ASSESSMENT OF EAR ASYMMETRY THROUGH VERBAL REACTION TIMES TO MONOTIC AND DICHOTIC LISTENING TASKS

By

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Bachelor of Science

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Stillwater, Oklahoma

1973

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF ARTS
May, 1974

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PREFACE

This study is based on the phenomenon of a right ear effect found by Doreen Kimura (1961a) in dichotic listening tasks. Research has shown dichotic listening tasks to be an adequate means for assessing cerebral dominance for speech and language. Researchers, utilizing dichotic listening tasks, have attempted to investigate the relationship of cerebral dominance to various speech disorders. However, problems in controlling variables in the production of dichotic speech stimulus material may have inhibited research in this area. The identification of a relatively simple, reliable means for assessing cerebral dominance, such as a monotic listening task, would greatly facilitate research in this area. Previous research with monotic and dichotic listening tasks has suggested that ear asymmetry occurs only under conditions of competition between the ipsilateral and contralateral auditory pathways. Recently, however, a right ear effect was found by J. Simon (1967) in a monotic listening task in which subjects were unaware of the ear to be stimulated. The primary objective of this study, therefore, is to determine the feasibility of utilizing verbal reaction time in a monotic listening task, with the subjects unaware of the ear to be stimulated, in assessing cerebral dominance.

The author gratefully expresses her appreciation to her major advisor, Dr. Burchard Carr, for his thoughtful supervision and guidance throughout this study. Appreciation is also extended to the other committee members, Dr. Cheryl Scott, Dr. Robert J. Weber, and Ms. Genese Warr, for their cooperation, time, and advice.

The author sincerely thanks Dr. Barbara Weiner for her assistance in the design of the statistical procedures utilized in this study.

A special note of gratitude is expressed to my husband, Michael, and our daughter, Michealle, for their patience, understanding, encouragement, and many sacrifices which helped make this study possible.

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CHAPTER I

INTRODUCTION

The phenomenon of a right ear effect in dichotic listening tasks has become well documented in the literature by D. Kimura (1961a, 1967), D. Broadbent (1954), M. Bryden (1963), B. Carr (1969b) and several others. This right ear effect was first demonstrated by Kimura (1961b) in a study in which subjects who had undergone unilateral temporal lobectomies were presented one digit in the right ear simultaneously with a different digit in the left ear. She found that accuracy in recalling the digits, as measured by the total number of digits correctly reported from both ears, was affected by left temporal lobectomies but not by right temporal lobectomies; that is, subjects with a right temporal lobectomy were more accurate in recalling the digits simultaneously presented to the two ears than those subjects with a left temporal lobectomy (Kimura, 1961b). In a subsequent study, using one group of subjects with speech represented in the right hemisphere and another group of subjects with speech represented in the left hemisphere, Kimura found that "when different verbal stimuli are presented to the two ears, those stimuli which arrive at the ear opposite the dominant hemisphere are more efficiently recognized" (Kimura, 1961a, p. 169). These results were consistent with the results of her previous study. She explained these findings by suggesting that the "crossed auditory pathways are stronger than the uncrossed, and that the dominant temporal lobe is more important than the non-dominant in the perception of spoken materials" (Kimura, 1961a, p. 171).

In a later study, M. P. Bryden found that most subjects tended to report material presented to the right ear before reporting material presented to the left and were more accurate in identifying the material presented to the right ear (Bryden, 1963). He suggested that one reason for this was that subjects tended to forget the left ear material before they were able to report it (Bryden, 1963). Results of a study by B. Carr (1969b), however, at least partially contradicted Bryden's results. In an experiment designed to study, among other things, the order in which subjects reported dichotic material, Carr found no statistically significant order of report preference. This contradiction between Carr's and Bryden's findings may have resulted from the inclusion in Carr's study of data from subjects who reported all digits correctly on all trials; a class which was not included in Bryden's analysis.

In another study, Bryden (1963) controlled the order of reporting the stimulus material in an attempt to eliminate the tendency of subjects to forget the material from the left ear before they were able to report it. He found that subjects were more accurate in identifying speech stimuli presented to the right ear than similar materials presented to the left ear even when the order of report was controlled (Bryden, 1963).

S. Springer (1973b) later theorized that in dichotic tasks the processing and output functions were confounded because processing of verbal stimuli required a verbal response. She did an experiment (Springer, 1973b), in which subjects listened to a dichotic stop-vowel tape and depressed a response button when one particular syllable occurred, thereby attempting to bypass the verbal output centers of the left hemisphere. She felt in this way any ear advantage effect could be attributed to a "true processing asymmetry between hemispheres" (Springer, 1973b, p. 1). She found that subjects detected the syllable more accurately when presented to the right ear and that the response time was shorter for the right ear than the left. She concluded that

> a right ear advantage can be obtained in a dichotic task when a non-verbal manual responding paradigm is utilized, indicatting that the right ear advantage phenomenon is at least partly perceptual in origin (Springer, 1973b, p. 1).

In a second dichotic study designed to explore the "extent or degree of hemispheric specialization for speech," (Springer, 1973b, p. 1), Springer compared manual and verbal responding in a target detection task. On half of the trials subjects repeated the "target" syllable each time it occurred, while on the other half of the trials they responded manually each time the "target" syllable occurred. She found that "right ear targets are responded to more quickly than left ear targets, while manual responding overall was faster than verbal responding" (Springer, 1973b, p. 2). She also found that there was no interaction between the ear of target and mode of response; i.e., in both manual and verbal responding, the reaction time difference between the right and left ears was identical. She feels this supports the idea that the "final terminus immediately preceding output for each speech stimulus is the left hemisphere" (Springer, 1973b, p. 2).

In a third experiment, Springer (1973b) attempted to determine if the dichotic stimuli had to be of the same perceptual class in order to obtain a right ear effect. A dichotic tape with CV syllables on one channel and white noise on the other channel was utilized. The subject's task was to move a lever in one direction if the syllable /ba/ was presented and in the opposite direction if any other syllable was presented. Reaction time was measured in milliseconds from the onset of the syllable to the onset of the subject's response. Results showed that left ear responses averaged 14 milliseconds longer than right ear responses, while responses indicating the presence of /ba/ were made more quickly than responses indicating the absence of /ba/. This demonstrated a right ear advantage in terms of reaction time for the recognition of speech material opposed by contralateral noise. This right ear advantage was not seen in a control group which received the same stimuli without the contralateral white noise. Springer concluded from this study that some kind of dichotic presentation was necessary for an ear advantage effect, however, the competing stimulus does not have to be of the same perceptual class (Springer, 1973b).

Much research has been aimed at recognizing variables which effect the perception and reporting of dichotic material (Thompson, Stafford, Cullen, Hughes, Lowe-Bell, and Berlin, 1972; Hannah, 1970; Berlin, Lowe, Cullen, Jr., 1971; Studdert-Kennedy, Shankweiler, Schulman, 1970; Kirstein, 1971; Lowe, Cullen, Jr., Berlin, Thompson, and Willet, 1970; Thompson and Hughes, USPHS Grant No. NS-07005).

