A STUDY OF AUDITORY ASYMMETRY USING AUDITORY EVOKED RESPONSES

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CURRICULUM STUDIORUM

Jerry V. Kroetsch was born July 2, 1940, in Nipiwan, Saskatchewan. He received the Bachelor of Arts degree from the University of Alberta in 1961. In 1965 he received the Master of Psychology degree from the University of Ottawa. His upgrading paper was titled Auditory Asymmetry and Auditory Evoked Responses.

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INTRODUCTION

Studies of asymmetric auditory functioning have varied greatly in approach and level of study. Anatomical studies have examined physical differences in cerebral hemispheres which may be related to language and thus auditory functioning. Dichotic listening studies have shown that auditory asymmetries exist at the level of perceptual and memory functions. At the level of speech production, delayed auditory feedback techniques have been used to demonstrate auditory asymmetries. In addition to these, studies using electrophysiological tools have examined auditory asymmetries at the end point of sensory input, the cerebral cortex.

The present study was conceived of as a logical step towards demonstrating auditory asymmetry at the simplest level of functioning. If auditory asymmetry can be demonstrated at the level of perception and speech production as well as with electrophysiological tools employing binaural stimulus presentation, then a possibility exists for demonstrating it at the afferent level using monaural stimulation.

This study should be important in providing some evidence of the existence of auditory asymmetry under conditions of monaural word and tone stimulation and bilateral evoked response recording. From a theoretical point of view it should help extend knowledge of auditory asymmetric functioning in normal subjects.

INTRODUCTION

The first portion of the report is concerned with a review of the literature of various demonstrations of auditory asymmetry. Brief reviews of possible mechanisms of asymmetric cerebral functioning and the tool used for this study are included.

The formulation of the hypothesis is followed by a description of the experimental procedures of the project.

The results of the study are then presented and discussed. This discussion pertains to the over-all trend of results of the main experimental variables and does not attempt to give specific interpretations to each result obtained.

A summary of the conclusions and the implications for future research are then indicated.

CHAPTER I

REVIEW OF LITERATURE

The study of functional asymmetry of the cerebral hemispheres of man has a relatively short history. Benton[1] has cited its onset as Broca's discovery of a specific association between motor aphasia and disease of the left frontal lobe. Clinical observations were at the fore in helping to establish the idea of left hemisphere dominance for language in right-handed persons. The concept of dominance for language functions was supplemented by observations linking praxic and gnosic deficits to left hemisphere diseases. As Benton[2] has cited, from the inception of claims for exclusive dominance of the left hemisphere there were those, notably Hughlings Jackson, who pointed out the importance of the right hemisphere for functions such as visual recognition and memory. These and subsequent observations and studies regarding various types of deficits following hemispheric lesions lead to the concept of and attempts to elucidate the distinctive functions of each of the hemispheres.

The following sections of this chapter will review some of the studies concerned with functional asymmetry of

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[1] A.L. Benton, "Hemispheric Cerebral Dominance," _Israel Journal of Medical Science_, Vol. 6, 1970, p. 294-303.

[2] _Ibid_., p. 296.

the brain. They will include anatomical, dichotic listening, delayed auditory feedback, directed attention and electrophysiological studies. The bulk of the studies concern auditory functioning but some studies in visual and somesthetic functioning are also included.

1. Anatomical Asymmetries of the Brain.

In a review of anatomical asymmetries of the cerebral hemispheres Von Bonin[3] found only small morphological differences between the left and right hemispheres. He did not attempt to correlate these differences, the slightly higher specific gravity of the left hemisphere, the slightly longer left Sylvian fissure, the higher and longer insula on the left side, the more frequent doubling of the sulcus cinguli on the left side or the more frequent hooking on the calcarine fissure on the left side, with the differences of functioning, such as the speech function on the left side.

Gerschwind and Levitsky[4] reinvestigated the problem of anatomical asymmetries of the two cerebral hemispheres in areas known to be of significance in language functions. They

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[3] G. Von Bonin, "Anatomicl Asymmetries of the Cerebral Hemispheres," in V. Mountcastle (ed.), <u>Interhemispheric Relations and Cerebral Dominance</u>, Baltimore, Johns Hopkins, 1962, p. 1-6.

[4] N. Gerschwind and W. Levitsky, "Human Brain: Left-Right Asymmetries in Temporal Speech Region," <u>Science</u>, Vol. 161, 1968, p. 186-187.

found marked anatomical asymmetries between the upper surfaces of the right and left temporal lobes in a sample of one hundred adult human brains free of significant pathology. These asymmetries may be important in the understanding of types of functional asymmetries of the two hemispheres.

2. Dichotic Listening.

Probably the most fruitful work done so far in the study of differential functional asymmetries of the right and left hemispheres in audition is the group of studies using dichotic listening tasks. The dichotic listening procedure developed by Broadbent,[5] by which different digits were presented simultaneously to the two ears through earphones, allowed for the assessment of information processing through each of the two ears under a condition of competition. In a dichotic listening task involving digits, three pairs of digits are presented, one half of the pair for each ear, in rapid succession, at the end of which the subject is asked to report all the numbers he heard, in any order. The term "dichotic" is used to describe the simultaneous presentation of different stimuli to the two ears. This technique has been modified by various investigators for types of material presented and order and type of response required of the subject.

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[5] D.E. Broadbent, "The Role of Auditory Localization in Attention and Memory Span," Journal of Experimental Psychology, Vol. 47, 1954, p. 191-196.

Kimura has extensively used the dichotic listening technique to study the functional asymmetry of the two ears in perceiving verbal and non-verbal stimuli. In one of her first studies,[6] on patients being investigated for seizures and not having tumors or diffuse cerebral disease, she found that impaired recognition for digits arriving at the ear contralateral to unilateral temporal lobectomy was found only under the condition of simultaneous presentation. Damage to the left temporal lobe impaired over-all performance, regardless of which ear received the stimuli. Also, for all groups of patients, regardless of the site of lesion, the preoperative scores showed the right ear to be more efficient than the left. Kimura concluded that in man, as in animal research, the contralateral pathways from ear to cortex are more efficient than the ipsilateral ones. Also, the explanation for the superiority of the right ear was that verbal stimuli presented to the ear opposite the dominant hemisphere for speech would be more accurately perceived than stimuli to the ipsilateral ear, under conditions of competition between the ears.

This interpretation led to the prediction and subsequent confirmation of the idea of greater right-ear efficiency for the person with speech representation in the left hemisphere

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[6] D. Kimura, "Some Effects of Temporal Lobe Damage on Auditory Perception," Canadian Journal of Psychology, Vol. 15, 1961, p. 156-165.

and greater left-ear efficiency for subjects having speech representation on the right. One hundred and twenty patients were used in this study,[7] thirteen with speech representation on the right hemisphere and the remainder with speech representation on the left. Sidedness for speech representation was determined by the Wada technique[8] of intracarotid injection of sodium amytal. Further analysis of the data, by dividing the group by handedness and focus of speech showed that laterality of speech rather than handedness appears to be the main factor in producing the achieved results.

It is important here to note that Kimura[9] emphasized that independence of ear asymmetry from handedness can only be demonstrated when the speech representation is known, by the Wada technique cited above. Where it is not known, as in normal subjects it is expected that ear pattern and handedness are related insofar as cerebral dominance is related to handedness. Kimura[10] cites a study by Branch, Milner and

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[7] D. Kimura, "Cerebral Dominance and the Perception of Verbal Stimuli," Canadian Journal of Psychology, Vol. 15, 1961, p. 166-171.

[8] J.A. Wada and T. Rasmussen, "Intracarotid Injection of Sodium Amytal for the Lateralization of Cerebral Speech Dominance Experimental and Clinical Observations," Journal of Neurosurgery, Vol. 17, 1960, p. 266-282.

[9] D. Kimura, "Functional Asymmetry of the Brain in Dichotic Listening," Cortex, Vol. 3, 1967, p. 163-178.

[10] Ibid., p. 166.

Rasmussen[11] which estimates that 90% of normal right-handers and over 60% of normal left-handers have speech functions represented in the left hemisphere.

Although the original studies done by Kimura were conducted with clinical populations, studies[12] using normal subjects reflected the same right-ear superiority on the dichotic digits test.

The problem of experimentally demonstrating functional differentiation between hemispheres in normal subjects was first studied using the simultaneous presentation of different numbers of clicks in each ear.[13] The task was to report the number of clicks in each ear. It was expected that the left ear would show superiority in mediating such a non-verbal task. The results showed a slight though insignificant difference in favor of the left ear. Counting the number of clicks arriving at each ear did not seem to be distinctively a non-verbal task equivalent in nature to the dichotic digits task. In a later study Kimura[14] used twenty sets of four

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[11] C. Branch, B. Milner, and T. Rasmussen, "Intracarotid Sodium Amytal for the Lateralization of Cerebral Speech Dominance," Journal of Neurosurgery, Vol. 21, 1964, p. 399-405.

[12] D. Kimura, "Speech Lateralization in Young Children as Determined by an Auditory Test," Journal of Comparative Physiological Psychology, Vol. 56, 1963, p. 899-902.

[13] --------, "Cerebral Dominance of the Perception of Verbal Stimuli," p. 166-171.

[14] --------, "Left-Right Differences in Perception of Melodies," Quarterly Journal of Experimental Psychology, Vol. 14, 1964, p. 355-358.

melodies which were excerpts from solo passages in concertos. For each set, two of the four melodies were first played simultaneously on the two separate channels, so that one melody was heard in one ear at the same time that the other was played in the other ear. There was then a four-second silence and the four melodies were played in succession, in normal binaural fashion; that is, with the same melody in each ear. The two melodies first heard dichotically were repeated separately, and the subject had simply to identify which two they were.

The results of the melodies tests were compared with the results on the standard dichotic digits task. It was shown in this experiment that the score in the melodies test for the left ear was significantly superior to that for the right, whereas on the digits test the right ear was superior. The subjects for this experiment were twenty female student nurses and post-graduate nurses, all right-handed.

Kimura concluded that melodies presented to the left ear are more accurately recognized than those arriving at the right. She states that this supports Milner's[15] view that the right temporal lobe plays a greater role in non-verbal auditory perception than the left. An analogous but opposite

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[15] B. Milner, "Laterality Effects in Audition," in Mountcastle (ed.), <u>op. cit</u>., p. 177-195.

effect occurs for verbal material presented to the two ears. Thus, Kimura states the left-right differences which occur in her study reflect an asymmetry of function in the two cerebral hemispheres which is not due to the difference in sensitivity of the two temporal lobes to the frequency characteristics of sounds, but rather is due to differentiation along the verbal-nonverbal dimension. Kimura emphasizes that the asymmetries observed in this study occur only under conditions of dichotic stimulation. She cites an unpublished study[16] in which the timbre test of the Seashore battery was presented to a group of normal subjects one ear at a time on two separate occasions. No significant difference between the two ears was found. This coincides with the absence of a right ear effect for digits in studies not using a dichotic presentation. She suggests one reason for this may be that dichotic listening puts more demands on the system than does normal listening. Kimura suggests that another factor is probably involved. She cites Rosenzweig's[17] suggestion that the auditory system is so arranged that some central units in each half of the brain fire to stimulation of the ipsilateral ear, some to the contralateral ear, and some to both. More units are activated by

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[16] Unpublished study cited by Kimura, "Left-Right Differences in Perception of Melodies," p. 355-358.

[17] M.R. Rosenzweig, "Representation of the Two Ears at the Auditory Cortex," American Journal of Physiology, Vol. 167, p. 146-158.

contralateral stimulation than by ipsilateral, but in addition, in those units which fired to both, the contralateral connections occlude the ipsilateral. Thus, the greater effectiveness of the contralateral pathways should become more apparent when both ears are stimulated but with different material. When different information travels along the different pathways those units which fired to both ears will be taken up by the contralateral pathway. In this way dichotic stimulation may enhance the difference between the two pathways.

The suggestions made by Kimura appear to be supported by a study done by Milner, Taylor and Sperry[18] using right-hand patients with surgical disconnection of the cerebral hemispheres. They found a complete or near complete suppression by the left hemisphere of input from the left ear under conditions of dichotic listening. All the commissurotomized patients were able to report digits presented to the left ear without difficulty when there was no competing input from the right ear indicating that the ipsilateral pathway could be utilized. However, suppression of ipsilateral input in the presence of a competing stimulus from the contralateral ear provided behavioral evidence of the dominance of the contralateral auditory projection system in man. From the above

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[18] B. Milner, L. Taylor and R.W. Sperry, "Lateralized Suppression of Dichotically Presented Digits After Commissural Section in Man," Science, Vol. 161, 1968, p. 184-186.

two articles it can be seen that asymmetric cerebral functioning is demonstrable under conditions of dichotic listening with both verbal and melodic tasks in normal subjects and dramatically observable in dichotic verbal tasks in commissurotomized subjects.

A study by Knox and Boone[19] concerned with the relationship between laterality of verbal listening and test of handedness as determined by Harris Test of lateral dominance, showed that the greater the difficulty involved in the dichotic listening task the more pronounced was the degree of lateralization in verbal listening. They used six dichotic listening tests. The first three were made from original competing digits test used by Kimura. One was the original Kimura tape, another was the Kimura tape with white noise superimposed on both channels and the third was the Kimura tape with random interruptions of output of both channels. The second set of tapes used was from the competing PB Words Test used by Dirks.[20] As with the Kimura tapes the first of the second set of three tapes was the original Dirks tape, the second was the original with white noise and the third was the original with random interruptions of the output of both channels. They concluded,

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[19] A.W. Knox and D.R. Boone, "Auditory Laterality and Tested Handedness," Cortex, Vol. 6, 1970, p. 164-173.

