Table 14

Interval-P4 THREE-WAY ANALYSIS OF VARIANCE
No. Correct WITH REPEATED MEASURES ON TWO FACTORS
Bottom Students

Source	SS	df	MS	F
Between Subjects	298.81	7		
Factor A (Hand)	215.19	1	15.19	.321
Subjects within Groups	283.63	6	47.27	
Within Subjects	175.17	40		
Factor B (Ear)	2.52	1	2.52	.328
AB	15.19	1	15.19	1.976
B x Subjects within Groups	46.13	6	7.69	
Factor C (Trials)	.29	2	1.46	.059
AC	24.88	2	12.44	5.059*
C x Subjects within Groups	29.5	12	2.46	
BC	5.79	2	2.90	.880
ABC	11.37	2	5.69	1.728
BC x Subjects within Groups	39.50	12	3.29	

* .05 level of significance

Table 15

Interval-P4 THREE-WAY ANALYSIS OF VARIANCE
Time WITH REPEATED MEASURES ON TWO FACTORS
Top Students

Source	SS	df	MS	F
Between Subjects	2.23	7		
Factor A (Hand)	.23	1	.23	.697
Subjects within Groups	2.	6	.33	
Within Subjects	1.77	40		
Factor B (Ear)	5.63E	1	5.63E	.098
AB	.02	1	.02	.295
B x Subjects within Groups	.34	6	.06	
Factor C (Trials)	.07	2	.04	1.966
AC	.04	2	.02	.973
C x Subjects within Groups	.22	12	.02	
BC	.23	2	.12	1.820
ABC	.08	2	.04	.617
BC x Subjects within Groups	.76	12	.06	

m) Perfect Fourth (Bottom Group): Time

This analysis revealed an interaction of B x C at the .05 level ($F=4.631, \alpha.05=3.89, \alpha.01=6.93$). This hand x trial combination showed that, for the poorer performers, trial 2 was best with the left ear, trial 3 was best with the right ear and trial 4 was best with the left ear. This trend is an additional source of variation which could mask any hand x ear effect (Table 16).

n) Major Third (Top Group): Number Correct

This analysis duplicated the Perfect Fourth (Top Group): Number Correct analysis except that the Major Third Group was used. No significant major effects or interactions were found (Table 17).

o) Major Third (Bottom Group): Number Correct

This analysis duplicated the above analysis except that the bottom group was used. No significant major effects or interactions were found (Table 18).

p) Major Third (Top Group): Time

This analysis was identical to the Major Third (Top Group): Number

Table 16

Interval-P4
Time
Bottom Students

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	4.31	7		
Factor A (Hand)	.32	1	.32	.479
Subjects within Groups	3.99	6	.67	
Within Subjects	4.11	40		
Factor B (Ear)	.05	1	.05	.401
AB	.13	1	.13	1.131
B x Subjects within Groups	.67	6	.11	
Factor C (Trials)	.42	2	.21	2.105
AC	.14	2	.07	.683
C x Subjects within Groups	1.19	12	.10	
BC	.65	2	.32	4.631*
ABC	.03	2	.02	.230
BC x Subjects within Groups	.84	12	.07	

* .05 level of significance

Table 17

Interval-M3 THREE-WAY ANALYSIS OF VARIANCE
No. Correct WITH REPEATED MEASURES ON TWO FACTORS
Top Students

Source	SS	df	MS	F
Between Subjects	402.25	7		
Factor A (Hand)	85.33	1	85.33	1.616
Subjects within Groups	316.92	6	52.82	
Within Subjects	75.67	40		
Factor B (Ear)	.33	1	.33	.511
AB	.08	1	.08	.128
B x Subjects within Groups	3.92	6	.65	
Factor C (Trials)	10.67	2	5.33	2.803
AC	5.17	2	2.58	1.358
C x Subjects within Groups	22.83	12	1.90	
BC	3.17	2	1.58	.659
ABC	.67	2	.33	.139
BC x Subjects within Groups	28.83	12	2.40	

Table 18

Interval-M3
No. Correct
Bottom Students

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	404.31	7		
Factor A (Hand)	150.52	1	150.52	3.559
Subjects within Groups	253.79	6	42.30	
Within Subjects	161.17	40		
Factor B (Ear)	.19	1	.19	.031
AB	.19	1	.19	.031
B x Subjects within Groups	36.79	6	6.13	
Factor C (Trials)	1.54	2	.77	.161
AC	2.54	2	1.27	.265
C x Subjects within Groups	57.58	12	4.80	
BC	.38	2	1.9	.042
ABC	8.37	2	4.19	.938
BC x Subjects within Groups	53.58	12	4.47	