C. Thompson and colleagues (1972) investigated the effect of interaural intensity differences on dichotic speech perception. Subjects were presented dichotic signals under unequal intensity conditions. This was accomplished by varying the intensity level of the signal to the variable ear by 5dB steps from 30dB through 80dB while maintaining the intensity of the signal to the reference ear constant at 50dB. Each ear served as reference ear in half of the conditions and as the variable ear in the other half of the conditions. They found the right ear effect occurred when there were large intensity imbalances, if these intensity imbalances were counterbalanced between ears. This suggested to them that, in general, $\pm$10dB is adequate intensity control in dichotic tapes to reveal an ear effect at intensity levels between 50dB and 80dB, if there is proper counterbalancing of channels between ears. Interaural differences, however, are more critical at lower intensity levels.

> At 80dB SPL differences as large as 10dB would not over-ride an overall effect, even if the intensity imbalance is not counterbalanced to the two ears, while at 50dB SPL even a 5dB difference can result in the left ear outperforming the right if the intensity advantage is always to the left ear (Thompson, et al., 1972, p. 6).

In another study reported in the same article (Thompson, et al., 1972) in which intensity levels were equal in both ears, but the level of presentation varied from 30dB to 80dB, they found that unvoiced stops were more accurately reported than voiced stops at intensity levels of 50dB SPL and above. At lower intensities, voiced stops were reported more accurately than unvoiced stops. They reported that in a previous study using the same tapes in a monaural situation, this unvoiced over voiced effect was not found.

In a similar study, C. Thompson and L. Hughes (USPHS Grant No. NS-07005) also investigated the effect of intensity using dichotic CV syllables at six intensity levels, 30dB, 40dB, 50dB, 60dB, 70dB and 80dB SPL. They found a right ear effect for "all intensity levels, but decreasing in magnitude as intensity increases above 50dB SPL" (Thompson and Hughes, USPHS Grant No. NS-07005, p. 1). The results showed a voiceless over voiced right ear effect at the higher intensity levels, with the reverse being true for intensity levels below 50dB SPL.

The control of the onset of stimuli syllables in dichotic pairs has been shown to effect the perception of the dichotic material. J. Hannah (1970), in an unpublished dissertation, indicated that larger laterality effects are obtained when the onset of the syllables of a dichotic pair are more precisely controlled.

S. Lowe, J. Cullen, Jr., C. Berlin, C. Thompson, and M. Willet (1970) found similar results in a study which was designed to investigate the difference in the perception of dichotically and monotically presented voiced and voiceless consonants. In the dichotic task they found differences in the perception of initial position voiced consonants. For both real and synthetic syllables the voiceless consonants were perceived more accurately. They explained this finding in terms of a "lag effect" described by M. Studdert-Kennedy, M. Shankweiler, and S. Schulmann (1970). In the dichotic tasks when the two stimuli words are staggered in time so that one leads the other by 30-90 milliseconds (msec.), the lagging word is heard more clearly. When two consonant explosions are lined up at precisely the same onset points, the transition from aperiodic to periodic tracings on an oscillograph occurs in the voiced CV syllable before the voiceless CV syllable, thus creating a "lag effect."

Charles Berlin and his colleagues (1971) found that in dichotic tapes

> at 15 msec. delay in either direction, the right ear superiority effect is still seen; however, if the left ear trails the right ear by 30 msec. or more, laterality effects in favor of the right ear are not seen (Berlin, et al., 1971, pp. 6-7).

Similar results with respect to the effect of delay of the onset of dichotic syllable pairs have also been obtained by Studdert-Kennedy, Shankweiler, and Schulmann (1970) and E. Kirstein (1971).

S. Lowe and colleagues (1970) used rhymed monosyllables to determine if laterality effects were the function of the vowel nucleus and to compare laterality effects of nonsense CV syllables containing the vowels /a/ and /i/ with laterality effects of rhymed words. In the first part of the study, the six stop consonants were paired with the vowels /ɛ/, /ɪ/, /o/, /i/, and /a/. Each stop was paired with every other stop. The CV syllables of each rhymed pair contained the same vowel and differed only in the stop (/pa/-/ba/). A significant right ear superiority was found for rhymed monosyllables with /a/, /ɪ/, and /o/ vowel nuclei, but no ear superiority was found for /i/ and /ɛ/. In the second part of the study, which used nonsense CV syllables rather than rhymed monosyllables, a right ear effect was obtained for syllables with /a/ and to a lesser extent for syllables with /i/. From these results it was concluded that subjects tend to do more poorly on tasks with the vowel nucleus /i/ than with vowels with lower second formants. With regard to consonants, it was found that subjects tended to more correctly report voiceless than voiced consonants.

J. Simon (1967) was the first to present findings which indicated that auditory asymmetry may occur under monotic conditions. He utilized a 1,000 Hz stimulus tone in a study which compared monaural vs. binaural listening conditions. Reaction time was measured from the onset of the stimulus tone to the depression of a finger key by the subject. Simon found that "under conditions of uncertainty as to which ear would be stimulated, subjects responded faster to a tone in the right ear than to a tone in the left" (Simon, 1967, p. 53). Until this time it had been thought that the right ear phenomenon occurred only in situations in which there was competition between ipsilateral and contralateral pathways to the dominant hemisphere (Kimura, 1963; Dirks, 1964; Bryden, 1969). Simon explained this right ear effect in monaural conditions by suggesting that when subjects were uncertain which ear would be stimulated, they tended to listen with their right ear and to react faster on trials which corresponded to their expectancy. He predicted that if the subjects were aware of which ear would be stimulated, the right ear effect would not occur (Simon, 1967).

In 1969, D. Bakkar investigated the monaural presentation of series of letters under three conditions: free recall in which subjects reported in any order they preferred; serial recall in which the subjects reported the series in the order presented; and order recall in which subjects indicated the position of a particular letter in the series. Results showed a right ear effect in a five letter series under serial and order recall, but not under the free recall condition. From these results, Bakkar concluded that requiring ordered recall apparently produces ear asymmetry in monaural situations.

Recently, W. Hernon (1972) used a verbal reaction time measure in order to study ear asymmetry in monotic and dichotic tasks. Digits were used as stimulus material and the subjects were instructed to repeat each digit immediately after hearing it. Verbal reaction time was measured in milliseconds from the onset of the stimulus to the onset of the subjects' response. In the dichotic situation, in which immediately preceding each digit pair the subjects were instructed which ear to respond to, Hernon found faster reaction times for the right ear. In the monotic condition the subjects heard one list of digits in the left ear and then another list of digits in the right ear. Each subject was informed prior to each list which ear would be stimulated during the presentation of that list and was instructed to repeat each digit in the list as soon as he heard it. Verbal reaction time was measured in the same way as in the dichotic condition. Hernon found no ear effect in the monotic condition, thus supporting Simon's (1967) prediction that if subjects knew in advance which ear would be stimulated in a monotic task, a right ear effect would not occur.

A right ear advantage for monaurally presented vowels was found by M. Studdert-Kennedy (1972) using three steady-state synthesized vowels /ɪ/, /ɛ/, /æ/. Each vowel was presented under two conditions: short duration - 20 msec.; and long duration - 80 msec., in both a monotic and a dichotic condition. In all conditions subjects depressed one of three keys depending on the vowel presented. Mean reaction times for vowels of short duration were longer than for vowels of long duration. Further, the mean right ear advantage for long duration vowels was not significant, but the mean right ear advantage for short vowels was significant. These results were the first to demonstrate a right ear advantage for vowels as a function of their stimulus properties instead of their context.