[20] D. Dirks, "Perception of Dichotic and Monaural Verbal Material and Cerebral Dominance for Speech," Acta Otolaryngology, Vol. 58, 1964, p. 73-80.

among other things, that whenever dichotic listening tasks become difficult, listening lateralization occurs in the ear ipsilateral to the tested side of hand-foot preference. This was the result of finding significant differences, in the sample they used, between left-sided and right-sided subjects on the Kimura tapes with white noise and with random interruptions. A significant lateralization preference was shown to take place in the left ear when vigorous testing criteria were established for subjects in the left-side group and when difficult dichotic material was presented. The authors noted that when less difficult dichotic tasks were used they were unable to develop significant left ear preference for the left side. In regards to the establishment of left-sidedness and right-sidedness the authors found considerable difficulty in finding strong left-handed subjects. Only 14% of the self-reported left-handed subjects were found to be primarily left-sided for hand- and foot-motor tasks. On the other hand, they concluded that it must be assumed that self reports of right-handedness are generally verified by motor-laterality testing. In other words, it is much safer to use self reports of right-handedness than self reports of left-handedness in selecting subjects.

Significant lateralization of ear preference can be shown then with dichotic listening tasks in normal right-handed subjects. In well screened or strongly left-handed subjects, difficult listening tasks are better for showing a lateralization effect in audition.

Other studies with variations on the main dichotic listening model have extended findings on stimulus qualities relevant to lateralization of auditory functioning. Shankweiler and Studdert-Kennedy[21] in a study comparing identification of dichotically presented pairs of synthetic consonant-vowel syllables and pairs of steady-state vowels showed a significant right-ear advantage for consonant-vowel syllables but not for steady-state vowels. They felt that:

> [...] in view of Kimura's finding of a left-ear advantage for musical melody recognition as against a right-ear advantage for the spoken digits the neutral status for steady-state vowels midway as it were between speech and music is perhaps not surprising.[22]

This finding may be important with respect to differentiation of hemispheric functioning on the level of stimulus material. Another interesting finding made in this study was that the left hemisphere dominance effect was demonstrated when only a single pair of syllables was presented on each trial. They felt that this indicated that the left hemisphere dominance

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[21] D. Shankweiler and M. Studdert-Kennedy, "Identification of Consonants and Vowels Presented in Left and Right Ears," Quarterly Journal of Experimental Psychology, Vol. 19, 1967, p. 59-63.

[22] *Ibid.*, p. 60.

pertained to the registration of stimuli and not to their retention. This supports the statement made by Knox and Kimura,[23] based on the facts of finding better identification of verbal stimuli by the right ear with both verbal and non-verbal methods of report and left-ear superiority in identification of non-verbal stimuli with a verbal method of identification, that:

> [...] the ear-difference scores resulted from asymmetries in the reception of the stimuli (input) rather than from the expression of what was perceived (output).[24]

The emphasis by the authors of the two studies mentioned above on the registration or reception of stimuli as the basis for observed asymmetric functioning is particularly important as part of the rationale for the present study since it purports to investigate asymmetries of auditory functioning at the afferent or input level.

As a follow-up to the study by Shankweiler and Studdert-Kennedy[25] which indicated the existence of lateralized mechanisms at the level of phonetic structure in language, Zurif and Sait[26] investigated the possibility that lateralized

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[23] C. Knox and D. Kimura, "Cerebral Processing of Non-verbal Sounds in Boys and Girls," Neuropsychologia, Vol. 8, 1970, p. 227-237.

[24] Ibid., p. 235.

[25] Shankweiler and Studdert-Kennedy, op. cit., p. 59-63.

[26] E.B. Zurif and P.E. Sait, "The Role of Syntax in Dichotic Listening," Neuropsychologia, Vol. 8, 1970, p. 239-244.

hemispheric mechanisms operate at the level of syntactic structure and possibly upon the overt rhythms of speech utterances. They used dichotically presented pairs of meaningless sequences presented under two different conditions respectively termed structured and unstructured. The dichotic sequences on both conditions contained the same nonsense syllable stems, English-bound morphemes and English function words. In the structured conditions the sequences were grammatically ordered and in the unstructured sequences, were randomly rearranged with none of the overt rhythms of speech. The results indicated that total accuracy of recognition was significantly superior in the structured condition. Also, although right-ear superiority was observed in both conditions the laterality effect was significant only in the structured condition. They suggested very tentatively that the neuropsychological systems that process the effects of intonation, rhythm, pause and stress associated with constituent structure are lateralized.

Kimura[27] reported on a study to investigate the functional differentiation between hemispheres not only from the point of view of verbal-nonverbal auditory stimuli but also from the point of view of familiarity-unfamiliarity and meaningfulness-nonmeaningfulness of words and mode of report.

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[27] Kimura, "Functional Asymmetry of the Brain in Dichotic Listening," p. 163-178.

Basically, she found that melodic patterns both familiar and unfamiliar have their major representation in the right hemisphere. Familiarity of itself does not appear to be a critical factor in hemispheric specialization of function. She also found that nonsense syllables, when used in the dichotic listening task, produced the same results as digits; namely, the right ear being reported much more accurately than the left. Her findings are the same as above-mentioned studies and she suggests that features of speech sounds which distinguish them from nonspeech sounds are related to articulability rather than conceptual content. Studies of auditory monitoring of speech, using delayed auditory feedback, which are cited below, would tend to substantiate this suggestion.

3. Delayed Auditory Feedback.

Roode[28] investigated auditory dominance and cerebral language laterality using a selected group of ten left-sided subjects and twenty right-sided subjects. The subjects were screened for eye, hand and foot dominance. The subjects were asked to read 127 syllable passages under different conditions of auditory feedback. The amplified feedback was direct binaural, delayed binaural and two conditions of

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[28] C. Roode, An Experimental Study of Auditory Dominance and Cerebral Language Laterality, unpublished doctoral thesis, University of Ottawa, 1963, 109 p.

direct monaural to one ear and delayed monaural to the opposite ear. These speech samples were tape recorded, transferred to paper on a level recorder and analyzed on three voice variables: per cent phonation time, mean syllable duration and mean intensity above an arbitrary reference. As Roode states:

> [...] analysis and interpretation of results reveal that both left- and right-sided groups showed a significantly longer mean syllable duration with delayed auditory feedback to the dominant ear than with delayed auditory feedback to the non-dominant ear. Per cent phonation time was also slightly higher for the right-sided group under a condition of delayed feedback to the dominant ear as compared to a condition of delayed feedback to the non-dominant ear. This did not occur with the left-sided group. The variable on mean intensity above an arbitrary reference did not show any significant difference between the two conditions of monaural delayed auditory feedback.[29]

He thus showed a difference in the temporal parameter of speech monitoring using the dominant and non-dominant ears and delayed auditory feedback.

A more recent study by Abbs and Smith[30] is one in which subjects received feedback of their own speech production with various degrees of delay. The object of the study was to test the assumption that auditory feedback to the right ear would be more critical in influencing speech production than auditory feedback to the left ear. The ear not receiving

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[29] Ibid., p. 108.

[30] J.H. Abbs and K.U. Smith, "Laterality Differences in the Auditory Feedback Control of Speech," Journal of Speech and Hearing Research, Vol. 3, 1970, p. 289-303.

the amplified feedback of the subject's own vocal productions was masked with white noise. The authors studied two aspects of the delayed auditory feedback disturbance, total speaking time and numbers of articulatory errors. The total speaking time was obtained by timing the recorded sample of each spoken sentence with a stop watch. No significant differences were found in the total speaking time. This is in contrast with Roode's study which indicated differences in mean syllable duration under various rates of delayed auditory feedback. Roode, however, used a more refined method for measuring the time for speech production since he transcribed the vocal production onto paper and measured it in that fashion. The number of articulatory errors under various conditions of auditory feedback were significantly different under left-ear and right-ear feedback. Auditory delay to the right ear produced a significantly greater number of speech errors than delayed presentation to the left ear. In a way, there is some agreement between the study by Abbs and Smith and the one by Roode in that per cent phonation time, which is really Roode's measure of Abbs and Smith's total speaking time, was not significant. However, Roode's refinement in terms of calculating mean syllable duration did show some differences. Abbs and Smith speculate that the differences in reaction of the two ears to different feedback parameters of speech may mean that vowels, where most elongation under delay occurs, are monitored equally for feedback control by both ears while consonants, where most articulatory errors occur, are monitored primarily by the right ear. As they note, these findings seem to be consistent with data presented on speech identification and laterality differences reported by Shankweiler and Studdert-Kennedy.[31] Abbs and Smith conclude that the findings disclosed that either the specialized functions of the separate ears or their binaural coordination are degraded by vocal-aural time lag. They speculate on a theoretical question as to whether the ear bias as displayed by their study is due to ear preference alone or to a bias determined by speech action and the active mechanisms of hearing. They state that if it is caused by the ear itself it must have consisted of a preference for parameters of certain speech sounds. In the present case, they state that:

> [...] the aural bias in auditory feedback control appears related most decisively to those components of speech demanding the greatest precision of motor control, that is the articulatory components.[32]

It is interesting at this point to compare this statement with that of both Shankweiler and Studdert-Kennedy[33] who stated that they could demonstrate the asymmetric functioning effect on one trial nonsense syllables indicating that left hemisphere

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[31] Shankweiler and Studdert-Kennedy, op. cit., p. 59-63.

[32] Abbs and Smith, op. cit., p. 303.

[33] Shankweiler and Studdert-Kennedy, op. cit., p. 59-63.

dominance pertained to the registration of stimuli, and that of Knox and Kimura[34] who stated that the asymmetric functioning in children appeared to be more on the input level rather than the memory or output level because of the success of demonstrating asymmetric functioning even when subjects report in a non-verbal mode. Perhaps these two views are complementary in that asymmetric functioning in precision of motor control is possibly closely related to asymmetric functioning at the input or registration level.

The next section of this chapter will pertain to electrophysiological studies of asymmetric auditory functioning.

4. Electrophysiological Studies of Asymmetric Auditory Functioning.

Research cited in this section includes studies on click detection and auditory evoked responses related to asymmetric auditory functioning.

In a study of ear asymmetry, Murphy and Venables[35] carried out an experiment to investigate the effect of prior shock stimulation on right- and left-ear differences in the detection of two clicks. The clicks were delivered to the subject's ears monaurally through earphones. Shock was

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[34] Knox and Kimura, op. cit., p. 235.

[35] E.H. Murphy and P.H. Venables, "Effects of Ipsilateral and Contralateral Shock on Ear Asymmetry in the Detection of Two Clicks," Psychonomic Sciences, Vol. 17, 1969, p. 214-215.

presented 100 milliseconds before the first click. Three blocks of trials were used. One block was presented to each ear with no shock; one with ipsilateral shock, that is, when the right ear was stimulated the shock was on the right arm; and one block with contralateral shock, that is, when the right ear was stimulated the shock was given to the left arm. The resolution of the two clicks was measured by a signal detection method. The results of the experiment indicated that left ear performance changed very little with ipsilateral or contralateral shock while the right ear performance showed considerable decrement with both shock conditions. No differences were found between the effect of ipsilateral and contralateral shock. The authors demonstrated an ear asymmetry effect with a simple non-verbal task. Their speculation on the mechanisms responsible for the type of functioning demonstrated will be presented in a following section on mechanisms of asymmetric hemispheric functioning.

In a study by Price _et al_.[36] of the latencies, amplitudes and frequency of occurrence of various late components of the auditory evoked responses of 160 normal hearing subjects were studied in relation to the race, age and sex of the subjects and to the side of the head from which the recording was taken.

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[36] L.L. Price, B. Rosenblut, R. Goldstein and D. Shepherd, "The Average Evoked Response to Auditory Stimulation," _Journal of Speech and Hearing Research_, Vol. 9, 1966, p. 361-370.

A series of four recordings was made for each subject: from the right side of the head when the right ear was stimulated, from the right side of the head when the left ear was stimulated, from the left side of the head when the left ear was stimulated, and from the left side of the head when the right ear was stimulated. The observations reported in their study were concerned exclusively with the "late" components of the auditory evoked response. Ipsilateral and contralateral recordings (re stimulated ear) were compared for differences in latency, amplitude and frequency occurrences of various components of the auditory evoked response. No differences were found in latency or frequency of occurrence. However, the authors report that "there was a tendency for the peak to peak amplitudes of the major components to be greater on the contralateral side of the head."[37] They found in measuring the amplitude of the major components studied, that significantly more subjects had ipsilateral-contralateral differences than had no differences and also those subjects who showed a difference, significantly more showed more positive than negative differences, that is contralateral larger than ipsilateral. The authors used a subtraction method whereby the ipsilateral responses were subtracted from the contralateral responses. They did not report, therefore,

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[37] Ibid., p. 365.

on differences between the left and right hemispheres in response amplitudes to click stimulation.

It should be noted here that recordings were made from electrodes placed as follows: vertex referred to the right ear lobe and vertex referred to the left ear lobe. Although this is a standard electrode placement for an auditory evoked response or "vertex potential"[38] a study on asymmetry might use to better advantage a symmetrical and more independent placement.

In a recent study on differential hemispheric processing of clicks and verbal stimuli, Cohn[39] found that click noises show a greater amplitude of initial output over the right brain and that verbal stimuli produce either equal or higher amplitudes of output over the left cerebral hemisphere. Using thirty-seven subjects with clinically normal auditory acuity and recording from homologous pairs of electrodes placed two centimeters anterior to the external acoustic meatus and in a vertical coronol plane two centimeters from the midsagittal line, he summated auditory evoked cortical responses to successive binaural click and verbal stimuli.