Table 19

Interval-M3
Time
Top Students

THREE-WAY ANALYSIS OF VARIANCE
WITH REPEATED MEASURES ON TWO FACTORS

Source	SS	df	MS	F
Between Subjects	4.85	7		
Factor A (Hand)	.64	1	.64	.907
Subjects within Groups	4.21	6	.70	
Within Subjects	3.85	40		
Factor B (Ear)	.09	1	.09	1.421
AB	1.75E	1	1.75E	.029
B x Subjects within Groups	.36	6	.06	
Factor C (Trials)	.34	2	.17	.809
AC	.19	2	.10	.453
C x Subjects within Groups	2.52	12	.21	
BC	.02	2	7.88E	.295
ABC	.02	2	8.06E	.302
BC x Subjects within Groups	.32	12	.03	

Table 20

Interval-M3 THREE-WAY ANALYSIS OF VARIANCE
Time WITH REPEATED MEASURES ON TWO FACTORS
Bottom Students

Source	SS	df	MS	F
Between Subjects	11.15	7		
Factor A (Hand)	.23	1	.23	.128
Subjects within Groups	10.92	6	1.82	
Within Subjects	9.13	40		
Factor B (Ear)	.62	1	.62	2.692
AB	.58	1	.58	2.498
B x Subjects within Groups	1.38	6	.23	
Factor C (Trials)	.47	2	.24	1.103
AC	.08	2	.04	.181
C x Subjects within Groups	2.57	12	.21	
BC	.22	2	.11	.520
ABC	.67	2	.34	1.595
BC x Subjects within Groups	2.54	12	.21	

Correct except the criterion of time was investigated. No significant major effects or interactions were found (Table 19).

q) Major Third (Bottom Group): Time

This analysis found no significant major effects or interactions (Table 20).

Musical Background Questionnaire

Data concering extraneous variables included school background and private music instruction.

The first three questions were designed to examine whether the musical background of students from the two different schools was comparable. All participants had received vocal music instruction during their elementary school career. Subjects were also taking instrumental music and the instructors from both schools were using the same method book which implies a similarity in the order and presentation of material.

Questions 4-7 requested information on any musical background obtained outside the schools (Table 21). It is important to note that any experience in the area of ear training was obtained only in conjunction with private piano lessons. Therefore, instruction varied from five minutes a week to one five-minute session per month.

Data from questions 4-7 were subjected to a Student t-test. The students were divided into a top or bottom group according to whether they had had some experience with ear training or private piano lessons outside the school environment and prior to this research. When these results were compiled it was found that half the subjects of both groups had been randomly assigned to the Perfect Fourth Group and the other half to the Major Third Group.

The musically experienced group showed a significant level of superiority both in the area of number of correct responses and faster response times (Number Correct, $t=4.64$, $p<0.01$ two tailed: Time, $t=-5.89$, $p<0.01$, two-tailed, 30 df).

Family Handedness Questionnaire

This form was used only to investigate which subjects had all right handed immediate family members and which did not. Once again, random asssignment of subjects to groups had successfully put an even number of subjects with no left handed family members and

Table 21

MUSICAL EXPERIENCE OUTSIDE OF SCHOOL

Instrument or Instruction	n	Years of Experience	n
Piano	15	1	2
		2	5
		3	2
		4	0
		5	2
		6	3
		7	0
		8	1
Tenor Sax	1	1	1
Organ	1	2	1
Theory	8	1	1
		2	0
		3	7
Ear Training	8	1	1
		2	4
		3	1
		4	1
		5	1

those with one or more left handed family members into each interval group.

Research Questionnaire

The Research Questionnaire consisted of three separate queries to ascertain:

a) if the student had any ear preference when recognizing the intervals

b) if the student remembered which ear was preferred

c) if there was anything of significance that was noticed or felt during the course of the study.

This form also gave the subject the opportunity to make any comments or ask any questions about the research. The data from the 32 participants were tabulated and are shown in Table 22.

In response to the comment section, one student indicated that she would have preferred to use her right hand rather than her left in responding. Another student expressed the desire that the "Yes" response key should have been on the right side of the board rather than the "No" key.

Table 22

RESEARCH QUESTIONNAIRE RESULTS

Noticed an Ear Preference	12 Yes	22 No
Of the Yes Answers	6 Right Ear	
	2 Left Ear	
	4 Couldn't Remember	
Reactions to the Study	5 Found it Challenging	
	1 Found it Boring	
	1 Found it Easy	
	1 Found it Fun	

CHAPTER V

SUMMARY, CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

Purpose

The purpose of this study was to investigate whether any hemispheric asymmetry was demonstrated by ear advantage in the recognition of monaural, melodic, ascending intervals. Such advantage would be indicated by a differential ability to recognize intervals using the criterion of response time or number of correct responses.