It is evident that a number of variables exist which make the production of well-controlled dichotic materials a difficult task to accomplish. Yet, when poorly controlled, these variables can influence a subject's perception of the stimulus. If a reliable monotic task could be found, therefore, which would result in an ear effect similar to that of a dichotic presentation, the relative simplicity of this type of stimulus would make it a desirable alternative to a dichotic task. The purpose of this study, then, was to further investigate the use of a monotic listening task in assessing cerebral dominance. Measurements were made of subjects' verbal reaction times in milliseconds to a monotic listening task in which the right and left ears were randomly stimulated, with the subject unaware of the ear to be stimulated. A dichotic listening task was used as a control condition. In the dichotic task the subjects were instructed which ear to respond to prior to the presentation of each dichotic pair. The results of the monotic condition were compared to the dichotic results in order to determine the feasibility of using verbal reaction time in a monotic listening task as a means of determining cerebral dominance.

CHAPTER II

METHODOLOGY

Subjects

The subjects were twelve male and twelve female student volunteers at Oklahoma State University. All subjects were right handed, had normal speech and language functioning, and were between the ages of 18 and 24. A pure-tone audiometric threshold test was administered to all subjects. Hearing threshold levels for all subjects were 15dB HL (ISO: 1964) or better for the frequencies 250 Hz, 500 Hz, 1kHz, 2kHz, 4kHz, and 6kHz. The subjects were further limited to those with no more than a 5dB difference between the right and left ears for the three frequency average of 500 Hz, 1kHz, and 2kHz. This limitation was utilized so that any ear effect would be due to the experimental stimuli and not to differences between subjects' right and left ears which might result in favoring one ear or the other. Subjects were also limited to those with no previous training in phonetics or experience with formal monotic or dichotic listening tasks.

Stimulus Material

The stimulus material consisted of CV nonsense syllables with the voiced stops /b/, /d/, /g/. Voiced stops were used exclusively in order to eliminate the variable of the unequal perception of voiceless compared with voiced stops as previously discussed (Thompson, et al., 1972;

Thompson and Hughes, USPHS Grant No. NS-07005; and Lowe, et al., 1970). Each of these voiced stops were paired with each of the relatively lax relatively short vowels /ɪ/, /ɛ/, /ʊ/ (Appendix A). The dichotic tape contained 18 randomized CV syllable pairs, repeated with the channels reversed so that each syllable appeared an equal number of times in each ear; resulting in a total of 36 dichotic pairs. The dichotic tape was recorded using a combination of two methods described by Carr (1969a, 1973).

Initial Dichotic Tape Preparation

Two Sony 650 stereophonic tape recorders and a custom-made cueing device were used in the first method. On Recorder A, the record and playback heads were reversed. Syllables were recorded in close time proximity onto Channel 1 of Recorder B. The output of this channel was fed back into and recorded onto Channel 2 of the same recorder (Recorder B). Thus the same syllables were recorded on both channels of Recorder B, with Channel 2 syllables lagging behind Channel 1 syllables by the distance between the record and playback heads of the recorder (Figure 1). A different set of syllables were recorded on Recorder A, Channel 1, with a greater time duration between syllables than those on Recorder B (Figure 2). The two recorders were then connected to the cueing device. Recorder A was then started and its first syllable activated Recorder B which reproduced a syllable from Channel 2 of Recorder B onto Channel 2 of Recorder A, where, as a result of the reversed heads on Recorder A, that syllable was recorded in synchronization with the previously recorded Recorder A, Channel 1 syllable (Figure 3). Recorder B then moved to its next syllable and stopped until it was again activated by