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[38] Called vertex potential by J. Bacaund, V. Block and J. Paillard, "Contribution EEG à l'étude des potentiels évoqués chez l'homme au niveau du vertex," Revue Neurologique, Vol. 89, 1953, p. 399-418, to emphasize anatomical distribution of this response, centering at the vertex.

[39] R. Cohn, "Differential Cerebral Processing of Noise and Verbal Stimuli," Science, Vol. 172, 1971, p. 599-601.

The verbal stimuli were words such as "cat," "bar," and "rat." To the click stimuli he found responses which consisted of:

> [...] a prominent positive going peak with a latency of around 14 milliseconds in the right brain derivation. Contemporaneously in the summated output of the left brain a complex-formed, notched or multiphasic wave, generally of lower amplitude and somewhat delayed.[40]

In one half of the subjects a second positive peak occurred which has a corresponding peak on the left side. The initial deflections were usually followed by a negative inflection, which in turn was succeeded by long positive peaked wave with an average peak latency of about 175 milliseconds. It was noted that the initial positive deflection on the right side to click stimulation remained invariant while the same deflection on the left brain varied.

In response to verbal stimuli, Cohn[41] found an initial almost synchronous negativity characterized these evoked responses. The initial negative deflection varied in time of occurrence but the first inflection ranged between 30 and 50 milliseconds. The succeeding positive wave generally showed almost synchronous peaking at about 125 milliseconds. Twenty individuals showed approximately equal

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[40] Ibid., p. 600.

[41] Ibid.

amplitudes of summated evoked cortical responses over the two sides to the verbal stimuli. Seventeen subjects showed a greater amplitude of output over the left brain when presented with verbal stimuli. Cohn concludes that:

> [...] if it is allowed that the amplitude of summated evoked cortical responses is directly related to the site of predominant processing of the auditory signals then it seems indisputable from these physiological data that noises (clicks) are initially processed primarily in the right brain. Again, if the above reasonable assumption is accepted single syllable words are processed in each cerebral hemisphere equally in approximately half of the subjects studied; in the other half of the subjects, however, the left brain shows a dominance for verbal processing.[42]

This study is very similar to the subject of this paper in that simultaneous recordings are made on the two sides of the head to successively presented verbal and non-verbal stimuli. One difference is that Cohn uses binaural presentation, whereas this study uses monaural presentation of stimuli and there is a difference in the non-verbal stimulation as well as the rate of presentation. Cohn's rate of presentation of stimuli is approximately one per second.

A recent study by Majkowski _et al_.[43] investigated the latencies of averaged evoked potentials to contralateral and

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[42] _Ibid_., p. 601.

[43] G. Majkowski, Z. Bochenek, W. Bochenek, D. Knapiak-Fijalkowska and J. Kopec, "Latency of Averaged Evoked Potentials to Contralateral and Ipsilateral Auditory Stimulation in Normal Subjects," _Brain Research_, Vol. 25, 1971, p. 416-419.

ipsilateral auditory stimulation in normal subjects. They used a symmetric electrode placement over both hemispheres and recorded simultaneously from both sides of the head with monaural tone stimulation at the rate of one per two seconds. When the left ear was stimulated it was found that for the first negative deflection of the auditory evoked response the latency for the response recorded on the right side of the head was shorter than that recorded on the left side of the head. The differences reported are statistically significant. Out of sixteen subjects, twelve showed shorter latency of 8 milliseconds, while four subjects had the same latency under both conditions. When the right ear was stimulated, response on the left side of the head showed a shorter latency in the first negative deflection than a latency for the same deflection on the right side response. In ten subjects out of thirteen, the latency of the response on the left side of the head was shorter. They reported that measurement of the latencies for the remaining components was more difficult because of peak location problems. They state that they did not find a simple relationship for the remaining components as was found for the first negative deflection component.

As a follow-up to their study on the localized origin of the late vertex potential of the somato-sensory evoked response, Vaughan and Ritter[44] did a similar analysis of the auditory evoked response. A small part of their study of mapping the spatial distribution of the auditory response included a study to detect possible contralateral response predominance under monaural stimulation. The stimulus used was a 1,000 cycle per second toneburst, 30 milliseconds in duration with an interstimulus interval of two seconds. Recordings were taken from a coronal chain of seven electrodes with three electrodes on either side of the mid-line electrode. Using four normal subjects they found a small but consistent shift towards higher amplitude contralateral to the ear stimulated on amplitude measures between the peak of the first stable negative wave with a latency of approximately 100 milliseconds and the peak of the second positive wave with a latency of approximately 200 milliseconds. Greater asymmetry was found over the left hemisphere than over the right hemisphere. The observed differences averaged 7.5% for the left hemisphere and 3.8% for the right hemisphere. This is in keeping with the theoretical difference in amplitude of the scalp responses between the two sides when the sum of fields contributed by each projection area is computed. This follows

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[44] H.G. Vaughan Jr. and W. Ritter, "The Sources of Auditory Evoked Responses Recorded from the Human Scalp," Electroencephalography and Clinical Neurophysiology, Vol. 28, 1970, p. 360-367.

from Rosenzweig's[45] estimate that cortical responses to stimulation of the ipsilateral ear were 3/4 the size of responses to the contralateral stimuli.

Although the study of response to monaural stimulation was not the main point of Vaughan and Ritter's experiment, this part along with the rest of the study led them to the conclusion that "all components of the auditory evoked response to repetititve stimulation including the late or vertex component are generated in or near the primary projection cortex in the supra temporal plane."[46] The results confirmed the assumption made that response to repetitive stimulation, that is stimulation with an interstimulus interval of less than five seconds, would have a field of generation reaching a maximum near the vertex and falling to zero over the Sylvian fissure. From their work it is evident that electrodes placed close to the Sylvian fissure would record responses of lower amplitude than those placed at the vertex. Electrodes placed near the Sylvian fissure, however, would be closest to the primary auditory projection cortex in the supra temporal plane which, as Vaughan and Ritter have concluded, is the localized origin of the late vertex component of the auditory evoked response.

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[45] Rosenzweig, op. cit., p. 147-158.

[46] Vaughan and Ritter, op. cit., p. 365.

An early study by Chatrian _et al_.[47] on one patient using intracerebral leads found that monaural repetitive clicks with a high rate resulted in a lower voltage in the driving response when the ear contralateral to the recording electrode was stimulated as compared to the response using binaural repetitive clicks. The reduction with contralateral ear stimulation was approximately 10%; however, with homolateral ear stimulation the response reduction was considerable, as much as 85%, and the response occurred less consistently. This was one of the first observations of difference between contralateral and ipsilateral influences in auditory cortical projections in human subjects.

The following section presents models and comments regarding mechanisms of asymmetric hemispheric functioning.

5. Mechanisms of Asymmetric Hemispheric Functioning.

This section presents some studies in visual perceptual, tactual sensory and auditory perceptual functioning which are pertinent to the discussion of mechanisms of asymmetric hemispheric functioning.

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[47] G.E. Chatrian, M.C. Petersen and J.A. Lazarte, "Responses to Clicks from the Human Brain: Some Depth Electrographic Observations," _Electroencephalography and Clinical Neurophysiology_, Vol. 12, 1960, p. 479-489.

Kinsbourne[48] has proposed a model of hemispheric integration based upon differential expectancy. He proposes that attentional factors are paramount because of the important interaction between input selection and processing efficiency. He states that Kimura's findings on differential processing of verbal and non-verbal material were related by her to the asymmetry of representation of function between the cerebral hemispheres of man. He notes that Kimura[49] proposed that input transmitted along the shorter more direct pathway in some way may better maintain its integrity and therefore is more amenable to processing. This reasoning accounts for the apparent superiority of the right ear for verbal materials and the left ear for certain non-verbal stimuli. He states that beyond the fact of asymmetry of representation of function in the human cerebral hemispheres, the claim that the effects are consequents of more efficient information transmission by the shorter pathway does not necessarily follow. Feeling that asymmetries based on representational asymmetries in the cerebral hemispheres should be more robust, Kinsbourne proposes an attentional model which questions the assumption he feels is made, that in tasks

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[48] M. Kinsbourne, "The Cerebral Basis of Lateral Asymmetries in Attention," Acta Psychologica, Vol. 33, 1970, p. 193-201.

[49] Kimura, "Functional Asymmetry of the Brain in Dichotic Listening," p. 163-178.

requiring perceptual reporting attention is symmetrically distributed in the two hemispheres.

He notes that in subhuman species the two hemispheres differ in terms of the space from which they select input and the direction towards which they program responses. He states that orientation to one side of space coincides with preparatory activation within the contralateral hemisphere. Assuming that the principle of reciprocal inervation holds at the cerebral level as well as at the spinal cord level, he states that as one hemisphere actually subserves its orienting function, the other is inhibited as regards the contrary tendency it subserves. In man the asymmetric representation of language gives way to the following model of functioning:

> [...] the left hemisphere is preponderantly active during verbal behavior, of which a state of expectancy for the verbal input, 'verbal set,' is one component. It is proposed here that this differential left hemisphere activity though in respect of a symbolic function unrelated to spatial location will nevertheless generate detectable orientation to the right, even though such orientation has lost its original adaptive value. Such orientation will characterize not only overt language use, but also covert and 'sub vocal' language behavior, including the state of expectancy of verbal response.[50]

He further states that a similar expectancy effect operates in dichotic listening with verbal material. Verbal material

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[50] Kinsbourne, op. cit., p. 196.

enlists the left hemisphere processing facilities, biasing attention to the right hemisphere resulting in performance superiority for that side. The converse would hold for material which would enlist the right hemisphere processing facilities. He predicts that:

> [...] when engaged in verbal activity a right handed subject is better able to focus his attention to the right, as this direction is congruent with the basic orientational bias of the left hemisphere than to the left which conflicts with that bias, thus, attention is more consistently focussed during right ear attending, while attending to the left is subject to fluctuating interruption with intrusion of the 'unattended channel.'[51]

He states that two types of predictions for experimentation can be made: "1. - If cognitive set proper to one hemisphere is adopted, attention is demonstrably biased to the opposite side; 2. - If attention is constrained to one side, cognitive processes proper to the opposite hemisphere are favored."[52]

He cites as evidence for this a study by Simon[53] on auditory asymmetry with non-competitive non-verbal reaction time tasks. Simon found that under the conditions of uncertainty as to which ear would be stimulated subjects responded

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[51] _Ibid_., p. 197.

[52] _Ibid_.

[53] J.R. Simon, "Ear Preference in a Simple Reaction Time Task," _Journal of Experimental Psychology_, Vol. 75, 1967, p. 49-55.

faster to a tone in the right ear than to a tone in the left. Where subjects knew the stimulus source, either in the right ear or the left ear, a right-ear superiority was not found. However, Simon states that other factors such as the subject's previous experience may have contributed to the findings along with the expectancy explanation.

Kinsbourne cites a study by Tsunoda.[54] In this study, subjects tapped in time with rhythms presented to the two ears and the effect of sudden delays of input in one ear was noted on the tapping. However, when the use of the vowel "ah" was used as a signal the tapping was disrupted more when the delay was on the right channel. This was seen by Kinsbourne as showing that the ear primarily guided the manual performance and that the attention was to the right with the verbal material and to the left with the non-verbal material.

In Kinsbourne's own study, the task was to identify the position of a gap in a square tachistoscopically presented under conditions of no concurrent verbal activity and conditions of concurrent verbal activity. The condition of concurrent verbal activity required that the subject keep in mind six one-syllable words while awaiting the test exposure. He was to repeat the first three words if a gap was on the left

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[54] Tsunoda, Indian Journal of Otolaringology, Vol. 18, 1966, p. 78-88, cited by Kinsbourne, op. cit., p. 193-201.

side of the square; the last three words if the gap was on the right side. When the gap was at the bottom or the top of the square he was not to repeat the words. The results indicated a significant difference in left and right gap detection with concurrent verbal activity, favoring performance on the right. Kinsbourne concluded:

> [...] that concurrent verbal activity in the form of sub-vocal rehearsal while awaiting the stimulus presentation introduced an asymmetry into what was without that verbal activity symmetrical performance, without lowering the over-all efficiency. This dependency of relative efficiency of performance on a simple visual task on the nature of concurrent cognitive set is predicted by the attentional model.[55]

Kinsbourne states that in normal subjects "transitory orientational biases accompanying shifting asymmetry of hemispheric activation during normal cognition are limited and can be largely counteracted by volition."[56] He comments on the role of the interhemispheric commissure. He also states that activation is never totally limited to one side of the cerebrum. His concluding statement is that:

> [...] unilateral hemispheric activation and contralateral orientation are correlates. The interaction between cognition and lateral orientation may serve as a behavioral indicator of the allocation of cognitive processes between the cerebral hemispheres of man.[57]

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[55] Kinsbourne, <u>op. cit</u>., p. 199-200.

[56] <u>Ibid</u>.

[57] <u>Ibid</u>., p. 200.

Kinsbourne has provided in a reasonably viable alternative or at least complementary explanation for various forms of asymmetric functioning which have not fallen under the standard interpretive framework. He does not deny the preponderance of the left hemisphere for processing verbal material. The whole process of afferent synthesis and subsequent cognitive and motor programming takes on a more dynamic and complex character in Kinsbourne's model.

In a study by Murphy and Venables,[58] cited above, where laterality differences were found in the detection of two click stimuli under the condition of shock before click presentation, the authors suggest that the two cerebral hemispheres may differ in the nature or extent of their interactions with non-specific mid-brain. They cite Nebylitsyn's[59] investigations on strength of the nervous system where he defines "a strong system as one that shows little change or slight facilitation in performance with heteromodal stimulation, the weak system as labile and showing performance decrement with heteromodal stimulation." They further suggest that it is possible that the left hemisphere, having a specific

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[58] Murphy and Venables, op. cit., p. 215.