Procedures

This study was conducted over a five month period during the 1985-1986 school year. Thirty-two grade six, seven and eight students from two schools in southwestern Ontario were used in this research experiment. The students were all right handed with no known hearing deficits or learning disabilities. None of the students had perfect pitch. Each subject was randomly assigned to a Perfect

Fourth or Major Third Group. All students were required to reach a mastery level in interval recognition before being allowed to participate in the testing. For the experiment, the student listened monaurally to 32 intervals and recognized the target intervals by pushing a "Yes" or "No" response key. Half of the students in each group used their right hand to respond and the other half used their left hand. After a five minute rest, the student listened to another set of 32 intervals with the opposite ear. The order of ear presentation was counterbalanced within the groups. Each student always listened with the same ear first for all four testing sessions and always used the same hand to respond.

The measuring instrument was a Commodore 64 computer. It was programmed to record the subject's responses and the time required. In addition to the individual testing sessions, the students were also required to fill out an investigator-designed Handedness Questionnaire, Family Handedness Questionnaire, Musical Background Questionnaire and a Research Questionnaire. These test forms were evaluated by the investigator.

Discussion

The statistical evidence indicates that there is no significant ear advantage in the recognition of the two intervals using the measures of response time or number of correct responses. These results imply one or more of the following:

a) The task may be performed equally well by both hemispheres.

b) The task is too simple to elicit a laterality effect.

c) The results were masked by factors such as subject variability.

d) The measurement of reaction time was not sufficiently sensitive to reveal an asymmetry. Future research should consider using at least .001 sec time factor.

However, the findings do suggest a number of points worthy of discussion. These points relate to the factors of group homogeneity, inconsistent trial results and the variation in interactions between the two intervals.

The large variance both between and among subjects indicated a lack of homogeneity which was not eliminated by random group assignment. In spite of the fact that a mastery level was imposed, a wide range of abilities was still evident within and between the groups. In retrospect, the investigator feels that the assigned mastery level was not stringent enough. It is unlikely that the level could be raised beyond 90 percent for students of this age group but this achievement could be required more often and over a longer period of time. This may have yielded more consistent group and individual results. Perhaps a different criterion could have been used to achieve group homogeneity. A larger number of subjects per group may also have reduced this problem.

The inter-subject variability in this research may also support the premise that there is no locus for music behaviours. Such variation could suggest that there is no specific lateralization of music functions.

It was also evident that the amount of practice (trials) was a variable which interacted with the ear to which the signal was given. Variance in individual scores from one trial to another may have been caused by boredom. If this was the case, more training would defeat the desired effect. Lack of feedback during the experiment may have caused disinterest. This may account for the Perfect Fourth (Bottom): Right Hand Group getting worse with subsequent trials. Perhaps the task could be made more interesting by providing some type of reinforcement which would not bias the results.

The statistical evidence that different results were seen with the different intervals used may reflect some of the variance in the actual Pre-Test Interval Instruction. The Perfect Fourth Group generally found their interval much easier to recognize and achieved mastery at an earlier stage. As a result of the pilot test, a larger number of students was assigned to the Major Third Group knowing that a smaller percentage would achieve the mastery level in comparison to the Perfect Fourth Group. This may imply that a different level of mastery existed between the two groups and, therefore, different strategies were used in the recognition task. The findings, however, are not consistent enough to make any generalizations.

The fact that musical experience reached a statistically significant level suggests that perhaps, in future experiments, this should be part of the subject selection criterion. According to Bever and Chiarello (1974), this factor may also alter the type of task processing which is used. Choosing subjects which are equally experienced or inexperienced may reduce the variance found in this research.

Some factors which may have influenced the findings of this study were:

1) A malfunction in the computer and relay equipment caused a four week delay in starting after the Pre-Test Instruction had been completed. This may account, in part, for the fact that the test scores are lower than one would normally expect from a task requiring a pre-test mastery level.

2) A synthesizer was used to produce the tapes in this experiment in order to achieve the degree of accuracy required to measure minimal time differences. This instrument was also used because it could approximate the sound of a piano since the instruction and pre-tests were given using that instrument. This investigator was disappointed with the resulting piano sound. Students were given an extra practice session with the computer and tapes in an attempt to compensate for this adjustment.

3) Two sets of tapes were made at two different times and on two different machines in an attempt to eliminate a slight echo of the

intervals. Since both synthesizers produced the same effect, to a varying degree, the tape "bleeding" which occurred was a difficult factor to control. The students seemed unaware that an echo existed on the set of tapes which was eventually used and the volume was kept at a comfortable but minimal level to eliminate as much of the echo as possible.