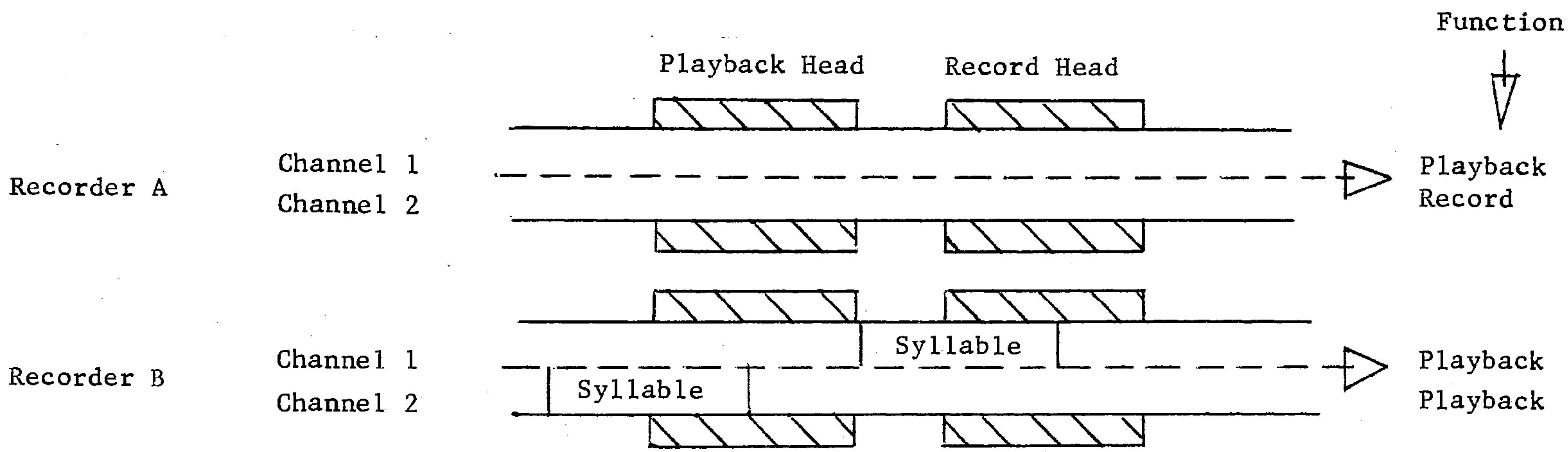

Figure 1. Alignment of CV Syllables on Channels 1 and 2 of Recorder B

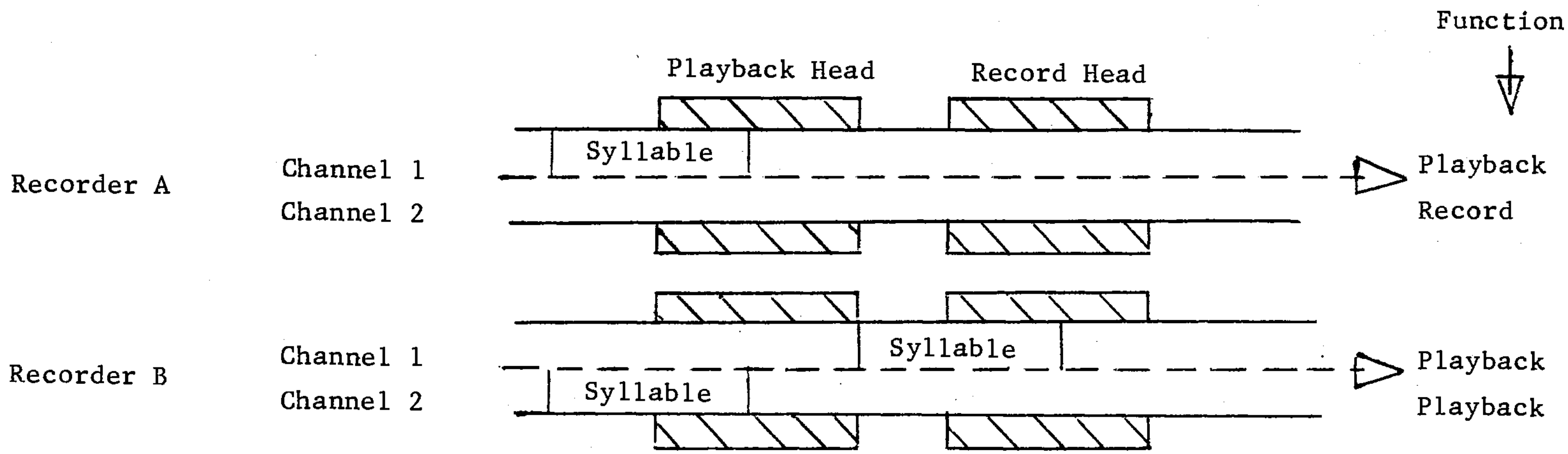

Figure 2. Alignment of CV Syllables on Channel 1 of Recorder A Compared to Those on Channels 1 and 2 of Recorder B Just Prior to Final Recording on Channel 2 of Recorder A

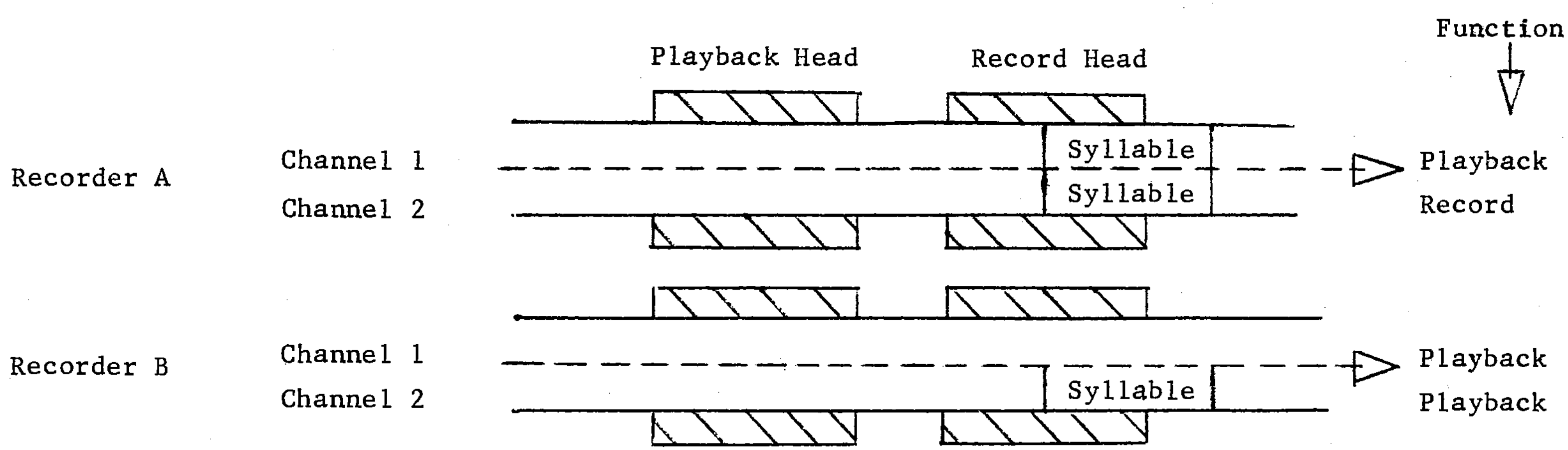

Figure 3. Final Alignment of Syllables on Channels 1 and 2 of Recorder A

Recorder A. Utilizing this method of tape production, a dichotic tape was produced with between channel delays in syllable onsets ranging from 0 msec. to 49.98 msec. According to studies previously cited (Berlin, et al., 1971; Studdert-Kennedy, et al., 1970; Kirstein, 1971) where there was a delay between the onset of syllable pairs of 20 msec. to 120 msec. (Kirstein, 1971) or 30 msec. (Berlin, et al., 1971; Studdert-Kennedy, et al., 1970), the delayed syllable was more accurately perceived regardless of which ear received it. Therefore, a second method (Carr, 1973) was utilized to enhance the synchrony of the syllable pairs.

Revised Dichotic Tape Preparation

This procedure also utilized two Sony 650 stereophonic tape recorders. One set of stimulus syllables was recorded on Channel 1 of Recorder A, with different syllables on Channel 2 of Recorder B. The two tapes were then rotated to find the onset of each syllable, indicated by the deflection of the needle of the VU meter of each recorder. At the exact point where the needle began to deflect, a vertical mark was placed on the tape. A mark was also made on the tape deck three inches in front of the record head of Recorder A and three inches in front of the playback head of Recorder B. The marks on the tapes which indicated the onset of each syllable were then matched with the marks on the tape decks of their respective recorders. Both recorders were activated simultaneously, with Channel 2 of Recorder A in the record mode and with Channel 2 of Recorder B in the playback mode. In this manner, when the marks on the tapes were placed in alignment with the markings on the tape decks, the Recorder B syllable passed the Recorder B playback head and was directed to and recorded onto Channel 2 of Recorder A simultaneously with the pre-recorded syllable on Channel 1 of Recorder A. Utilizing this method, it was possible to produce dichotic syllable pairs with onset differences ranging from 4.16 msec. to 8.55 msec. These onset differences were well within the range found by Berlin, et al., (1971), Studdert-Kennedy, et al., (1970), and Kirstein, (1971) which produces a right ear advantage (within ±20 to ±30 msec.). The intensity levels of the two syllables on Channels 1 and 2 of Recorder A were controlled so that the syllables were within ±2dB of each other. According to previous research by Thompson, et al., (1972), ±10dB is adequate intensity control in dichotic tapes for an ear effect to occur at intensity levels from 50dB to 80dB.

Monotic Tape Preparation

The monotic tape contained nine randomized CV syllables, listed twice and then randomized. These were repeated with channels reversed to make a total of 36 stimulus syllables, the same as the dichotic stimuli. The monotic CV syllables were randomized so that each syllable was heard an equal number of times in the right and left ear. Approximately 3 to 4 seconds prior to each monotic presentation, the subject heard a trial number, bilaterally, which alerted him to the upcoming trial.

Master Experimental Tape

The monotic syllables and dichotic syllable pairs were recorded onto a master experimental tape, along with taped instructions and three practice trials for each task. The monotic task series was recorded both before and after the dichotic task series in order to facilitate the presentation of the monotic task first to half of the subjects and the dichotic task first to the other half of the subjects, thus counteracting any possible order effect. The experimental stimuli were presented to subjects through TDH-39 headphones at 55dB SPL.