[59] V.D. Nebylitsyn, "Individual Differences in the Strength and Sensitivity of Both Visual and Auditory Analysers," in N. O'Connor (ed.), Recent Soviet Psychology, Oxford, Pergamon, 1961, cited by Murphy and Venables, op. cit., p. 215.

role in speech functions differs from the right hemisphere in responses to stimulation and/or in cortico-reticular interactions. Thus, equal performance of the left and right ears in the detection of two clicks without shock and a considerable decrement in the right-ear performance but little change in the left-ear performance with shock prior to click presentation suggests a difference between the two hemispheres in lability or in cortico-reticular interactions rather than the effect of larger cortical response to stimulation in crossed pathways under monaural conditions or the accentuation of crossed pathways under binaural stimulation.

Semmes,[60] after performing studies of sensory and motor capacities of the hands in brain injured subjects, speculates on the subject of hemispheric specialization. She hypothesizes a different form of neural organization for the two hemispheres which allows specialization at the simple and complex motor and sensory level. She states that motor and sensory capacities are represented focally in the left hemisphere and diffusely in the right. Her investigation looks at specialization in the two hemispheres and compares the contralateral influences and the ipsilateral influences. In terms of focal and diffuse representation Semmes states that:

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[60] J. Semmes, "Hemispheric Specialization: A Possible Clue to Mechanism," Neuropsychologia, Vol. 6, 1968, p. 11-26.

> [...] focal representation of elementary functions in the left hemisphere favors integration of similar units and consequently specialization for behaviors which demand fine sensory-motor control, such as manual skills and speech. Conversely, diffuse representation of elementary functions in the right hemisphere may lead to integration of dissimilar units and hence specialization for behaviors requiring multimodal co-ordination such as various spatial abilities.[61]

Semmes notes that two types of asymmetries involving the hands exist. One type is a difference between the hemispheres in contralateral function and the other is a difference in ipsilateral function. Contralateral functional asymmetry is manifest in terms of handedness in man. Asymmetry of ipsilateral function is manifest in the observations that damage to the left hemisphere produces ipsilateral as well as contralateral effects on the hands, whereas right hemisphere damage is usually followed by strictly contralateral effects. She states that:

> [...] hemispheres differ not only in mechanisms of complex behavior but also in processes dealing with the input and the output. It is hypothesized that the difference at these simpler levels are indicative of a contrast in neural organization which favors hemispheric specialization.[62]

In her disucssion of asymmetry in contralateral sensory motor processes she concludes that on tests of sense of passive movement, touch-pressure thresholds, two-point

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[61] *Ibid*., p. 6.

[62] *Ibid*., p. 12.

discrimination and point localization the incidence and severity of deficits for the right hand were greatest after lesions of the left sensory-motor region. Deficits on cutaneous tests for the left hand were not clearly related to lesions of the right sensory-motor region.

In terms of asymmetry and ipsilateral sensory-motor processes, she states that:

> Whether or not the two hemispheres are equally potent in their influence on ipsilateral sensory-motor processes--can be tentatively answered in the negative. The left hemisphere seems to exhibit 'dominance' with respect to the bilaterality of its role in sensation and movement.[63]

Her findings indicated that right hand impairment is found about equally often with lesions within or outside the right sensory-motor region which implies a diffuse representation. Left-hand impairment is found much more frequently with sensory-motor than with nonsensory-motor lesions of the left hemisphere, implying a focal representation. Thus, the differing characteristics of the hemispheres are reflected in the mode of representation.

Semmes further states that hemispheric differences in representation of elementary functions may be the basis for true hemispheric dominance at higher levels of function:

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[63] *Ibid.*, p. 17.

> One might assume that the more complex coordinations characterizing the higher centers are brought about by convergence of lower-level units. Sensory-motor integrations involving a set of similar functional units would presumably be favored by the anatomic concentration of these units within a small area, that is, by focal representation of elementary functions. Where there is a higher concentration of units representing a particular part at one level, the convergence of these units upon those of the next level would bring about a more precise coding of the input and would thus make possible a more finely modulated control of the output. This finer control could be based not only on concentration of similar input elements, but also on an analogous concentration of similar output elements. The development of such precise control of the articulatory apparatus may provide an optimal substrate for speech representation in the left hemisphere.[64]

In discussing diffuse representation as a mechanism of right hemisphere specialization, Semmes hypothesizes that the diffuse representation is advantageous in terms of allowing the right hemisphere to better mediate unlike elements such as visual, kinesthetic, vestibular stimuli and perhaps others in a heteromodal integration.

Some of the interesting points raised by Semmes include specialization of the hemispheres on more elemental aspects of afferent processing which lays the foundation for more precise efferent processing. She has also given plausible explanations for asymmetry in both contralateral and ipsilateral functioning of the two hemispheres. Lastly, her

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[64] Ibid., p. 22.

comments on right hemispheric specialization have given a dimension to division of labor between the two hemispheres which goes beyond the classical verbal-nonverbal continuum.

Kimura[65] has speculated on the reasons for functional asymmetry of the two hemispheres. She has noted that studies on animals, notably Rosenzweig[66] and Tunturi[67] have indicated that crossed pathways are stronger than uncrossed pathways. Data from studies on patients with temporal lobe lesions appear to indicate the same holds true for man. Each ear has connections with the auditory receiving area in each hemisphere but the pathways connecting the ears to their opposite hemispheres are apparently more effective than the ipsilateral pathways.

Right ear superiority on dichotic digits was due to the fact that the right ear had better connections with the left hemisphere which was the one in which speech sounds were presumably analyzed. Kimura's hypothesis that subjects in which speech representation was in the right hemisphere should be left ear suprior on dichotic digits was confirmed.

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[65] Kimura, "Functional Asymmetry of the Brain in Dichotic Listening," p. 163-178.

[66] Rosenzweig, op. cit., p. 147-158.

[67] A.R. Tunturi, "A Study on the Pathway from the Mediate Geniculate Body to the Acoustic Cortex in the Dog," American Journal of Physiology, Vol. 147,   , p. 311-319.

Kimura[68] has stated that competitive conditions of stimulation were required to demonstrate asymmetry using a dichotic digit task. The reason for this was the manner in which the auditory pathways were arranged. From Rosenzweig's study she noted that auditory receiving area receives only a slightly greater number of fibres from the contralateral than from the ipsilateral ear. In addition to this, there is a point of overlap between the ipsilateral and contralateral pathways and at this overlap the contralateral pathways are capable of occluding impulses arriving along the ipsilateral pathways. In simultaneous stimulation the subcortical occlusion or partial occlusion would enhance the advantage already held by the contralateral pathway. Kimura also notes a possible factor of central competition. She hypothesizes this on the basis of studies requiring subjects to report monaurally under dichotic presentation. Although there are no differences in the number of words reported, there was a difference in the accuracy scores so that a right ear superiority remains.

Kimura proposes a functional differentiation between the two hemispheres with the left hemisphere having an advantage for spoken digits, words and verbal stimuli, whereas the right hemisphere has an advantage for tonal pattern perception and melodic patterns. She proposes a

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68 Kimura, "Functional Asymmetry of the Brain in Dichotic Listening," p. 163-178.

neuro-anatomical basis for dual auditory asymmetry. Under this system, ipsilateral and contralateral pathways exist to each auditory cortex. The predominance of the right temporal lobe in the assimilation of melodic patterns is reflected in left-ear superiority and the predominance of the left temporal lobe in the perception of words is reflected in right-ear superiority. Her model allows for both subcortical occlusion and cortical competition.

Bryden and Zurif[69] studied the performance of a patient with agenesis of the corpus collosum on a dichotic listening task. The patient's performance was compared with the performance of twelve normal subjects. Essentially, they found that the patient's performance did not differ appreciably in terms of accuracy or absolute laterality effect from the normal controls in dichotic listening performance. They remark that this contrasted rather sharply with patients who underwent surgical section of the corpus collosum or commissurotomization. From their study and review of the literature they suggest that weaker inputs from the ipsilateral ear are suppressed in the presence of competing inputs from the contralateral ear. They note that Kimura[70] has suggested

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69 M.P. Bryden and E.B. Zurif, "Dichotic Listening in a Case of Agenesis of the Corpus Collosum," <u>Neuropsychologia</u>, Vol. 8, 1970, p. 371-377.

70 Kimura, "Functional Asymmetry of the Brain in Dichotic Listening," p. 163-178.

that this suppression takes place at a subcortical and a cortical level. They go on, however, basing their argument on studies by Netley[71] on hemispherectomized patients; Sparks and Gerschwind's[72] study on their patients with a collosal section, and the study by Milner et al.[73] on the commissurotomized patients. The summary of the argument is as follows: in the hemispherectomized patients none of the cases showed an extreme unilateral suppression and in two cases the dominant ear was on the same side as the remaining hemisphere. They felt it was difficult to account for these two cases if one assumes that the contralateral inputs are occluding the ipsilateral ones at a subcortical level. In the patient with the collosal section, it was shown that improvement in performance was raised greatly on the left ear over three test sessions. In the last study on the commissurotomized patients they note that two of the seven subjects who showed the least suppression were one boy who was operated on at an early age and a second patient who had had four years post-recovery time. Therefore, they concluded that the laterality effect in dichotic listening

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[71] C. Netley, Dichotic Stimulation in Hemispherectomized Patients, unpublished manuscript, Hospital for Sick Children, Toronto, 1969, cited by Bryden and Zurif, op. cit., p. 371-377.

[72] R. Sparks and N. Gerschwind, "Dichotic Listening in Man After Section of Neocortical Commissures," Cortex, Vol. 4, 1968, p. 3-16.

[73] Milner, Taylor and Sperry, op. cit., p. 184-186.

is more dependent upon cortical competition than on subcortical occlusion.

The next section contains studies regarding the tool used in this study, auditory evoked responses.

6. Auditory Evoked Responses.

Refinements in electroencephalographic measurements, such as the development of averaging techniques for determining the presence of evoked responses, have made possible the accurate recording of latencies and amplitudes of the evoked response. In these techniques the general procedure is to time-lock the recording apparatus with the stimulus presentation so that the recording of the electrical activity of the brain is started when the stimulus is presented and continues for a specified time. The recordings can be then summated through various techniques and random activity taken out leaving the non-random activity due to the stimulation.

Certain common points have stood out in different studies on the auditory evoked response. It is generally agreed that peak latency and amplitude vary with the intensity of the stimuli.[74,75,76,77,78] The amplitude of the auditory evoked response decreases gradually and the latencies increase as the stimulus intensity is reduced. Davis <u>et al</u>.,[79] however, state that latency increases are evident only with near threshold stimulus levels and that the amplitude of wave forms increases slowly with stimulus intensity increases. Buchsbaum,[80] in a recent article, has commented on the variance of amplitude of a subject's average evoked response components. He notes that amplitude may increase, remain the same or even decrease with increasing stimulus intensity. He feels that averaged evoked response data on stimulus intensity may reflect the

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[74] M. Abe, "Electrical Responses of the Human Brain to Acoustic Stimuli," <u>Tokyo Journal of Experimental Medicine</u>, Vol. 60, 1954, p. 47-58.

[75] P.A. Davis, "Effect of Acoustic Stimulation During Sleep," <u>Journal of Neurophysiology</u>, Vol. 2, 1939, p. 494.

[76] C.D. Geisler, L.S. Frishkopf and W.A. Rosenblith, "Extra-Cranial Responses to Acoustic Clicks in Man," <u>Science</u>, Vol. 128, 1958, p. 1210-1211.

[77] T. Suzuki and K. Taguchi, "Cerebral Evoked Response to Auditory Stimuli in Waking Man," <u>Annals of Otology, Rhinology and Larnygology</u>, Vol. 74, 1965, p. 128-139.

[78] D.E. Rose and H.B. Ruhm, "Some Characteristics of the Peak Latency and Amplitude of the Acoustically Evoked Response," <u>Journal of Speech and Hearing Research</u>, Vol. 9, 1966, p. 412-422.

[79] H. Davis, T. Mast, N. Yoshie and S. Zerlin, "The Slow Response of the Human Cortex to Auditory Stimuli; Recovery Process," <u>Electroencephalography and Clinical Neurophysiology</u>, Vol. 21, 1966, p. 105-113.

[80] M. Buchsbaum, "Neural Events and Psychophysical Law," <u>Science</u>, Vol. 172, 1971, p. 502.

operation of a complex system of interpretation and modulation. The changes in component amplitude with increasing stimulus intensity could be related to other factors such as drug treatment, psychiatric diagnosis or behavior on other perceptual tasks. Stevens[81] agrees with Buchsbaum and states that:

> [...] the amplitude of the potential pick-up on the skull does not keep pace either with the subject's experience of intensity or with the potential that can be recorded in closer proximity to the sense organ. Much additional processing appears to have intervened.[82]

In discussing variability of the averaged evoked potential, Lindsley has stated:

> For visual and auditory areas, an early primary sensory response has not been considered a very reliable kind of response until recently. Even now it is dubious in the auditory area. Up to 80 or 100 milliseconds, the early components in repeated averages for the same individual vary, but show some consistency; however, from individual to individual they are exceedingly variable [...]
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> From 100 to about 300 milliseconds, there are major response components that most of us have been recording with some reliability. We call these 'late' components, and in any given individual there is a certain amount of consistency; however, from individual to individual there is much greater variability.

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[81] S.S. Stevens, "Neural Events and Psychophysical Law," Science, Vol. 172, 1971, p. 502.

[82] Ibid.

[83] D.B. Lindsley, "Average Evoked Potentials--Achievements, Failures and Prospects," in D. Donchin and D.B. Lindsley (eds.), Average Evoked Potentials: Methods, Results and Evaluation, Washington, National Aeronautics and Space Administration, 1969, p. 18-19.