4) The fact that two different schools had to be used in this experiment may have influenced results. In one school this investigator was the music teacher whereas, in the other school, merely a guest who came in several times a week to do auditory testing. The difference in rapport with the students may have resulted in varying performance behaviour.

5) The limited number of subjects made it difficult to statistically analyze or account for the factors of musical background and family handedness.

Implications for Further Research

It is recommended that this investigation be replicated with more subjects. This limited sample does not give conclusive results. A greater number of eligible students within one school would have made it possible to control the variables of prior music instruction in ear training.

Also recommended is a similar study using left handed students (sinistrals). Although sinistrals were not used in this research, they were allowed to participate in the Pre-Test Interval Instruction. In three different classes, a total of 21 left handed students were present. Nineteen of these reached mastery level and 17 of these were among the first group in each class to achieve that level. In general, it appeared that the sinistrals showed a more natural ability in regard to this task than the right handed students.

There has been some research as to the effect of handedness on musical abilities. Quinan (1930) stated that sinistrals are more musical in their tastes than right handed persons and that a higher proportion of sinistrals elect aesthetic vocations. More recently, Byrn (1974) questioned whether mixed handedness affected music ability. Although he found a large proportion of mixed handed instrumentalists, right handed and mixed handed subjects received comparable scores on Seashore timbre and tonal tests. The pre-test results indicated that more research could be done comparing the auditory acuity of sinistrals with right handers.

This study could also be duplicated using family handedness as part of the selection criteria. Some researchers have implied that "pure" right handers (having no left handed immediate family members) achieve different results than "mixed" right handed people (having one or more left handed immediate family members). The limited number of subjects in this study made it statistically unfeasible to examine such an effect.

It is suggested that this test be done again using the same subjects for both intervals. These subjects would be involved in a repeated measures paradigm where each person would go through the four ear-hand combinations. Students would be started with a different combination to compensate for practice and fatigue effects. This would allow the examiner to better control the extraneous variables of background and mastery level for interval recognition.

More research should be done in the area of why certain intervals appear to be more difficult to learn and recognize. This may have some effect upon the method and sequence in which they are taught.

FOOTNOTES

[1] Anne Gates and John Bradshaw, The Role of the Cerebral Hemispheres in Music, Brain and Language 4(3) (July 1977), 415-416.

[2] Anne Gates and John Bradshaw, The Role of the Cerebral Hemispheres in Music, Brain and Language 4(3) (July 1977), 416-418.

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APPENDICES

Appendix 1

LETTER TO PARENTS

Dear Parents:

I am presently conducting experimental research for a Master of Music Education degree from the University of Calgary. This research is designed to investigate how grade six, seven and eight students process or analyze music intervals. The study will attempt to find out if one ear is actually faster or more accurate in recognizing certain musical sounds.

Before the actual research begins, the student will be given a hearing test by the County Health Unit to ensure that there is adequate hearing in both ears. After that has been established, the student will listen to a series of 32 music intervals on a cassette tape and recognize either the perfect fourths or the major thirds that occur. This will be heard through one ear at a time and then, after a five minute rest, the test will be done for the other ear. This procedure will be repeated on four different occasions. A computer will keep record of the accuracy and time for each ear.

This study will be carried out in accordance with the University of Calgary ethical standards for research.

All of the information collected will be strictly confidential and the students will not be identified individually.

Your son or daughter's participation is, of course, completely voluntary.

Please complete the attached permission form and have your son or daughter return it to his or her music teacher.

Appendix 2

PERMISSION FORM

I hereby give permission for my son or daughter to participate in the study being conducted

by Patricia Hoag

of the University of Calgary

entitled Hemispheric Asymmetry in the Recognition of Monaural, Melodic, Ascending Intervals in Grade Six, Seven and Eight Students

During the course of this study my child's hearing may be tested and, by signing below, I hereby approve of the testing for the purposes of this study only.

Name of Child: ______________________________

Date of Birth: ______________________

Date: ___________________

Signature of Parent or Guardian ___________________________

Appendix 3

GROUP A
INTERVAL IDENTIFICATION

Name- ____________________ Grade- ____________________

School- ____________________ Date- ____________________

IF YOU HEAR THE PERFECT FOURTH INTERVAL, WRITE P4.

Example: 99. P4

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

Appendix 4

GROUP B
INTERVAL IDENTIFICATION

Name- ____________________ Grade- ____________________

School- ____________________ Date- ____________________

IF YOU HEAR THE MAJOR THIRD INTERVAL, WRITE M3.