Procedure

Subjects were seated in an IAC booth (Model 403-A). After passing the pure-tone audiometric threshold test, the subjects received all instructions and stimulus materials through the TDH-39 headphones from a Sony 650 recorder. Taped practice material and instructions (Appendix B) were utilized to insure that the subjects understood the task and that the instructions were identical each time. In addition to the taped instructions, the subjects were also requested to be as accurate as possible in their responses. Prior to each testing day, the Sony 650 recorder was calibrated with a sound level meter to insure the presen- of the stimulus material to each subject at 55dB SPL.

The experimental stimulus tape was played on a Sony 650 recorder (Recorder A) at an intensity level which allowed the stimulus syllables to activate the solid state voice operated relay/reaction timer. The outputs of Channels 1 and 2 of Recorder A were also fed into Channels 1 and 2 of Recorder B and the volume adjusted so that the experimental stimuli were presented to the subjects at 55dB SPL. The outputs of Channels 1 and 2 of Recorder B were then channeled into the IAC booth where the subjects received the stimuli through the TDH-39 headphones (Figure 4). The output of Recorder B was also monitored by the examiner through Koss Pro-600A Stereo Headphones. As the subject received the stimulus syllable from Recorder B, the reaction timer simultaneously

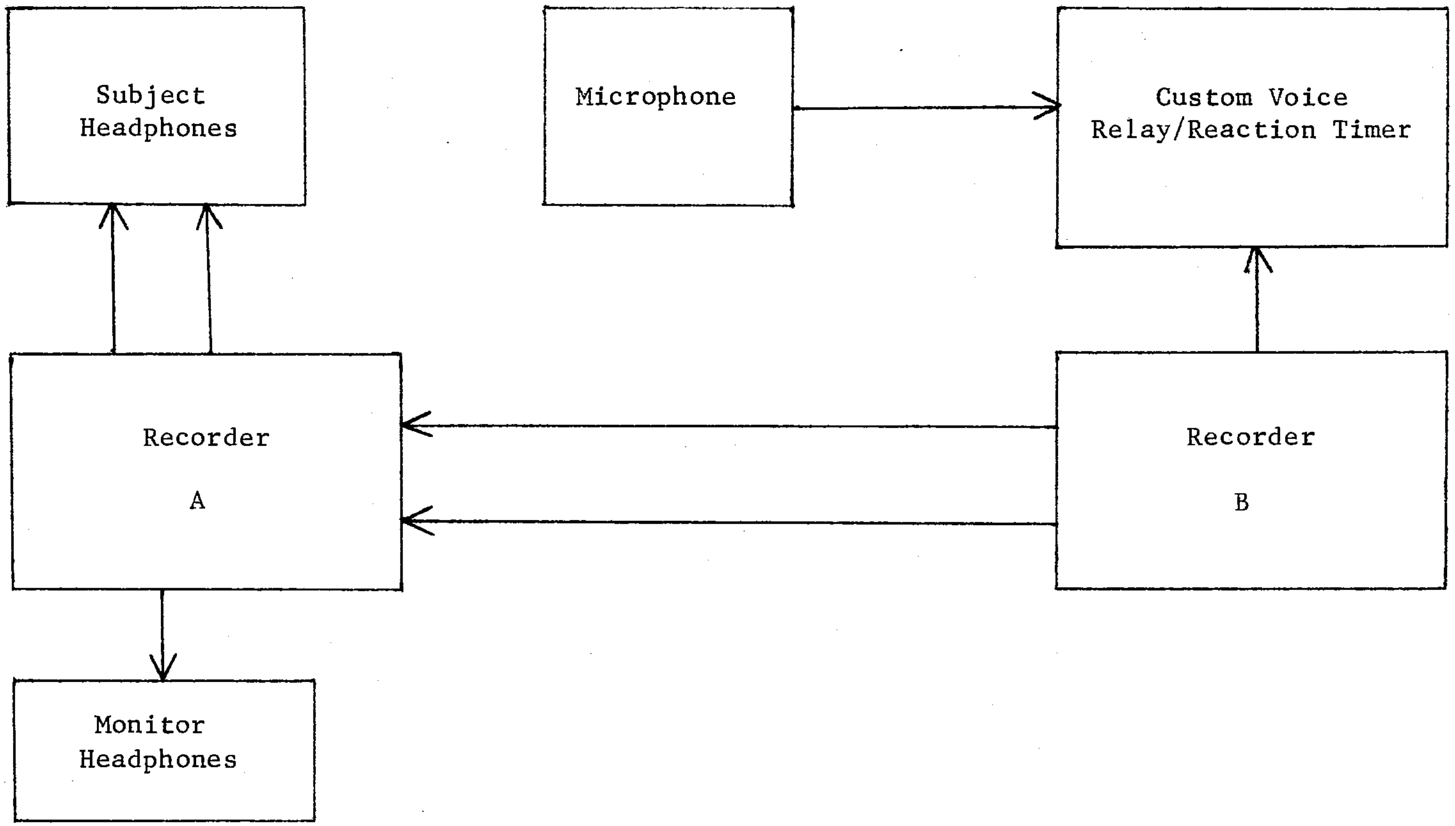

Figure 4. Diagram of Instrumentation

received the same stimulus syllable from Recorder A and was activated by the onset of that syllable. Subjects had approximately ten seconds to respond verbally, after which the next trial number and syllable were automatically presented. The subject's verbal response stopped the reaction timer and the examiner graphically recorded the reaction time in milliseconds and reset the timer to zero. The subject's verbal response was also recorded by a Sony TC-106A tape recorder so that the accuracy of responses could be examined later. One half of the subjects received Channel 1 in the right ear and Channel 2 in the left, with the channels reversed for the other half of the subjects. This counterbalanced any possible asymmetries in the experimental tape. The order of presentation of the two experimental conditions, dichotic and monotic, was also randomly alternated between subjects in an attempt to eliminate any order effects.

CHAPTER III

RESULTS

Analysis of Mean Verbal Reaction Times

Mean verbal reaction times were computed for each of the two groups; that is, the Dichotic-Monotic Group (D-M) and the Monotic-Dichotic Group (M-D). These means were obtained by averaging the verbal reaction times of the 36 responses for each condition of each of the 12 subjects in each group and then averaging the means of all 12 subjects in each group (Table I).

A t-test for independent samples revealed no significant difference at or beyond the .20 level of significance between the mean verbal reaction times of the two groups (M-D, D-M). The observed t values with 22 df for comparing these two groups on each of the conditions are as follows: left ear monotic, t = .9388; right ear monotic, t = 1.0748; left ear dichotic, t = .2878; right ear dichotic, t = .7089. Since there were no order effects, data were combined from the two orders of presentation for further analysis. Table II shows the mean verbal reaction times for all subjects in both conditions, dichotic and monotic.

A t-test for correlated observations indicated that the mean verbal reaction time for the right ear ($\bar{x}$ = 1169 msec.) was significantly faster than the mean verbal reaction time for the left ear ($\bar{x}$ = 1311 msec.) in the dichotic condition (t_{obs} = 5.3232, df = 23, $p < .01$).