In a similar vein, Vaughan has stated:

> The amplitude and peak delays of the various components vary as a function of stimulus parameters and arousal level of the subject. When stimulus and state variables are carefully controlled, and the number of samples taken is sufficient to reduce the level of background EEG adequately, wave form stability within subjects is quite high. In contrast, individual differences in the absolute and relative amplitudes of the various components are prominent. Peak delays tend to be substantially more reliable, so that for given stimulus conditions, a 'standard' evoked response wave form can generally be defined. Discrepancies which appear in the literature may be attributed to the joint effects of variations in electrode placements and stimulus parameters, as well as variability contributed by background EEG activity and fluctuations in arousal level.[84]

Although there are many intersubject variations in auditory evoked responses, there seems to be less intrasubject variability when conditions are comparable.[85,86] The pattern of the auditory evoked response for each subject shows a considerable degree of individuality.

The stimulus for an auditory evoked response can be any auditory stimulus that is sufficiently abrupt in time to yield a time-locked response. Tone bursts, tone pips and clicks have been used. Tone bursts of one-half second or

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[84] H.G. Vaughan, Jr., "The Relationship of Brain Activity to Scalp Recordings of Event-Related Potentials," in Donchin and Lindsley (eds.), op. cit., p. 48-49.

[85] Rose and Ruhm, op. cit., p. 412-422.

[86] H. Davis and S. Zerlin, "Acoustic Relations of the Human Vertex Potential," Journal of Acoustical Society of America, Vol. 39, 1966, p. 109-116.

longer produce an evoked wave form at the end as well as at the beginning of the burst. If the frequency make-up of the stimuli is between 300 and 4800 cycles per second, the latencies of the auditory evoked response wave form do not differ significantly as long as the stimuli are of equal intensity.[87] Intervals between stimuli presentation from 0.5 seconds to 4.2 seconds do not have different effects on latencies of the wave form. Amplitude is, however, affected by the stimulation rate, with the maximum amplitude being produced when an interval of 10 seconds or more between stimulus presentation is used.[88]

The wave form of the auditory evoked response has a characteristic sequence of successive vertex-positive and vertex-negative troughs or peaks. Their sequence is as follows: P_1 (vertex-positive), 50 to 60 milliseconds; N_1 (vertex-negative), 95 to 105 milliseconds; P_2, 170 to 200 milliseconds; and N_2, about 300 milliseconds.[89] Davis *et al.*[90] state that the most stable and reproductible feature of the wave form sequence is the slope from N_1 to P_2. Price *et al.*[91] agree with this observation and also state that P_2 was the most frequently occurring component.

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[87] *Ibid*., p. 114.

[88] Davis *et al*., *op. cit*., p. 105-113.

[89] *Ibid*., p. 107.

[90] *Ibid*., p. 108.

[91] Price *et al*., *op. cit*., p. 363.

The measures of the auditory evoked response used in this study are the mean root mean square amplitude of the EEG during the epoch observed, the mean root mean square amplitude of the evoked response during the epoch observed, the latencies and amplitudes of various main evoked response components. These measures are the easiest and most frequently used in studies employing evoked response. The mean root mean square amplitude measures gave an over-all measure of amplitude during the epoch observed while the component amplitude values help to provide some breakdown in response parameters in terms of various components. Both component amplitude values and latency values have the possible advantage of showing where differences occur in the evoked responses. Both have the disadvantage that accompanies component-linked measures when waveform variability exists. That is, comparisons may not always be made of the same component. This danger, however, should be reduced by the use of a repeated measures design. Latency measures of visual evoked responses are less variable than amplitude measures and require a larger range of change in stimulus parameters to produce an effect.[92] This is generally true of latency measures of auditory evoked responses also. It may be seen as an advantage in that observed

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[92] N.W. Perry and D.G. Childers, The Human Visual Evoked Response, Springfield, Ill., Thomas, 1969, p. 97-99.

differences in latency values may reflect substantive differences in factors studied.

The following section contains the summary of literature, rationale for the study and statement of the hypothesis.

7. Summary and Hypothesis.

The study of asymmetric cerebral functioning has been carried out in many different ways. Anatomical studies have shown hemispheric asymmetries which may be important for language functioning and auditory functioning.

Studies of asymmetric auditory functioning using dichotic listening tasks have indicated functional asymmetries between hemispheres for verbal and non-verbal materials and asymmetries in ears contralateral to the cerebral hemispheres. Investigators have studied various stimulus parameters that can elicit asymmetric functioning in audition. Although these studies have been mainly of the type requiring perceptual functions, some authors have suggested that asymmetries can be demonstrated on an input or registration level.

Besides demonstrating asymmetric auditory functioning on a perceptual level, studies have shown that an asymmetry exists in auditory monitoring of speech production in both temporal and accuracy parameters.

Electrophysiological studies of asymmetric auditory functioning have indicated asymmetry in click detection with prior shock. Studies using auditory evoked responses have demonstrated slight amplitude differences with contralateral conditions showing greater response amplitudes with vertex recordings. Another study has indicated differential hemispheric processing of clicks and verbal stimuli with verbal stimuli tending to produce greater left-hemisphere response amplitude and click stimuli producing greater response amplitude on the right hemisphere with binaural stimulation. Latency differences have been demonstrated in contralateral and ipsilateral stimulation with tone indicating that contralateral stimulation produces shorter latencies than ipsilateral stimulation for the first major negative deflection of the auditory evoked response. In addition, recent studies have indicated amplitude differences in auditory evoked responses recorded from a coronal chain of electrodes with monaural stimulation. Again, higher amplitude responses were found contralateral to ear stimulated than were found ipsilateral to ear stimulated. Greater asymmetry was found over the left hemisphere than over the right hemisphere.

Studies which have included speculation on mechanisms of asymmetric functioning have added new dimensions to the more classic representational proposals. One study demonstrates a model of hemispheric integration based on differential expectancy which influences the interaction between input selection and processing efficiency. The representational model maintains that crossed pathways are more efficient for information transmission to differentially functioning hemispheres with allowances for both cortical and subcortical competition with and occlusion of ipsilateral pathways by contralateral pathways. Besides this, other investigators have alluded to a model of cortico-reticular interaction which suggests that appropriate systems, for example, the right hemisphere and the left ear, are less liable to show performance decrement with heteromodal stimulation and non-verbal material than the left hemisphere and right ear system. Presumably the latter system would display a similar small degree of change with heteromodal stimulation and verbal material.

Another study has suggested different types of functional representation in the two cerebral hemispheres, the left hemisphere having focal representation and the right hemisphere having diffuse representation. Differences are also shown to exist in contralateral and ipsilateral functioning of the two hemispheres. This study also proposes that hemispheric differences in representation of elementary functions may be the basis for hemispheric specialization at higher levels of function. In other words, more exact processing of input, because of hemispheric specialization, makes possible more refined control of output.

Lastly, one author questions the proposals of cortical and subcortical occlusion of ipsilateral pathways by contralateral pathway influences and argues for a more cortically oriented position. This argument is close to the differential cortico-reticular position cited above.

Studies on the auditory evoked response showed that although many authors agree that peak latency and amplitude vary with the intensity of stimuli, the relationship is not linear, nor unaffected by such things as drug treatment, personality variables or attentional factors. Variability of the auditory evoked response has been noted to be considerable between subjects but to a lesser degree within subjects.

Some of the above mentioned studies have indicated differential auditory processing by the two cerebral hemispheres on the basis of response to different stimulus material and differential influences to each hemisphere from ipsilateral and contralateral auditory pathways. The focus of this study is on these differential auditory processes in afferent functioning as opposed to functioning requiring a motor response. Thus, an experimental design with symmetric simultaneous bilateral recordings of responses evoked by monaural tone and word stimuli should help to study aspects of complex differential asymmetric auditory functioning at the afferent level.

This investigation proposes to study possible asymmetric auditory functioning in response to a word and tone stimulus presented monaurally to the left and right ears, with auditory evoked responses recorded on the left and right side of the head. The end point of the investigation is at the afferent level as reflected in the auditory evoked response. The main thrust of this investigation is towards possible differential effects displayed in auditory functioning to monaural stimulation to different ears and response recording on different sides of the head, rather than towards possible differences between the two stimuli used. Measurements will be made of standard auditory evoked response parameters, amplitude and latency, under conditions of left-side and right-side recording pickup, left-ear and right-ear stimulation and word and tone stimuli. General expectations for results are that contralateral conditions will show higher amplitude values and shorter latency values than ipsilateral conditions in auditory evoked responses. Some differential treatment by the two hemispheres of the word and tone stimuli should be evidenced with more efficient left hemisphere processing of the former and more efficient right hemisphere processing of the latter.

The general experimental hypothesis for this study, stated in the null form, is that no significant differences will be found in the latency or amplitude measures of the auditory evoked responses recorded under various pickup, stimulation and stimulus conditions.

The next chapter presents the design of the experiment.

CHAPTER II

DESIGN OF STUDY

This chapter will describe the sample used, the selection procedures, the tools, the testing procedures and the means of analyzing the data used to test the experimental hypotheses.

1. Sample and Selection Procedures.

The sample consisted of thirty male subjects with reported normal hearing and a negative history of both ear pathology and neurological involvement. All subjects were unpaid volunteers and ranged from sixteen to forty-four years of age. Only subjects with reported right-hand preference were used in the sample.

2. Tools.

All AER's were recorded from the surface of the scalp of subjects. Grass silver disc electrodes were used. Raw electroencephalographic[1] activity was amplified by two matched Mousseau Scientific Instruments SA3 amplifiers with bandwidths 1 to 100 cycles per second. These bandwidth settings were constant throughout the experiment. The amplification was set at 60,000 gain for all subjects and all experimental conditions.

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[1] Hereafter referred to as EEG.

The amplified EEG was analyzed on-line to determine the presence of an AER, and simultaneously recorded on a Thermionic Product T3000 FM tape recorder for later analysis. During on-line analysis the amplified EEG and the computer display were monitored on a Tektronix type-RM 565 Dual-Beam Oscilloscope.

For on-line analysis, one second samples of amplified EEG activity, immediately following a stimulus presentation, were fed into the input of an Enhancetron 1024 computer of average transients which was triggered by a pulse from a Datapulse 101 Pulse Generator. The Enhancetron digitized each sample of the EEG activity and recorded the amplitudes of its component waveforms at a number of successive reference points to produce a single cumulative wave pattern, which was an average of the samples fed into the computer. Thus, the activity time-locked to the stimulus, the evoked response was summated and became easily recognized while random activity tended to average towards zero.

The amplified EEG activity was recorded on two channels of the FM tape recorder, one channel for the respective placement on each side of the head of the subject. A pulse, coinciding with the presentation of the stimulus pulse, was recorded on one of two other channels of the FM tape recorder. One channel recorded a pulse coinciding with the presentation of a tone burst and one channel recorded a pulse coinciding with the presentation of a word.

The stimuli, presented to the subject through one earphone of a set of Sony Stereo Headphones Model DR5A, were produced by a Sharp Stereo Cassette Player Model RD802. The cassette recording was made using a Sony-O-Matic TC8 Stereo 8 Cartridge Recorder, a Hewlett Packard Function Generator Model 3302A, a voice-operated relay with manual shut-off, two microphones and a four-second loop of tape in a cassette. The Sony Cartridge recorder was found to be best for channel separation and elimination of cross talk between the word stimulus and the tone burst stimulus. The stimuli were recorded on two channels of the cassette tape. They were simultaneous in terms of onset so that the tone burst could be used, not only as an experimental stimulus but also as the synchronous pulse for the onset of itself and the word stimulus.

A switching box was used to receive the output of the Sharp Stereo Cassette Player and parcel it out so that either the word or tone burst could be presented to the subject, a synchronous pulse could be directed to the respective channel of the FM tape recorder and both stimuli could be monitored by the experimenter through a set of Phillips Stereophonic Earphones.

The stimuli used for the experiment were a tone burst of 880 cycles per second of 400 milliseconds duration and the word "tea" of 400 milliseconds duration. The sound level for both stimuli as measured at the earphone by a Bruel and Kjaer Impulse Precision Sound Level Meter Type 2204 was 87 decibels and 81 decibels respectively for the tone and word. The root mean square or standard deviation of voltages of the two stimuli were 69.73 millivolts for the tone and 46.67 millivolts for the word. This indicated that, although the sound pressure levels of the two stimuli were fairly similar, the root mean square of voltages for the tone was considerably higher than the root mean square of voltages for the word.

The analysis of the recorded EEG activity was done with a Digital PDP8 computer with Laboratory 8 configuration. The recorded EEG material was fed through a Knohn-Hite Variable Filter Model 3342 with an 18 db low pass cut-off of 50 cycles per second and an 18 db high pass cut-off of 3 cycles per second, into the PDP8 Computer. The computer was triggered by a Datapulse 101 Pulse Generator which was fired by a pulse recorded on another channel of the tape with the EEG activity. The pulse was synchronous with the onset of the stimulus for the respective experimental condition to be analyzed. The computer was set to receive and summate one hundred one-half second samples of EEG activity. The readout of the waveform was then made on a Telex printer, Moseley 7035B x-Y Recorder and on punched paper tape. Cursor values were set on the computer oscilloscope for latencies of various waveform components. The Telex printout then recorded the latency as well as amplitude in values from the mean of the waveform for the cursor value selected. This procedure allowed accurate determination of latency and amplitude values of the waveform. In addition to the latency and amplitude values of selected points along the waveform the computer typed out values for the root mean square or standard deviation of voltages of the ongoing EEG activity sampled, as well as a value for the root mean square or standard deviation of voltages of the AER.