Example: 99. M3

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

Appendix 5

EXPLANATION OF HANDEDNESS INDEX

The handedness index was calculated on the basis of the items found in the Handedness Chart. Questions concerning handedness when using a broom or opening a box lid were counted as one item. The ratio used to determine handedness was the number of pluses in the right column minus the number of pluses in the left column divided by the total number of possible pluses and multiplied by 1000.

$$\frac{R - L}{\text{Total Possible Pluses}} \times 1000$$

Therefore, a negative number indicates left handedness. A strength of eighty percent right handedness was required to participate in this experiment.

Appendix 6

HANDEDNESS CHART

Please show your choice in the use of hands for the following activities by putting + in the appropriate column. If you would never try to use the other hand unless absolutely forced to, put ++, if it really doesn't matter put + in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand choice is wanted is shown in brackets.

Please try to answer all the questions and only leave a blank if you have no experience at all with the object or task.

	RIGHT	LEFT
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking a Match (match)		
10. Opening a Box (lid)		

Appendix 7

VOCAL RANGE CHART

Name- ______________________________

School-______________________________

Age- __________

Grade- __________

Date- __________

Range- __________

PRE-TEST RESULTS

1) __________
2) __________
3) __________
4) __________
5) __________

Appendix 8

FAMILY HANDEDNESS QUESTIONNAIRE

Name-____________________ School-____________________

In the following chart please check the appropriate boxes. A box can be checked more than once; for instance, if you have two brothers and both are right handed, you would put two checks in the box under "Right", on the line alongside where it says "Brothers". Note also that the chart is concerned with blood relatives only.

Blood Relation	How Many	Right	Left	Ambidextrous	Don't Know
Father	1				
Mother					
Older Brother(s)					
Younger Brother(s)					
Older Sister(s)					
Younger Sister(s)					
Father's Father					
Father's Mother					
Mother's Father					
Mother's Mother					

Appendix 9

MUSICAL BACKGROUND QUESTIONNAIRE

Name-__________________ Date-__________________

School-__________________ Grade-__________________

Age-______________ Birthdate-__________________

1) How many years have you taken vocal music in school?

____

2) How long have you studied instrumental music in school?

____

On what instrument? ________________________

3) Do you sing regularly in extra-curricular choirs? ____________

4) Have you taken piano lessons? ____________________

5) Have you taken private theory lessons? ________________

6) Have you taken any formal ear training prior to the instruction for this testing? ________________________

If so, when and for how long? ____________________

7) Have you taken any private instrumental lessons other than piano?

____

On what instrument? ________________________

For what period of time? ______________________

RESEARCH QUESTIONNAIRE

Name-____________________ School-_________________________

Age-_____________________ Date-__________________________

You have now completed all aspects of this research. Your participation, time and effort were very much appreciated. Please take a minute and fill out the following questions.

1) Did you notice any ear preference when doing the testing?

Yes________ No________

2) If the answer to question number 1 was yes, which ear did you prefer to use?

Right________ Left-________ Can't Remember-________

3) Did you notice or feel anything of significance during the course of the study?

____

____

____

____

____

Appendix 11

GROUP A TAPES

TAPE 1

1) P4- D 4 to G 4
2) P5- D 4 to A 4
3) M3- C 4 to E 4
4) P5- F 4 to C 5
5) P5- C 4 to G 4
6) M3- F 4 to A 4
7) P5- Db4 to Ab4
8) P5- B 3 to F*4
9) P5- E 4 to B 4
10) M3- F*4 to A*4
11) P4- Bb3 to Eb4
12) M3- C 4 to E 4
13) P4- D 4 to G 4
14) M3- Ab4 to C 5
15) P4- Eb4 to Ab4
16) P5- Bb3 to F 4
17) P4- A 3 to D 4
18) M3- Eb4 to G 4
19) M3- D 4 to F*4
20) P5- Eb3 to Bb4
21) P4- C 4 to F 4
22) P5- Ab3 to Eb4
23) P4- E 4 to A 4
24) P4- G 4 to C 5
25) P4- Db4 to Gb4
26) M3- E 4 to G*4
27) P4- B 3 to E 4
28) P5- D 4 to A 4
29) P4- F 4 to Bb4
30) M3- Db4 to F 4
31) M3- B 3 to D*4
32) P5- C 4 to G 4