TABLE I

MONOTIC REACTION TIMES (MSEC.) ACCORDING TO GROUPS BASED ON ORDER OF PRESENTATION

Order of Presentation	Condition			
	Monotic		Dichotic	
	Left Ear	Right Ear	Left Ear	Right Ear
Monotic - Dichotic	1498	1050	1288	1135
Dichotic - Monotic	1023	948	1334	1238

TABLE II

MEAN REACTION TIMES (MSEC.) OF SUBJECTS IN DICHOTIC AND MONOTIC CONDITIONS

Ear	Condition	
	Monotic	Dichotic
Left	1086	1311
Right	999	1187

In the monotic condition, the results of a t-test for correlated observations revealed that the mean verbal reaction time for the right ear ($\bar{x}$ = 999 msec.) was significantly faster than the mean verbal reaction time for the left ear ($\bar{x}$ = 1086 msec.), (t_{obs} = 4.2570, df = 23, $p < .01$).

Further analysis with a t-test for correlated observations showed the mean verbal reaction time for the right ear in the monotic condition ($\bar{x}$ = 999 msec.) to be significantly faster than the mean verbal reaction time for the right ear in the dichotic condition ($\bar{x}$ = 1187 msec.), (t_{obs} = 5.3550, df = 23, $p < .01$). Mean verbal reaction time for the left ear in the monotic condition ($\bar{x}$ = 1086 msec.) were also significantly faster than the mean verbal reaction time for the left ear in the dichotic condition ($\bar{x}$ = 1311 msec.), as evidenced by a t-test for correlated observations (t_{obs} = 3.1991, df = 23, $p < .01$).

Twenty-two of the twenty-four subjects demonstrated a right ear effect, as measured by verbal reaction time, in both the dichotic and monotic conditions. Individual subject ear effect was determined by which ear resulted in the faster mean verbal reaction time; that is, if a subject's mean verbal reaction time was faster for right ear trials than for left ear trials, he was said to show a right ear effect.

Analysis of Accuracy of Responses

When assessment of ear asymmetry was based upon accuracy of responses or percent correct, the right ear effect was not observed in the dichotic condition and was minimal in the monotic condition (Table III). Individual ear effect was defined as the ear with which a subject was more accurate in his responses; that is, if a subject had

TABLE III

COMPARISON OF VERBAL REACTION TIME EAR EFFECT TO RESPONSE ACCURACY EAR EFFECT ON DICHOTIC AND MONOTIC TASKS

Type of Measure	Number of Subjects With Right Ear Effect	Number of Subjects With Left Ear Effect	Number of Subjects With No Ear Effect
Verbal Reaction Time - Dichotic Condition	22	2	0
Response Accuracy - Dichotic Condition	4	7	13
Verbal Reaction Time - Monotic Condition	22	2	0
Response Accuracy - Monotic Condition	9	4	11

even one more correct response for right ear responses, he was said to demonstrate a right ear effect. Although not subjected to a statistical analysis, it should be noted that in the dichotic condition 4 subjects demonstrated a right ear effect, 7 a left ear effect, and 13 subjects no ear effect. Fifty-nine percent of all dichotic responses were incorrect, with right ear responses accounting for fifty-one percent of the incorrect responses and left ear responses accounting for forty-nine percent of the incorrect responses. Sixty-one percent of all right ear responses were in error, whereas fifty-seven percent of all the left ear responses were in error. The errors in the dichotic condition for the right ear responses ranged from 7 to 16 and from 7 to 14 for the left ear responses. Subjects averaged 9.4 and 10.4 errors for the right and left ear responses, respectively. In the monotic condition, 9 subjects showed a right ear effect, 4 a left ear effect and 11 no ear effect. The total error responses represented only 8.2 percent of all responses. Right ear responses accounted for forty-five percent of the total errors and left ear errors for fifty-five percent of the total errors. Seven percent of all right ear responses and nine percent of all left ear responses were incorrect. The range of errors in the monotic condition was from 0 to 8 errors for the right ear and 0 to 7 for the left ear responses, with subjects averaging 1.3 and 1.6 errors for the right and left ears, respectively.

The lack of a right ear accuracy effect and the large number of subjects who showed no ear effect in the dichotic condition may be primarily the result of the difficulty of the task. The syllable pairs were made difficult to discriminate because they were practically synchronous, equal in intensity, relatively low in intensity (55dB SPL) and phonemically similar. The majority of errors consisted of combining paired syllables into one syllable, so that /gʊ- dɪ/ might be reported as /gɪ/, and incorrectly reporting the consonant /b/ when it was paired with /g/ and /d/.

The verbal reaction times to the dichotic and monotic tasks were further analyzed regarding the vowels which produced a right ear effect. Table IV shows the mean verbal reaction times for the syllables which contained the vowels /ɪ/, /ɛ/, and /ʊ/. The vowels /ɪ/ and /ʊ/ resulted in faster mean reaction times than the vowel /ɛ/ in both conditions. In the monotic condition, the mean verbal reaction times for /ɪ/ and /ʊ/ for the right ear were 955 msec. and 948 msec., respectively, whereas the mean verbal reaction time for /ɛ/ for right ear responses was 1024 msec. Monotic mean verbal reaction times for the left ear responses for /ɪ/ and /ʊ/ were 1030 msec. and 1015 msec., respectively. Monotic mean verbal reaction time for left ear responses for /ɛ/ was 1019 msec. In the dichotic condition, the mean verbal reaction times for /ɪ/ and /ʊ/ for right ear responses were 1085 msec. and 1114 msec., respectively, whereas the vowel /ɛ/ resulted in a mean verbal reaction time of 1178 msec. for right ear responses. Left ear responses produced mean verbal reaction times of 1232 msec. for /ɪ/, 1206 msec. for /ʊ/, and 1107 msec. for /ɛ/. These differences were not treated statistically. The vowels /ɪ/ and /ʊ/ were also more accurately reported than the vowel /ɛ/.

TABLE IV

MEAN VERBAL REACTION TIMES (MSEC.) FOR CV SYLLABLES
WITH THE VOWELS /ɪ/, /ɛ/, /ʊ/ IN BOTH
MONOTIC AND DICHOTIC CONDITIONS

Condition	Vowels					
	/ɪ/		/ɛ/		/ʊ/	
	Right Ear	Left Ear	Right Ear	Left Ear	Right Ear	Left Ear
Dichotic Condition	1085	1232	1178	1107	1114	1206
Monotic Condition	955	1030	1024	1019	948	1015

CHAPTER V

DISCUSSION

This study is the first to demonstrate an unequivocal ear effect in a monotic listening task, as measured by verbal reaction time. Previous researchers have indicated that auditory asymmetry occurs only under conditions of competition between the ipsilateral and contralateral auditory pathways to the dominant hemisphere (Kimura, 1963; Bryden, 1969; Dirks, 1964; Springer, 1973b). The results of this study revealed that a right ear effect does occur in a monotic listening task which suggests that competition between these two pathways is not necessary for ear asymmetry to occur.