3. Testing Procedures.

AER recordings were made using Grass silver disc electrodes as bipolar leads on both sides of the head. The front lead was positive and the back was negative. Earclips on both ears were used to provide two common grounds to both amplifiers. The placement of the leads were as follows: on the left side of the head leads were 3 centimeters in front of and behind C_3, on the right side of the head the leads were 3 centimeters in front of and behind C_4.[2]

Prior to placement of the electrodes each area of placement was cleaned with rubbing alcohol and rubbed with Beckman Electrode Paste. The electrodes were then secured with tape. An Industrial Medical Automotive Electronics Impedance Tester Model ERT7 was used to determine if electrode

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[2] H.H. Jasper, "The Ten-Twenty Electrode System of the International Federation," Electroencephalography and Clinical Neurophysiology, Vol. 10, 1958, p. 371-375.

impedance was within the acceptable range of 1 to 8K ohms with less than 2K ohms difference in impedance between any two electrodes.

The subject was seated comfortably in a quiet room with his back to the experimental equipment and experimenter. The earphones were placed on his ears and he was told to listen to the stimuli emitted in one earphone. Each testing session lasted approximately one hour which included preparation of electrodes, stimulus presentation, a short rest period between left-ear and right-ear stimulus presentations and post-experiment clean up. The stimulus presentation time was twenty-six minutes, thirteen minutes for each ear.

Stimulus presentation to each ear consisted of two hundred stimuli, one hundred presentations of the word "tea" and one hundred presentations of the tone burst, presented in a random alternating order. The time between the start of each stimulus presentation was four seconds. The order of presentation to left-ear-first and right-ear-first was counterbalanced over subjects. Counterbalancing was also carried out for site of EEG recording, left or right side of the head, and amplifier used.

Only one earphone was used for stimulus presentation to the left and right ear so as to eliminate errors due to differences between the two earphones.

4. Analysis of Data.

The waveforms of the AER's for each experimental condition and each subject were displayed individually on the PDP Laboratory 8 Computer oscilloscope. Latency and amplitude values were recorded directly from the computer on a telex printout for values of the tops and bottoms of selected positive and negative deflections of the waveform. The waveforms were also recorded on metrically lined graph paper and on punched paper tape.

Latency in milliseconds and amplitude (in millivolts from the mean of the waveform to the tops or bottoms of selected peaks) values were recorded from the following points where possible: the first major positive deflection, P_1; the first major negative deflection, N_1; the second major positive deflection, P_2; and the second major negative deflection, N_2. Where the wave was rounded, double peaked or uneven, the center of the wave was estimated by measuring the width of the wave as close to the top as possible, where both sides were continuous and even, and taking the center point.

With the above procedures, the known sources of measurement errors include the 0.5 per cent accuracy specification of the Digital PDP8 Computer time base and the possible one millisecond error in cursor value readings with the clock values of the computer set at two milliseconds per division.

The error factor in measurement of latencies when all sources of error are considered is about ±3.5 milliseconds.

5. Statistical Design.

The general statistical method used in this study was a triple classification repeat-measure factorial design, employing analysis of variance.[3] Tests for simple main effects and simple simple main effects were made for all analyses of variance.[4]

The next chapter contains the presentation of results.

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[3] Q. McNemar, Psychological Statistics (4th ed.), New York, Wiley, 1969, p. 440.

[4] R.E. Kirk, Experimental Design: Procedures for the Behavioral Sciences, Belmont, Cal., Brooks/Cole, 1968, p. 263-266.

CHAPTER III

PRESENTATION OF RESULTS

In this chapter the results of the experiment are presented.[1] The presentation of measurements of EEG amplitude[2] is followed by the results of the measurements of evoked response amplitude.[3] These results are followed by the results of measurements of latencies and then amplitudes of the four main components of the auditory evoked responses under the various experimental conditions. The components of the auditory evoked response measured are: P_1, N_1, P_2 and N_2.

1. EEG Amplitude Values.

The results of the analysis of variance of EEG amplitude values are presented in Table I. The sums and means of EEG amplitude values for various experimental conditions are presented in Table II. No significant differences were found for any of the main effects or double interactions. The

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[1] The designation for experimental conditions are as follows: P_1, left-side pickup; P_2, right-side pickup; S_1, word stimulation; S_2, tone stimulation; and E_1, left-ear stimulated, E_2, right-ear stimulated.

[2] The EEG amplitude is defined as the mean root mean square amplitude of the EEG during the epoch observed, 500 milliseconds.

[3] The evoked response amplitude is defined as the mean root mean square amplitude of the evoked response during the epoch observed, 500 milliseconds.

Table I.-

Analysis of Variance: EEG Amplitude Values (N=30).

Source of Variation	SS	df	MS	F	P
P	5430.6863	1	5430.6863	2.0196	ns
S	111.1256	1	111.1256	1.0652	ns
E	2744.3577	1	2744.3577	2.2077	ns
PS	0.0095	1	0.0095	0.0002	ns
PE	210.2070	1	210.2070	0.2079	ns
SE	32.7895	1	32.7895	0.5835	ns
PSE	229.9279	1	229.9279	5.6333	.025[a]
R	753768.5972	29			
PR	77980.3948	29	2688.9791		
SR	3025.1512	29	104.3155		
ER	36049.2465	29	1243.0774		
PSR	939.5946	29	32.3998		
PER	29309.7454	29	1010.6808		
SER	1629.5355	29	56.1908		
PSER	1183.6461	29	40.8153		
Total	912645.0148	239			

[a] $_{.975}F(1, 29) = 5.59$

Table II.-

Means of EEG Amplitude Values for Various Experimental Conditions in Millivolts.
(2 x 2 x 2 Factorial Experiment, N=30)

Ear		Left			Right					
Stimulus		Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Pickup	Left	151.77	155.84	153.81	163.10	161.78	162.44	157.44	158.81	158.12
	Right	165.13	165.26	165.19	168.80	171.38	170.08	166.96	168.31	167.64
Total		158.45	160.54	159.50	165.95	166.57	166.26	162.20	163.56	162.88

triple interaction, however, obtained an F-value of 5.6333 which was significant at the .025 level. Table II presents the means of EEG amplitude values for various experimental conditions. The results of tests of simple main effects and simple simple main effects of EEG amplitude values for Pickup, Ear and Stimulus are presented in Tables III, IV and V, respectively.

From these tables it is seen that none of the main effects, simple main effects or simple simple main effects are significant for EEG amplitude values.

2. Evoked Response Amplitude Values.

The results of the analysis of variance of evoked response amplitude values are presented in Table VI. One main effect, Stimulus, shows a significant F-value which is significant beyond the .001 level. Table VII presents the means of evoked response amplitude values for various experimental conditions. The results of tests of simple main effects and simple simple main effects of evoked response amplitude values for Pickup, Ear and Stimulus are presented in Tables VIII, IX and X, respectively.

From Tables VIII and IX it is seen that none of the main effects, simple main effects or simple simple main effects are significant on Pickup or Ear for evoked response values. Table X shows that the main effect, simple main

Table III.-

Summary of Simple Main Effects and Simple Simple Main Effects on Pickup for EEG Amplitude Values.

Source		F^a	p^b
Main		2.0196	ns
Simple Main at Levels	S_1	1.0124	ns
	S_2	1.0071	ns
	E_1	1.4462	ns
	E_2	0.6515	ns
Simple Simple Main at Levels	S_1E_1	0.9950	ns
	S_1E_2	0.1810	ns
	S_2E_1	0.4945	ns
	S_2E_2	0.5127	ns

[a] F-values are computed using PR mean square values as the error term for respective EEG amplitude variables.

[b] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) = 7.60$; $_{.999}F(1,29) = 13.39$.

Table IV.-

Summary of Simple Main Effects and Simple Simple Main Effects on Ear for EEG Amplitude Values.

Source		F^a	p^b
Main		2.2077	ns
Simple Main			
at Levels	P_1	1.7994	ns
	P_2	0.5774	ns
	S_1	1.3583	ns
	S_2	0.8757	ns
Simple Simple Main			
at Levels	P_1S_1	1.5494	ns
	P_1S_2	0.4254	ns
	P_2S_1	0.1627	ns
	P_2S_2	0.4504	ns

[a] F-values are computed using ER mean square values as the error term for respective EEG amplitude variables.

[b] ${}_{.95}F(1, 29) = 4.18$; ${}_{.99}F(1, 29) = 7.60$; ${}_{.999}F(1, 29) = 13.39$.

Table V.-

Summary of Simple Main Effects and Simple Simple Main Effects on Stimulus for EEG Amplitude Values.

Source		F^a	p^b
Main		1.0652	ns
Simple Main			
at Levels	P_1	0.5425	ns
	P_2	0.5228	ns
	E_1	1.2684	ns
	E_2	0.1111	ns
Simple Simple Main			
at Levels	P_1E_1	2.3823	ns
	P_1E_2	0.2518	ns
	P_2E_1	0.0024	ns
	P_2E_2	0.9472	ns

[a] F-values are computed using SR mean square values as the error term for respective EEG amplitude variables.

[b] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) = 7.60$; $_{.999}F(1, 29) = 13.39$.

Table VI.-

Analysis of Variance: Evoked Response Amplitude Values (N=30).

Source of Variation	SS	df	MS	F	P
P	758.8860	1	758.8860	3.8121	.10(ns)[a]
S	3188.1357	1	3188.1357	25.1544	.001[b]
E	3.8990	1	3.8990	0.0173	ns
PS	23.2442	1	23.2442	0.4336	ns
PE	157.6422	1	157.6422	1.7830	ns
SE	2.3980	1	2.3980	0.0665	ns
PSE	10.9696	1	10.9696	0.8208	ns
R	27815.9997	29			
PR	5773.0196	29	199.0696		
SR	3675.5365	29	126.7426		
ER	6516.1792	29	224.6958		
PSR	1554.3391	29	53.5979		
PER	2563.9117	29	88.4107		
SER	1045.6784	29	36.0578		
PSER	387.5558	29	13.3639		
Total	53477.3947	239			

[a] $_{.90}F(1, 29) = 2.89$

[b] $_{.999}F(1,29) = 13.39$

Table VII.-

Means of Evoked Response Amplitude Values for Various Experimental Conditions in Millivolts. (2 x 2 x 2 Factorial Experiment, N=30)

Ear	Left			Right					
Stimulus	Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Left	26.9823	33.4216	30.2020	28.1206	35.0152	31.5680	27.5515	34.2185	30.8850
Pickup									
Right	31.1096	39.6490	35.3793	29.8613	37.1456	33.5035	30.4855	38.3973	34.4414
Total	29.0460	36.5353	32.7906	28.9910	36.0805	32.5357	29.0185	36.3079	32.6632

Table VIII.-

Summary of Simple Main Effects and Simple Simple Main Effects on Pickup for Evoked Response Amplitude Values.

Source		F^a	p^b
Main		3.8121	ns
Simple Main			
at Levels	S_1	1.2972	ns
	S_2	2.6316	ns
	E_1	4.0395	ns
	E_2	0.5645	ns
Simple Simple Main			
at Levels	S_1E_1	1.2835	ns
	S_1E_2	0.2283	ns
	S_2E_1	2.9220	ns
	S_2E_2	0.3419	ns

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[a] F-values are computed using PR mean square values as the error term for respective evoked response amplitude variables.

[b] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) = 7.60$; $_{.999}F(1, 29) = 13.39$.

Table IX.-

Summary of Simple Main Effects and Simple Simple Main Effects on Ear for Evoked Response Amplitude Values.

Source		F^a	p^b
Main		0.0173	ns
Simple Main at Levels	P_1	0.2491	ns
	P_2	0.4698	ns
	S_1	0.0004	ns
	S_2	0.0276	ns
Simple Simple Main at Levels	P_1S_1	0.0865	ns
	P_1S_2	0.1695	ns
	P_2S_1	0.1040	ns
	P_2S_2	0.4183	ns

[a] F-values are computed using ER mean square values as the error term for respective evoked response amplitude values.

[b] ${}_{.95}F(1, 29) = 4.18$; ${}_{.99}F(1, 29) = 7.60$; ${}_{.999}F(1, 29) = 13.39$.

Table X.-

Summary of Simple Main Effects and Simple Simple Main Effects on Stimulus for Evoked Response Amplitude Values.

Source		F^a	p^b
Main		25.1544	.001
Simple Main at Levels	P_1	10.5210	.01
	P_2	14.8167	.001
	E_1	13.2765	.01
	E_2	11.8967	.01
Simple Simple Main at Levels	P_1E_1	4.9073	.05
	P_1E_2	5.6259	.05
	P_2E_1	8.6301	.01
	P_2E_2	6.2798	.05

[a] F-values are computed using SR mean square values as the error terms for respective evoked response amplitude variables.

[b] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) = 7.60$; $_{.999}F(1, 29) = 13.39$.

effect and simple simple main effect are all significant on Stimulus for evoked response amplitude values. All of the significant results are in the same direction, S_1, word stimulus evoked response amplitude values smaller than S_2, tone stimulus evoked response amplitude values.

3. Component Latency Values.

Results of analyses of variance for latency values of events P_1, N_1, P_2 and N_2 are presented in Tables XI, XIII, XV and XVII, respectively. Means of Latency values under various experimental conditions are presented for events P_1, N_1, P_2 and N_2, in Tables XII, XIV, XVI and XVIII, respectively.

From Table XI it is seen that for latency P_1 values the Stimulus condition F-value is significant at the $p < .001$ level. Also the Pickup X Ear interaction condition F-value is significant at the $p < .05$ level.

Table XIII shows that for latency N_1 values the Pickup X Ear interaction F-value is significant at the $p < .001$ level.