TAPE 2

1) P4- D 4 to G 4
2) P5- D 4 to A 4
3) P5- C 4 to G 4
4) P4- F 4 to Bb4
5) M3- E 4 to G*4
6) P5- Eb4 to Bb4
7) P5- B 3 to F*4
8) P4- D 4 to G 4
9) P5- E 4 to B 4
10) P4- Ab3 to Db4
11) P4- E 4 to A 4
12) M3- C*4 to E*4
13) M3- D 4 to F*4
14) M3- Bb3 to D 4
15) P5- Db4 to Ab4
16) P4- C 4 to F 4
17) M3- F*4 to A*4
18) P4- G*3 to C*4
19) P5- B 3 to F*4
20) M3- F 4 to A 4
21) P5- G 3 to D 4
22) P4- C 4 to F 4
23) M3- B 3 to D*4
24) P5- A*3 to E*4
25) M3- D 4 to F*4
26) M3- F 4 to A 4
27) P4- D 4 to G 4
28) P5- F 4 to C 5
29) P4- E 4 to A 4
30) P4- D 4 to G 4
31) P5- Ab3 to Eb4
32) M3- C 4 to E 4

G3-B3=196-246Hz C4-B4=261-493 Hz C5=523 Hz

Appendix 12

GROUP A TAPES

TAPE 3	TAPE 4
1) P4- D 4 to G 4	1) P4- D 4 to G 4
2) P5- D 4 to A 4	2) P5- D 4 to A 4
3) M3- F 4 to Bb4	3) M3- C 4 to E 4
4) M3- C 4 to E 4	4) P4- F 4 to Bb4
5) P4- Ab3 to Db4	5) P4- C 4 to F 4
6) P5- F 4 to C 5	6) P5- E 4 to B 4
7) M3- B 3 to D#4	7) P5- Db4 to Ab4
8) P5- C#4 to G#4	8) M3- B 3 to D#4
9) P4- Bb3 to Eb4	9) M3- D 4 to F#4
10) M3- C 4 to E 4	10) P4- E 4 to A 4
11) M3- D 4 to F#4	11) M3- Bb3 to D 4
12) P5- Eb4 to Bb4	12) P5- C#4 to G#4
13) P4- E 4 to A 4	13) P5- D 4 to A 4
14) P5- C 4 to G 4	14) P4- Ab3 to Db4
15) M3- Bb3 to D 4	15) M3- Eb4 to G 4
16) M3- Eb4 to G 4	16) P5- Bb3 to F 4
17) M3- F 4 to A 4	17) P4- A 3 to D 4
18) P5- C 4 to G 4	18) P4- Eb4 to Ab4
19) P4- B 3 to E 4	19) P4- D 4 to G 4
20) P4- Eb4 to Ab4	20) M3- F 4 to A 4
21) P5- B 3 to F#4	21) P4- C 4 to F 4
22) P5- Db4 to Ab4	22) P5- Ab3 to Eb4
23) P4- A 3 to D 4	23) P5- E 4 to B 4
24) M3- Db4 to F 4	24) P5- F 4 to C 5
25) P5- Ab3 to Eb4	25) P5- Db4 to Ab4
26) P4- B 3 to E 4	26) P4- E 4 to A 4
27) P5- G 3 to D 4	27) M3- B 3 to D#4
28) M3- C 4 to E 4	28) P4- D 4 to D 4
29) P4- G 4 to C 5	29) P5- F 4 to C 5
30) P4- D 4 to G 4	30) M3- Db4 to F 4
31) P5- F 4 to C 5	31) M3- B 3 to D#4
32) M3- D 4 to F#4	32) M3- D 4 to F#4

G3-B3=196-246Hz   C4-B4=261-493 Hz   C5=523 Hz

Appendix 13

GROUP B TAPES

TAPE 5	TAPE 6
1) M3- D 4 to F*4	1) M3- D 4 to F*4
2) P4- D 4 to G 4	2) P4- D 4 to G 4
3) M2- C 4 to D 4	3) P4- F 4 to Bb4
4) P4- F 4 to Bb4	4) M3- C 4 to E 4
5) P4- C 4 to F 4	5) M2- Ab4 to Bb4
6) M2- F 4 to G 4	6) P4- G 4 to C 5
7) P4- Db4 to Gb4	7) P4- B 3 to E 4
8) P4- B 3 to E 4	8) M3- C*4 to E*4
9) P4- D 4 to G 4	9) P4- Bb3 to Eb4
10) M2- F*4 to G*4	10) M3- D 4 to F*4
11) M3- Bb3 to D 4	11) M3- F 4 to A 4
12) M2- C*4 to D*4	12) M2- Eb4 to F 4
13) M3- D 4 to F*4	13) M2- A 4 to B 4
14) M2- Ab4 to Bb4	14) M2- C 4 to D 4
15) M3- Eb3 to G 4	15) P4- Bb3 to Eb4
16) P4- Bb3 to Eb4	16) M3- D 4 to F*4
17) M3- A 3 to C*4	17) M2- F*4 to G*4
18) M2- Eb4 to F 4	18) M3- C 4 to E 4
19) M2- D 4 to E 4	19) P4- D 4 to G 4
20) P4- Eb4 to Ab4	20) M2- Eb4 to F 4
21) M3- C 4 to E 4	21) P4- B 3 to E 4
22) P4- Ab3 to Db4	22) M3- Db4 to F 4
23) M3- E 4 to G*4	23) M2- A 3 to B 3
24) M3- G 4 to B 4	24) P4- Db4 to Gb4
25) M3- Db4 to F 4	25) M2- Ab3 to Bb3
26) M2- E 4 to F*4	26) M2- F 4 to G 4
27) M3- B 3 to D*4	27) M3- B 3 to D*4
28) P4- D 4 to G 4	28) P4- C 4 to F 4
29) M3- F 4 to A 4	29) M3- G 4 to B 4
30) M2- Db4 to Eb4	30) M3- D 4 to F*4
31) M2- B 3 to C*4	31) P4- F 4 to Bb4
32) P4- D 4 to G 4	32) M2- D 4 to E 4