The finding of a right ear effect in a monotic task differs from the results of previous research with monotic tasks by Springer (1973a) and Hernon (1972) in which no ear effect occurred with monotic stimulation. The reason for these differences is apparently due to the manner of presentation of stimuli materials. In both Springer's and Hernon's studies the subjects knew which ear would be stimulated. They were presented blocks of speech stimuli first to one ear and then to the other ear, with no significant ear effect. In the present study, the ears of the subjects were randomly stimulated so that the the subjects were unaware of which ear would be stimulated. This suggests that in a monotic listening task, the subjects must be unaware of the ear to be stimulated in order for a right ear effect to occur.

The results of this study support findings of a previous study by Simon (1967) in which subjects responded to monotic stimuli by depressing a finger key. Simon attributed the right ear effect, under conditions of uncertainty as to the ear to be stimulated, to set and expectancy on the part of the subject. He suggested that under these conditions of uncertainty subjects tend to "tune in with their right ear and therefore react faster on the trials where the stimulus source corresponds to their expectancy" (Simon, 1967, p. 54). This same explanation of set and expectancy might also be applied to the findings of this study. An alternative explanation might be that there is a more efficient internal processing of right ear stimuli, as Kimura (1967) and others hypothesize occurs in dichotic conditions. It could be that there are two types of ear effect, one based on set and expectancy and one stemming from a more efficient internal processing of stimuli from one ear. If so, both effects may reflect cerebral dominance, as Bryden (1963) and Carr (1969a) have suggested. Regardless of the explanation for the ear effect in this study, the results indicate that a right ear effect does occur with monotic speech stimulation under the conditions of this study.

Twenty-two of the twenty-four subjects in this study demonstrated a faster mean verbal reaction time for the right ear than for the left ear in both monotic and dichotic conditions (Table V, Appendix C). The right ear effect in the dichotic condition is in accordance with previous similar research (Kimura, 1961a, 1967; Broadbent, 1954; Bryden, 1963; Hernon, 1972). These twenty-two subjects, then, apparently have left cerebral dominance for speech. The other two subjects had faster mean verbal reaction times for left ear than for the right ear in both conditions, suggesting that they have right cerebral dominance for speech.

The results also showed no significant difference among subjects due to order of presentation (D-M vs. M-D). Familiarity with the tasks conceivably could have resulted in reduced reaction times as the tasks progressed; therefore, the order of presentation was alternated between subjects. The results revealed no significant difference in reaction times between subjects who received the dichotic stimuli first, monotic second and those who received monotic materials first and dichotic second. Order of presentation, therefore, apparently is not a significant factor in these types of tasks.

The analysis of the data also revealed that the verbal reaction times for the right and left ears in the monotic condition were significantly faster than reaction times for the right and left ears in the dichotic condition. This finding is contradictory to the results of Simon's study (1967), in which he found a significant "superiority of binaural over monaural reaction times" (Simon, 1967, p. 54). He attributed this superiority to the set and expectancy of the subjects. He stated that if the subjects "tuned in with one ear or the other, they would always be tuned in correctly for the binaural trials," (Simon, 1967, p. 54), however, they

> would be incorrectly attuned on some monaural trials [where the stimulus source did not correspond with their expectancy], and this would tend to produce slower average reaction times (Simon, 1967, p. 54).

This contradiction may be due to the types of stimuli used in the studies. Simon utilized a 1,000 Hz pure tone for binaural and monaural presentations. Subjects depressed a finger key as soon as they heard the tone in the binaural condition. The set and expectancy explanation appears logical in this case, where the subjects did not have to make a decision as to a correct response, but only signal as soon as they heard the tone. In the present study, however, subjects were presented one CV syllable in the left ear and a different CV syllable in the right ear. The subjects, upon hearing the dichotic pair, must first process the two stimuli syllables before responding with the correct one. In the monotic condition, however, the subjects' response was not complicated by a conflicting stimulus in the opposite ear. Their monotic reaction times, therefore, would be faster than dichotic reaction times where the conflicting stimulus was present. This faster monotic verbal reaction time may be due to the monotic task being a simpler task in which the subject's response is not complicated by a conflicting stimulus in the opposite ear, such as in the dichotic condition.

Results of this study also indicated that responses for CV syllables containing the vowels /ɪ/ and /ʊ/ resulted in a right ear effect, in terms of verbal reaction time, whereas, the responses for the CV syllables containing the vowel /ɛ/ did not. The vowels /ɪ/ and /ʊ/ were also more accurately reported than the vowel /ɛ/. These findings support findings of a previous study by Lowe (1970) in which she used rhymed monosyllables to determine if laterality effects were the function of the vowel nucleus. She found a significant right ear superiority for rhymed monosyllables with /a/, /ɪ/, and /o/ vowel nuclei, but not for /i/ and /ɛ/. The findings of these studies suggest that, to be effective in generating an ear effect with CV syllables, dichotic speech stimuli can consist of syllables with the vowels /a/, /ɪ/, /o/, and /ʊ/, but not the vowels /ɛ/ and /i/.

The final area under investigation in this study concerns the accuracy, rather than the verbal reaction times of subjects' responses, in both monotic and dichotic conditions. Traditional studies (Kimura, 1967; Studdert-Kennedy, et al., 1970; Dirks, 1964) with dichotic listening tasks have utilized percent correct as measures of ear asymmetry. With this type of measure, ear asymmetry is based upon whether or not a subject heard and reported the stimulus correctly. Recent studies (Springer, 1973a; Hernon, 1972) have successfully utilized reaction time measures in assessing ear asymmetry. Springer (1973a) performed a dichotic listening study in which she compared response accuracy results with reaction time results. She found a right ear effect in terms of reaction time, but not in terms of percent correct. This suggested to her that "reaction time might be a more sensitive measure of ear asymmetry and hence a good tool to study stimuli which have not typically shown ear advantage effects" (Springer, 1973a, p. 391). The results of the present study support Springer's suggestion. When percent correct was utilized as a measure of ear asymmetry, only 4 subjects showed a right ear effect, 7 a left ear effect and 13 no ear effect in the dichotic task. In the monotic task 9 subjects demonstrated a right ear effect, 4 a left ear effect, and 11 no ear effect (Table VI, Appendix D). As reported earlier, however, when verbal reaction time was utilized 22 of the 24 subjects demonstrated a right ear effect for speech stimuli in both monotic and dichotic conditions. This finding further demonstrates, then, that verbal reaction time is a more sensitive measure for assessing dominance.

Summary

There may be valuable practical applications for the monotic and dichotic procedures used in this study. Various researchers (Curry and

Gregory, 1967; Prins-Walton, 1971; and Sommers and Taylor, 1972) have utilized dichotic tasks in order to investigate the relationship of cerebral dominance to various speech disorders, such as stuttering, language disorders, and articulation disorders. Researchers in this area may have been inhibited, however, by problems in controlling variables in the production of dichotic tapes which effect the perception of dichotic stimulus material. This study has demonstrated faster right ear verbal reaction times to a monotic speech stimulus in which normal subjects were not aware which ear would be stimulated. This finding, then, provides researchers with a relatively simple means of assessing cerebral dominance and it should facilitate research in this area.