For latency P_2 values, Table XV shows that the Ear condition F-value is significant at the $p < .025$ level and the Pickup X Ear interaction condition F-value is significant at the $p < .001$ level.

Lastly, Table XVII shows that none of the main effect or interaction effect values reach significance.

Table XI.-

Analysis of Variance: P_1 Latency Values (N=25).

Source of Variation	SS	df	MS	F	P
P	88.445	1	88.445	0.5318	ns
S	1711.125	1	1711.125	20.5489	.001[a]
E	132.845	1	132.845	2.4932	ns
PS	0.6050	1	0.6050	0.0020	ns
PE	1044.245	1	1044.245	4.8224	.05[b]
SE	75.645	1	75.645	0.4685	ns
PSE	0.0050	1	0.0050	0.000032	ns
R	36142.68	24			
PR	3990.18	24	166.2575		
SR	1998.50	24	83.2708		
ER	1278.78	24	53.2825		
PSR	7222.52	24	300.9383		
PER	5196.88	24	216.5366		
SER	3874.48	24	161.4366		
PSER	3786.62	24	157.7758		
Total	66543.555	199			

a $_{.999}F(1, 24) = 14.03$

b $_{.95}F(1, 24) = 4.26$

Table XII.-

Means of P_1 Latency Values for Various Experimental Conditions in Milliseconds.
(2 x 2 x 2 Factorial Experiment, N=25)

Ear		Left			Right					
Stimulus		Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Pickup	Left	91.04	95.56	93.30	86.88	93.84	90.36	88.96	94.70	91.83
	Right	85.04	89.76	87.40	90.00	97.20	93.60	87.52	93.48	90.50
Total		88.04	92.66	90.35	88.44	95.52	91.98	88.24	94.09	91.17

Table XIII.-

Analysis of Variance: N_1 Latency Values (N=30).

Source of Variation	SS	df	MS	F	P
P	448.2667	1	448.2667	1.7713	ns
S	1622.4	1	1622.4	2.9909	.1(ns)[a]
E	2.4	1	2.4	0.0059	ns
PS	56.0667	1	56.0667	0.1965	ns
PE	2856.6	1	2856.6	13.5796	.001[b]
SE	72.6	1	72.6	0.4075	ns
PSE	493.0666	1	493.0666	2.7776	ns
R	72228.9334	29			
PR	7338.7333	29	253.0597		
SR	15730.6	29	542.4344		
ER	11608.6	29	400.2965		
PSR	8270.9333	29	285.2045		
PER	6100.4	29	210.3586		
SER	5166.4	29	178.1517		
PSER	5147.9334	29	177.5149		
Total	137143.9334	239			

[a] $_{.90}F(1, 29) = 2.89$

[b] $_{.999}F(1, 29) = 13.39$

Table XIV.-

Means of N_1 Latency Values for Various Experimental Conditions in Milliseconds.
(2 x 2 x 2 Factorial Experiment, N=30)

Ear	Left			Right					
Stimulus	Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Left	132.13	142.26	137.20	129.00	131.20	130.10	130.56	136.73	133.65
Pickup									
Right	131.80	134.26	133.03	136.73	142.73	139.73	134.26	138.50	136.38
Total	131.96	138.26	135.11	132.86	136.96	134.91	132.41	137.61	135.01

Table XV.-

Analysis of Variance: P_2 Latency Values (N=30).

Source of Variation	SS	df	MS	F	P
P	996.3375	1	996.3375	0.3462	ns
S	1787.6042	1	1787.6042	3.1154	.1(ns)[a]
E	2767.6042	1	2767.6042	7.0200	.025[b]
PS	329.0042	1	329.0042	0.5104	ns
PE	2877.3375	1	2877.3375	14.0848	.001[c]
SE	33.0041	1	33.0041	0.0963	ns
PSE	51.3375	1	51.3375	0.3720	ns
R	136677.0209	29			
PR	22622.2825	29	780.0788		
SR	16640.7938	29	573.7938		
ER	11433.0208	29	394.2420		
PSR	18692.8478	29	644.5809		
PER	5924.2875	29	204.2857		
SER	9930.8479	29	342.4430		
PSER	4001.0605	29	137.9676		
Total	234764.3959	239			

[a] $_{.90}F(1, 29) = 2.89$

[b] $_{.975}F(1, 29) = 5.59$

[c] $_{.999}F(1, 29) = 13.39$

Table XVI.-

Means of P_2 Latency Values for Various Experimental Conditions in Milliseconds.
(2 x 2 x 2 Factorial Experiment, N=30)

Ear		Left			Right					
Stimulus		Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Pickup	Left	194.73	200.86	197.80	192.93	202.40	197.66	193.83	201.63	197.73
	Right	193.30	196.60	194.95	207.20	210.13	208.66	200.25	203.36	201.80
Total		194.01	198.73	196.37	200.06	206.26	203.16	197.04	202.50	199.77

Table XVII.-

Analysis of Variance: N_2 Latency Values (N=30).

Source of Variation	SS	df	MS	F	P
P	2863.5041	1	2863.5041	2.4336	ns
S	519.2041	1	519.2041	0.6844	ns
E	3003.3375	1	3003.3375	4.0126	.1(ns)[a]
PS	119.0043	1	119.0043	0.1972	ns
PE	840.0042	1	840.0042	2.5176	ns
SE	0.7042	1	0.7042	0.0013	ns
PSE	367.5374	1	367.5374	0.0330	ns
R	264238.3375	29			
PR	34122.3709	29	1176.6334		
SR	31997.1709	29	758.5231		
ER	21705.5375	29	748.4668		
PSR	17496.3707	29	603.3231		
PER	9675.8708	29	333.6507		
SER	15367.6708	29	529.9196		
PSER	11119.8376	29	383.4426		
Total	403436.4625	239			

[a] $_{.90}F(1, 29) = 2.89$

Table XVIII.-

Means of N_2 Latency Values for Various Experimental Conditions in Milliseconds.
(2 x 2 x 2 Factorial Experiment, N=30)

Ear		Left			Right					
Stimulus		Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Pickup	Left	276.97	273.07	275.02	277.93	278.77	278.35	277.45	275.92	276.68
	Right	279.07	277.30	278.18	292.47	285.53	289.00	285.77	281.42	283.59
Total		278.02	275.18	276.60	285.20	282.15	283.68	281.61	278.67	280.14

Table XIX presents a summary of simple main effects and simple simple main effects on Pickup for component latency values. From this summary it is seen that four F-values are significant. At latency P_1 left-side pickup has a greater latency than right-side pickup at the level of left-ear stimulated. At latency N_1 right-side pickup has a greater latency than left-side pickup at the level of right-ear stimulated. The same result is evident for latency P_2 where right-side pickup has a greater latency value than left-side pickup at the level of right-ear stimulated. At latency N_1, right-side pickup shows a greater latency value than left-side pickup at the level of the tone stimulus and right-ear stimulated.

Table XX presents a summary of simple main effects and simple simple main effects on Ear for component latency values. Four F-values are significant for simple main effects and five for simple simple main effects. All of the results except one at the simple simple main effects level are in the same direction, latency value for right-ear stimulated greater than left-ear stimulated. At latency P_1, right-ear stimulated has a greater latency value than left-ear stimulated at the level of right-side pickup. The same result is evident for latencies P_2 and N_2. Also, at latency P_2, right-ear stimulated has a greater latency value than left-ear stimulated at the level of tone stimulus.

Table XIX.-

Summary of Simple Main Effects and Simple Simple Main Effects on Pickup for Component Latency Values

Source		Latency P_1		Latency N_1		Latency P_2		Latency N_2	
		F[a]	p[b]	F	p[c]	F	p[c]	F	p[c]
Main		0.5319	ns	1.7713	ns	0.3462	ns	2.4336	ns
Simple Main at Levels	S_1	0.3118	ns	1.6229	ns	1.5834	ns	1.7635	ns
	S_2	0.2238	ns	0.3700	ns	0.1155	ns	0.7712	ns
	E_1	5.2343	.05	2.0581	ns	0.3123	ns	0.2556	ns
	E_2	1.5785	ns	11.0014	.01	4.6533	ns	2.8918	ns
Simple Simple Main at Levels	S_1E_1	2.7066	ns	0.0065	ns	0.0395	ns	0.3007	ns
	S_1E_2	0.7318	ns	3.5448	ns	3.9137	ns	0.0137	ns
	S_2E_1	2.5292	ns	3.7935	ns	0.3500	ns	0.0617	ns
	S_2E_2	0.8488	ns	7.8845	.01	1.1499	ns	0.9506	ns

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[a] F-values are computed using PR mean square values as the error terms for respective latency events.

[b] $_{.95}F(1, 24) = 4.26$; $_{.99}F(1, 24) = 7.82$; $_{.999}F(1, 24) = 14.03$.

[c] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) - 7.60$; $_{.999}F(1, 29) = 13.39$.

Table XX.-

Summary of Simple Main Effects and Simple Simple Main Effects on Ear for Component Latency Values.

Source		Latency P_1		Latency N_1		Latency P_2		Latency N_2	
		F[a]	p[b]	F	p[c]	F	p[c]	F	p[c]
Main		2.4932	ns	0.0059	ns	7.0200	.05	4.0126	ns
Simple Main at Levels	P_1	4.0555	ns	3.7779	ns	0.0013	ns	0.4453	ns
	P_2	18.0359	.001	3.3642	ns	14.3171	.001	4.6895	.05
	S_1	0.0750	ns	0.6070	ns	2.7852	ns	2.0682	ns
	S_2	3.8378	ns	0.1266	ns	4.3184	.05	1.9453	ns
Simple Simple Main at Levels	P_1S_1	4.0598	ns	0.3678	ns	0.1232	ns	0.0187	ns
	P_1S_2	0.6940	ns	4.5892	.05	0.0894	ns	0.6511	ns
	P_2S_1	5.7715	.05	0.9119	ns	7.3511	.05	3.5985	ns
	P_2S_2	12.9858	.01	2.6861	ns	6.9684	.05	1.3585	ns

[a] F-values are computed using ER mean square values as the error terms for respective latency events.

[b] ${}_{.95}F(1, 24) = 4.26$; ${}_{.99}F(1, 24) = 7.82$; ${}_{.999}F(1, 24) = 14.03$.

[c] ${}_{.95}F(1, 29) = 4.18$; ${}_{.99}F(1, 29) = 7.60$; ${}_{.999}F(1, 29) = 13.39$.

For both latencies P_1 and P_2 right-ear stimulated has a greater latency value than left-ear stimulated at levels right-side pickup and word-stimulus and right-side pickup and tone-stimulus. Lastly, for latency N_1, left-ear stimulated has a greater latency value than right-ear stimulated at the level of left-side pickup and tone-stimulus.

Table XXI presents a summary of simple main effects and simple simple main effects on Stimulus for component latency values. All significant F-values fall under latency P_1. All values are in the same direction, tone-stimulus obtaining greater latency value than word-stimulus, with all levels of simple main effects being significant and two simple simple main effects being significant. For the simple main effect levels tone-stimulus obtains a greater latency value than word-stimulus at the levels of left-side pickup, right-side pickup, left-ear stimulated and right-ear stimulated. For the simple simple main effect levels tone-stimulus obtains a greater latency value than word-stimulus at the levels of left-side pickup and right-ear stimulated and right-side pickup and right-ear stimulated.

Table XXI.-

Summary of Simple Main Effects and Simple Simple Main Effects on Stimulus for Component Latency Values.

Source		Latency P_1		Latency N_1		Latency P_2		Latency N_2	
		F^a	p^b	F	p^c	F	p^c	F	p^c
Main		20.5489	.001	2.9909	ns	3.1154	ns	0.6844	ns
Simple Main at Levels	P_1	9.8917	.01	2.1031	ns	3.1809	ns	0.0929	ns
	P_2	10.6644	.01	0.9911	ns	0.5078	ns	0.7483	ns
	E_1	6.4081	.05	2.1951	ns	1.1631	ns	0.3175	ns
	E_2	15.0492	.001	0.9296	ns	2.0097	ns	0.3679	ns
Simple Simple Main at Levels	P_1E_1	3.0668	ns	2.8395	ns	0.9833	ns	0.3007	ns
	P_1E_2	7.2716	.05	0.1338	ns	2.3427	ns	0.0137	ns
	P_2E_1	3.3442	ns	0.1682	ns	0.2846	ns	0.0617	ns
	P_2E_2	7.7818	.05	0.9955	ns	0.2249	ns	0.9506	ns

[a] F-values are computed using SR mean square values as the error terms for respective latency events.

[b] ${}_{.95}F(1, 24) = 4.26$; ${}_{.99}F(1, 24) = 7.82$; ${}_{.999}F(1, 24) = 14.03$.

[c] ${}_{.95}F(1, 29) = 4.18$; ${}_{.99}F(1, 29) = 7.60$; ${}_{.999}F(1, 29) = 13.39$.

4. Component Amplitude Values.

Results of analyses of variance for amplitude values of events P_1, N_1, P_2 and N_2 are presented in Tables XXII, XXIV, XVI and XXVIII, respectively. Means of amplitude values under various experimental conditions are presented for events P_1, N_1, P_2 and N_2, in Tables XXIII, XXV, XXVII and XXIX, respectively.

Table XXX presents a summary of simple main effects and simple simple main effects on Pickup for component amplitude values. Significant F-values are found only for amplitude values of event P_2. Two significant F-values are found for simple main effects and one for simple simple main effects. In simple main effects right-side pickup amplitude values were greater than left-side pickup amplitude values at the level of tone stimulus and also at the level of left-ear stimulated. In simple simple main effects right-side pickup amplitude values were greater than left-side pickup amplitude values at the level of tone stimulus and left-ear stimulated.