G3-B3=196-246Hz   C4-B4=261-493 Hz   C5=523 Hz

Appendix 14

GROUP B TAPES

TAPE 7	TAPE 8
1) M3- D 4 to F#4	1) M3- D 4 to F#4
2) P4- D 4 to G 4	2) P4- D 4 to G 4
3) M3- C 4 to E 4	3) M2- G 4 to A 4
4) M2- F 4 to G 4	4) M3- D 4 to F#4
5) M3- E 4 to G#4	5) M3- F 4 to A 4
6) P4- B 3 to E 4	6) P4- C 4 to F 4
7) M2- Eb4 to F 4	7) P4- B 3 to E 4
8) P4- G 3 to C 4	8) M2- C#4 to D#4
9) M3- B 3 to D#4	9) M2- E 4 to F#4
10) M2- F 4 to G 4	10) M3- Ab4 to C 5
11) M2- Ab4 to Bb4	11) M2- Eb4 to F 4
12) P4- A 3 to D 4	12) P4- A 3 to D 4
13) M3- E 4 to G#4	13) P4- D#4 to G#4
14) P4- C#4 to F#4	14) M3- Bb3 to D 4
15) M2- Bb3 to C 4	15) M2- Db4 to Eb4
16) M2- D 4 to E 4	16) P4- F#4 to B 4
17) M2- F#4 to G#4	17) M3- Eb4 to G 4
18) P4- F 4 to Bb4	18) M3- G#4 to B#4
19) M3- Db4 to F 4	19) M3- B 3 to D#4
20) M3- Eb4 to G 4	20) M2- F 4 to G 4
21) P4- A 3 to D 4	21) M3- C 4 to E 4
22) P4- C 4 to F 4	22) P4- A 3 to D 4
23) M3- B 3 to D#4	23) P4- F 4 to Bb4
24) M2- F#4 to G#4	24) P4- D 4 to G 4
25) P4- Db4 to Gb4	25) P4- A#3 to D#4
26) M3- F 4 to A 4	26) M3- G 4 to B 4
27) P4- D 4 to G 4	27) M2- Bb4 to C 5
28) M2- C 4 to D 4	28) M3- A 3 to C#4
29) M3- E 4 to G#4	29) P4- D 4 to G 4
30) M3- D 4 to F#4	30) M2- B 3 to C#4
31) P4- Ab3 to Db4	31) M2- G#4 to A#4
32) M2- F 4 to G 4	32) M2- Eb4 to F 4

G3-B3=196-246Hz   C4-B4=261-493 Hz   C5=523 Hz

Appendix 15

RAW SCORES FOR THE PERFECT FOURTH GROUP

Sub-Group	Subject Number	Trial 1 RE	Trial 1 LE	Trial 2 RE	Trial 2 LE	Trial 3 RE	Trial 3 LE	Trial 4 RE	Trial 4 LE
R Hand	1	*26	28	26	28	26	24	26	26
R Ear First		**2.47	3.10	2.74	2.68	2.79	2.30	2.91	3.06
	2	27	25	29	28	27	27	25	29
		2.17	1.98	2.13	2.18	2.38	2.28	2.08	2.21
	3	26	25	27	28	27	29	29	26
		1.96	1.89	1.91	1.84	2.00	1.93	1.79	1.85
	4	30	30	28	29	30	30	29	27
		2.60	2.22	2.26	2.37	2.11	2.17	2.15	2.20
R Hand	5	21	18	25	22	24	19	21	16
L Ear First		2.23	2.27	2.01	2.01	1.96	2.12	2.74	1.86
	6	29	26	26	27	29	29	27	27
		2.28	2.62	2.14	2.48	2.56	2.36	2.39	2.32
	7	28	27	28	29	26	28	28	27
		2.70	2.70	2.30	2.63	2.79	2.41	2.50	2.63
	8	19	20	23	20	21	22	22	18
		3.10	3.43	2.59	4.01	2.79	2.81	2.86	3.49