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APPENDIX A

DICHOTIC AND MONOTIC TASK SYLLABLES

Dichotic Syllable Pairs

1.	/bɪ-dɛ/	19.	/dɛ-bɪ/
2.	/dʊ-gɪ/	20.	/gɪ-dʊ/
3.	/gɛ-bɪ/	21.	/bɪ-gɛ/
4.	/dɛ-gʊ/	22.	/gʊ-dɛ/
5.	/gɛ-bʊ/	23.	/bʊ-gɛ/
6.	/dʊ-gɛ/	24.	/gɛ-dʊ/
7.	/dɛ-gɪ/	25.	/gɪ-dɛ/
8.	/bɪ-dʊ/	26.	/dʊ-bɪ/
9.	/dɪ-gɛ/	27.	/gɛ-dɪ/
10.	/bɛ-dɪ/	28.	/dɪ-bɛ/
11.	/gɪ-bʊ/	29.	/bʊ-gɪ/
12.	/bɛ-dʊ/	30.	/dʊ-bɛ/
13.	/gɪ-bɛ/	31.	/bɛ-gɪ/
14.	/gʊ-bɛ/	32.	/bɛ-gʊ/
15.	/bʊ-dɛ/	33.	/dɛ-bʊ/
16.	/bʊ-dɪ/	34.	/dɪ-bʊ/
17.	/gʊ-bɪ/	35.	/bɪ-gʊ/
18.	/dɪ-gʊ/	36.	/gʊ-dɪ/

Monotic Syllables

1.	/bʊ/	19.	/bʊ/
2.	/gɛ/	20.	/gɛ/
3.	/bɛ/	21.	/bɛ/
4.	/bɛ/	22.	/bɛ/
5.	/gɪ/	23.	/gɪ/
6.	/dʊ/	24.	/dʊ/
7.	/bɪ/	25.	/bɪ/
8.	/dɪ/	26.	/dɪ/
9.	/gʊ/	27.	/gʊ/
10.	/dɛ/	28.	/dɛ/
11.	/dɪ/	29.	/dɪ/
12.	/dɛ/	30.	/dɛ/
13.	/bʊ/	31.	/bʊ/
14.	/bɪ/	32.	/bɪ/
15.	/gɪ/	33.	/gɪ/
16.	/gʊ/	34.	/gʊ/
17.	/dʊ/	35.	/dʊ/
18.	/gɛ/	36.	/gɛ/

APPENDIX B

INSTRUCTIONS TO SUBJECTS

Instructions for Monotic Task

In this task you will hear single syllables presented sometimes to the right and sometimes to the left ear. You will not be informed as to which ear will be stimulated each time, so you will need to pay close attention to the recording. You are to repeat each syllable just as soon as you can after you hear it. We will measure the time it takes you to respond. You will hear a total of 36 syllables. There will be a pause of about eight seconds between syllables. Please remember to listen carefully and to respond as soon as you hear each syllable. Please raise your hand now if you have any questions. (Five second pause - The tape was stopped if the subject had any questions, otherwise it continued). Now we will have a short practice run in order to familiarize you with the task (Practice tape played).

Now that you are familiar with the procedures we will begin the actual experiemnt. Please remember to listen carefully and respond as soon as you hear the syllables. Again, raise your hand if you have any questions. (Five second pause - The tape was stopped if the subject had any questions). Okay, let's begin.

Instructions for Dichotic Task

In this task you will hear a large group of syllables, some of which you will be asked to repeat. These syllables will come in pairs, one to your right ear and simultaneously, a different one to your left ear. Just prior to each pair of syllables you will be asked to repeat the following right ear or left ear syllable. Specifically, the tape will say, "Repeat right ear," or "Repeat left ear." Then you will hear a pair of syllables. Your task is to say the appropriate syllable as quickly as possible after you hear it. We will measure the time it takes you to respond. There will be a pause of about eight seconds between syllable pairs. There will be a total of 36 pairs of syllables.

Please raise your hand now if you have any questions. (Five second pause - The tape was stopped if the subject had any questions, otherwise, the tape continued).

Now let's have a short practice run in order to familiarize you with the task. Remember, before each syllable pair the tape will indicate which ear you are to respond to and your response should be as quick as possible after you hear the syllables (Practice tape played).

Now that you are familiar with the procedure we will begin the actual experiment. Please remember to listen carefully and respond as soon as possible after hearing the syllable pair. Raise your hand if you have any questions. (Five second pause - The tape was stopped if the subject had any questions). Okay, let's begin.

APPENDIX C

TABLE V

MEAN VERBAL REACTION TIMES (MSEC.) OF SUBJECTS

Subject	Monotic Condition		Dichotic Condition	
	Right Ear	Left Ear	Right Ear	Left Ear
1	817	767	827	798
2	587	625	727	814
3	996	1104	1226	1470
4	933	1006	1394	1636
5	1255	1285	2058	2062
6	1341	1347	1477	1563
7	713	738	1029	1105
8	923	955	1259	1277
9	869	883	1058	1070
10	854	982	649	680
11	1002	1211	1644	1894
12	1105	1352	1513	1638
13	1297	1376	1373	1453
14	1272	1373	1391	1530
15	1231	1492	1103	1397
16	760	834	1073	1169
17	1623	1497	807	737
18	860	922	775	806
19	535	633	691	937
20	830	850	855	908
21	888	924	1175	1295
22	1149	1254	1439	1699
23	1318	1650	1510	1765
24	815	1012	1429	1760
Summation:	23974	26069	28483	31460
Means:	999	1086	1187	1311

APPENDIX D

TABLE VI

ACCURACY OF RESPONSE RESULTS

Subject	Monotic Condition					Dichotic Condition				
	Right Ear		Left Ear		EF*	Right Ear		Left Ear		EF*
	Cor. Resp.	Inc. Resp.	Cor. Resp.	Inc. Resp.		Cor. Resp.	Inc. Resp.	Cor. Resp.	Inc. Resp.	
1	10	8	11	7	L	4	14	8	10	L
2	18	0	16	2	R	6	12	4	14	R
3	16	2	15	3	R	8	10	8	10	No
4	16	2	15	3	R	6	12	8	10	L
5	17	1	16	2	R	8	10	8	10	No
6	16	2	16	2	No	6	12	6	12	No
7	18	0	18	0	No	4	14	7	11	L
8	18	0	18	0	No	5	13	5	13	No
9	18	0	17	1	R	8	10	8	10	No
10	14	4	14	4	No	2	16	7	11	L
11	16	2	16	2	No	10	8	10	8	No
12	16	2	13	5	R	9	9	11	7	L
13	18	0	18	0	No	6	12	6	12	No
14	15	3	17	1	L	6	12	6	12	No
15	18	0	17	1	R	5	13	5	13	No
16	17	1	17	1	No	10	8	10	8	No
17	18	0	18	0	No	7	11	7	11	No
18	18	0	18	0	No	5	13	7	11	L
19	16	2	18	0	L	11	7	10	8	R
20	18	0	17	1	R	8	10	8	10	No
21	18	0	17	1	R	8	10	6	12	R
22	15	3	15	3	No	9	9	9	9	No
23	18	0	18	0	No	10	8	7	11	R
24	18	0	18	0	No	5	13	11	7	L
Total Errors:		32		39			266		250	

*Ear Effect

VITA 2

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Candidate for the Degree of

Master of Arts

Thesis: ASSESSMENT OF EAR ASYMMETRY THROUGH VERBAL REACTION TIMES TO MONOTIC AND DICHOTIC LISTENING TASKS

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