*Number Correct **Time RE-Right Ear LE-Left Ear

Appendix 16

RAW SCORES FOR THE PERFECT FOURTH GROUP(continued)

Sub-Group	Subject Number	Trial 1 RE	Trial 1 LE	Trial 2 RE	Trial 2 LE	Trial 3 RE	Trial 3 LE	Trial 4 RE	Trial 4 LE
L Hand	9	*22	20	21	25	24	24	24	28
R Ear First		**4.19	2.75	3.28	3.35	2.84	2.64	2.60	2.34
	10	24	25	26	27	28	26	28	30
		2.73	2.67	2.63	2.57	2.16	2.27	2.33	2.66
	11	28	27	27	30	30	30	28	30
		2.03	1.93	2.07	2.06	1.99	2.23	1.88	1.94
	12	30	30	27	28	28	29	29	28
		2.15	2.25	2.03	2.45	2.05	2.23	2.05	2.09
L Hand	13	30	29	30	30	30	30	29	29
L Ear First		2.49	2.64	2.63	2.40	2.34	3.19	2.81	2.49
	14	24	25	24	26	23	28	27	27
		2.66	2.51	2.36	2.89	3.22	2.39	3.13	2.90
	15	22	24	23	23	27	19	22	22
		2.07	1.99	2.29	2.34	2.54	2.21	2.63	1.87
	16	27	30	30	29	30	29	30	30
		3.49	2.93	3.46	3.31	3.24	2.85	2.73	3.31

*Number Correct **Time RE-Right Ear LE-Left Ear

Appendix 17

RAW SCORES FOR THE MAJOR THIRD GROUP

Sub-Group	Subject Number	Trial 1 RE	Trial 1 LE	Trial 2 RE	Trial 2 LE	Trial 3 RE	Trial 3 LE	Trial 4 RE	Trial 4 LE
R Hand	1	*20	27	26	28	25	27	27	28
R Ear First		**2.80	2.66	2.79	2.65	2.34	2.37	2.22	2.43
	2	30	29	30	30	30	30	30	29
		1.78	1.88	1.76	1.91	1.88	2.15	1.88	2.04
	3	30	30	29	30	30	30	30	30
		1.92	1.91	1.88	1.85	1.71	1.83	1.78	1.63
	4	20	22	19	21	20	22	21	19
		2.67	2.47	2.22	2.30	2.30	2.15	2.54	2.12
R Hand	5	29	30	28	27	26	29	28	25
L Ear First		4.09	4.55	4.73	4.24	3.75	3.84	3.95	2.90
	6	25	21	25	23	25	23	25	22
		2.82	3.03	3.18	3.15	2.99	2.92	3.12	4.96
	7	30	30	29	29	29	30	29	30
		2.38	2.24	2.40	2.92	2.28	2.34	2.23	2.52
	8	20	26	22	20	17	19	18	18
		2.74	2.68	2.50	2.22	2.67	2.83	2.31	2.20

*Number Correct **Time RE-Right Ear LE-Left Ear

Appendix 18

RAW SCORES FOR THE MAJOR THIRD GROUP(continued)

Sub-Group	Subject Number	Trial 1 RE	Trial 1 LE	Trial 2 RE	Trial 2 LE	Trial 3 RE	Trial 3 LE	Trial 4 RE	Trial 4 LE
L Hand	9	*19	20	27	19	22	19	17	20
R Ear First		**2.92	4.09	3.51	2.88	3.62	2.51	3.54	2.85
	10	30	30	29	30	30	30	30	30
		2.22	2.25	2.17	2.24	2.35	2.45	2.31	2.23
	11	24	24	21	21	26	26	19	23
		3.07	3.90	2.32	2.41	2.51	2.42	2.38	2.03
	12	22	20	18	17	20	20	18	18
		2.88	2.56	3.00	2.98	2.92	2.88	3.61	2.59
L Hand	13	25	23	22	24	23	25	25	20
L Ear First		3.68	3.19	3.51	3.17	3.73	2.76	3.49	3.06
	14	30	30	30	29	30	30	30	30
		1.89	1.90	2.10	1.88	2.06	2.00	2.03	2.25
	15	20	21	18	20	18	21	19	18
		3.87	2.94	2.82	4.09	3.39	2.87	3.29	2.43
	16	20	15	13	19	18	16	18	22
		4.10	4.82	3.74	3.76	2.09	2.56	2.13	2.83

*Number Correct **Time RE-Right Ear LE-Left Ear