Table XXXI presents the summary of simple main effects and simple simple main effects on Ear for component amplitude values. No significant F-values were found on Ear for component amplitude values.

Table XXXII presents the summary of simple main effects and simple simple main effects on Stimulus for

Table XXII.-

Analysis of Variance: P_1 Amplitude Values (N=24).

Source of Variation	SS	df	MS	F	P
P	0.3951	1	0.3951	0.0013	ns
S	3246.3253	1	3246.3253	6.3694	.025[a]
E	699.9387	1	699.9387	0.9888	ns
PS	142.6403	1	142.6403	0.5480	ns
PE	573.6338	1	573.6338	3.5477	.1(ns)[b]
SE	117.2969	1	117.2969	0.2716	ns
PSE	88.1428	1	88.1428	0.4314	ns
R	45225.8131	23			
PR	6514.7966	23	283.2520		
SR	11722.4367	23	509.6711		
ER	16279.6629	23	707.8114		
PSR	5986.0037	23	260.2610		
PER	3718.8423	23	161.6887		
SER	9930.4540	23	431.7588		
PSER	4698.759	23	204.2938		
Total	108945.1412	191			

[a] $_{.975}F(1, 23) = 5.75$

[b] $_{.90}F(1, 23) = 2.94$

Table XXIII.-

Means of P_1 Amplitude Values for Various Experimental Conditions in Millivolts.
(2 x 2 x 2 Factorial Experiment, N=24)

Ear		Left			Right					
Stimulus		Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Pickup	Left	32.63	36.22	34.42	29.35	38.77	34.06	30.99	37.49	34.24
	Right	33.10	42.84	37.97	25.62	35.77	30.70	29.36	39.31	34.33
Total		32.87	39.53	36.20	27.49	37.27	32.38	30.18	38.40	34.29

Table XXIV.-

Analysis of Variance: N_1 Amplitude Values (N=30).

Source of Variation	SS	df	MS	F	P
P	875.9260	1	875.9260	1.3353	ns
S	7902.3737	1	7902.3767	19.4208	.001[a]
E	0.61	1	0.61	0.0016	ns
PS	183.9951	1	183.9951	1.1811	ns
PE	1063.1093	1	1063.1093	2.1994	ns
SE	548.4932	1	548.4932	1.2345	ns
PSE	668.0613	1	668.0613	3.6172	.1(ns)[b]
R	85963.0936	29			
PR	19021.9886	29	655.9306		
SR	11800.1220	29	406.9007		
ER	10979.2683	29	378.5954		
PSR	4517.7009	29	155.7827		
PER	14017.3947	29	483.3584		
SER	12884.2565	29	444.2847		
PSER	5355.9094	29	184.6865		
Total	175782.3025	239			

[a] $_{.999}F(1, 29)=13.39$

[b] $_{.90}F(1, 29) = 2.89$

Table XXV.-

Means of N_1 Amplitude Values for Various Experimental Conditions in Millivolts.
(2 x 2 x 2 Factorial Experiment, N=30)

Ear		Left			Right					
Stimulus		Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Pickup	Left	37.88	49.22	43.55	43.60	51.71	47.66	40.74	50.46	45.60
	Right	42.75	60.41	51.58	42.87	51.66	47.27	42.81	56.04	49.42
Total		40.31	54.81	47.56	43.23	51.69	47.46	41.77	53.25	47.51

Table XXVI.-

Analysis of Variance: P_2 Amplitude Values (N=30).

Source of Variation	SS	df	MS	F	P
P	5665.6912	1	5665.6912	5.6676	.025[a]
S	17944.7732	1	17944.7732	17.6376	.001[b]
E	443.6592	1	443.6592	0.4459	ns
PS	749.5968	1	749.5968	1.5635	ns
PE	1296.0019	1	1296.0019	2.1454	ns
SE	892.0852	1	892.0852	1.5695	ns
PSE	17.7185	1	17.7185	0.0739	ns
R	132289.7427	29			
PR	28990.2326	29	999.6631		
SR	29505.0031	29	1017.4139		
ER	28852.1952	29	994.9032		
PSR	13903.4328	29	479.4287		
PER	17518.3477	29	604.0809		
SER	16482.6723	29	568.368		
PSER	6945.2985	29	239.4930		
Total	301496.4509	239			

[a] $_{.975}F(1,\ 29) = 5.59$

[b] $_{.999}F(1,\ 29) = 13.39$

Table XXVII.-

Means of P_2 Amplitude Values for Various Experimental Conditions in Millivolts.
(2 x 2 x 2 Factorial Experiment, N=30)

Ear	Left			Right					
Stimulus	Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Left	47.12	56.48	51.80	44.65	62.80	53.72	45.88	59.64	52.76
Pickup									
Right	57.40	74.92	66.16	46.72	70.87	58.79	52.06	72.89	62.48
Total	52.26	65.70	58.98	45.68	66.83	56.26	48.97	66.27	57.62

Table XXVIII.-

Analysis of Variance: N_2 Amplitude Values (N=30).

Source of Variation	SS	df	MS	F	P
P	2939.79	1	2939.79	3.3777	.1(ns)[a]
S	15817.923	1	15817.923	13.7972	.001[b]
E	69.4342	1	69.4342	0.0655	ns
PS	2.9949	1	2.9949	0.0054	ns
PE	711.4271	1	711.4271	1.3878	ns
SE	118.7649	1	118.7649	0.3268	ns
PSE	15.9393	1	15.9393	0.0852	ns
R	159850.881	29			
PR	25239.8245	29	870.3387		
SR	33247.2728	29	1146.4576		
ER	30709.1857	29	1058.9374		
PSR	15943.9583	29	549.7916		
PER	14866.036	29	512.6219		
SER	10538.649	29	363.4616		
PSER	5423.1315	29	187.0045		
Total	315495.2122	239			

[a] $_{.90}F(1,\ 29) = 2.89$

[b] $_{.999}F(1,\ 29) = 13.39$

Table XXIX.-

Means of N_2 Amplitude Values for Various Experimental Conditions in Millivolts. (2 x 2 x 2 Factorial Experiment, N=30)

Ear	Left			Right					
Stimulus	Word	Tone	Word & Tone	Word	Tone	Word & Tone	Word	Tone	Total
Left	45.95	61.52	53.74	49.58	66.93	58.26	47.77	64.23	56.00
Pickup									
Right	57.13	71.23	64.18	52.84	70.78	61.81	54.99	71.00	63.00
Total	51.54	66.37	58.96	51.21	68.86	60.03	51.38	67.61	59.50

Table XXX.-

Summary of Simple Main Effects and Simple Simple Main Effects on Pickup for Component Amplitude Values.

Source		Amplitude P_1		Amplitude N_1		Amplitude P_2		Amplitude N_2	
		F^a	p^b	F	p^c	F	p^c	F	p^c
Main		0.0013	ns	1.3353	ns	5.6676	.025	3.3777	ns
Simple Main at Levels	S_1	0.2259	ns	0.1959	ns	1.1472	ns	1.7484	ns
	S_2	0.2789	ns	1.4199	ns	5.2702	.05	1.5827	ns
	E_1	1.0664	ns	2.9492	ns	6.1926	.05	3.7592	ns
	E_2	0.9601	ns	0.0069	ns	0.7713	ns	0.4359	ns
Simple Simple Main at Levels	S_1E_1	0.0093	ns	0.5417	ns	1.5878	ns	2.1549	ns
	S_1E_2	0.5910	ns	0.0121	ns	0.0648	ns	0.1836	ns
	S_2E_1	1.8603	ns	2.8650	ns	5.1038	.05	1.6230	ns
	S_2E_2	0.3806	ns	0.0000	ns	0.9750	ns	0.2552	ns

[a] F-values are computed using PR mean square values as the error terms for respective amplitude epochs.

[b] ${}_{.95}F(1, 23) = 4.28$; ${}_{.99}F(1, 23) = 7.88$; ${}_{.999}F(1, 23) = 14.19$.

[c] ${}_{.95}F(1, 29) = 4.18$; ${}_{.99}F(1, 29) = 7.60$; ${}_{.999}F(1, 29) = 13.39$.

Table XXXI.-

Summary of Simple Main Effects and Simple Simple Main Effects on Ear for Component Amplitude Values.

		Amplitude P_1		Amplitude N_1		Amplitude P_2		Amplitude N_2	
Source		F^a	p^b	F	p^c	F	p^c	F	p^c
Main		0.9888	ns	0.0016	ns	0.4459	ns	0.0655	ns
Simple Main at Levels	P_1	0.0044	ns	1.3375	ns	0.1121	ns	0.5785	ns
	P_2	1.7948	ns	1.4720	ns	1.6364	ns	0.1588	ns
	S_1	0.9821	ns	0.6768	ns	1.3036	ns	0.0031	ns
	S_2	0.1724	ns	0.7735	ns	0.0389	ns	0.1746	ns
Simple Simple Main at Levels	P_1S_1	0.1823	ns	1.2964	ns	0.0920	ns	0.1864	ns
	P_1S_2	0.1108	ns	0.2469	ns	0.6036	ns	0.4146	ns
	P_2S_1	0.9495	ns	0.0006	ns	1.7194	ns	0.2606	ns
	P_2S_2	0.8468	ns	3.0301	ns	0.2478	ns	0.0028	ns

[a] F-values are computed using ER mean square values as the error terms for respective amplitude epochs.

[b] $_{.95}F(1, 23) = 4.28$; $_{.99}F(1, 23) = 7.88$; $_{.999}F(1, 23) = 14.19$.

[c] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) = 7.60$; $_{.999}F(1, 29) = 13.39$.

Table XXXII.-

Summary of Simple Main Effects and Simple Simple Main Effects on Stimulus for Component Amplitude Values.

Source		Amplitude P_1		Amplitude N_1		Amplitude P_2		Amplitude N_2	
		F[a]	p[b]	F	p[c]	F	p[c]	F	p[c]
Main		6.3694	.025	19.4208	.001	17.6376	.001	13.7972	.001
Simple Main									
at Levels	P_1	1.9895	ns	6.9731	.05	5.5823	.05	7.0897	.05
	P_2	4.6598	.05	12.8999	.01	12.7920	.01	6.7100	.05
	E_1	2.0890	ns	15.5509	.001	5.3246	.05	5.7548	.05
	E_2	4.5105	.05	5.2678	.05	13.1897	.01	8.1459	.01
Simple Simple Main									
at Levels	P_1E_1	0.3020	ns	4.7380	.05	1.2916	ns	3.1712	ns
	P_1E_2	2.0885	ns	2.4266	ns	4.8614	.05	3.9392	ns
	P_2E_1	2.2334	ns	11.5004	.01	4.5233	.05	2.5978	ns
	P_2E_2	2.4284	ns	2.8497	ns	8.5921	.01	4.2088	.05

[a] F-values are computed using SR mean square values as the error terms for respective amplitude epochs.

[b] $_{.95}F(1, 23) = 4.28$; $_{.99}F(1, 23) = 7.88$; $_{.999}F(1, 23) = 14.19$.

[c] $_{.95}F(1, 29) = 4.18$; $_{.99}F(1, 29) = 7.60$; $_{.999}F(1, 29) = 13.39$.

component amplitude values. A considerable number of significant F-values were found with the direction being the same for each; that is, tone stimulus obtaining a greater amplitude value than word stimulus.

For P_1 amplitude values two significant F-values were found for simple main effects. The amplitude value for tone stimulus was greater than that for word stimulus at the level of right-side pickup and also at the level of right-ear stimulated.

For N_1 amplitude values significant F-values were found for all levels of simple main effects: left-side pickup, right-side pickup, left-ear stimulated and right-ear stimulated. Two significant F-values were found for simple simple main effects at two levels: left-side pickup and left-ear stimulated and also right-side pickup and left-ear stimulated.

For P_2 amplitude values all levels of simple main effects and three out of four levels of simple simple main effects were found to have significant F-values. Thus, significant F-values were found for simple main effects for the levels of left-side pickup, right-side pickup, left-ear stimulated and right-ear stimulated. For simple simple main effects significant F-values were found for the levels of left-side pickup and right-ear stimulated, right-side pickup and left-ear stimulated and right-side pickup and right-ear stimulated.

For N_2 amplitude values the same results as for N_1 and P_2 amplitude values were obtained in simple main effects. Significant F-values were found for all levels of simple main effects: left-side pickup, right-side pickup, left-ear stimulated and right-ear stimulated. For simple simple main effects one significant F-value was found at the level of right-side pickup and right-ear stimulated.

The discussion of results is presented in the next chapter.

CHAPTER IV

DISCUSSION OF RESULTS

This chapter contains discussion of the results presented in the previous chapter. Discussion of EEG amplitude values will be followed by discussion of evoked response amplitude values. Next, a discussion of component latency values will be presented, followed by a discussion of component amplitude values. The last section of this chapter will concern conclusions and suggestions for further research.

Since this study is exploratory in nature, interpretation will be of a more general type rather than necessarily specific to each individual result. Also, more interpretive emphasis will be placed on results of tests of simple main effects than on tests of simple simple main effects. This is because of the difficulty in adequately interpreting simple simple main effects which contain two factors at each level.

The discussion of EEG amplitude values follows.

1. Discussion of EEG Amplitude Values.

The EEG amplitude values reflect the general EEG amplitude during the observational epoch, which in this study is 500 milliseconds from the onset of the stimulus. The analysis of variance indicated a significant F-value at the level of the triple interaction but tests of simple main effects and simple simple main effects were all non-significant. If differences had occurred at these levels, especially at the levels of simple main effects, a serious bias would have been introduced into all of the results. The inability to reject the null hypothesis of no differences between various experimental conditions on EEG amplitude values gives credence to the assumption that background EEG values are similar for all experimental conditions.

2. Discussion of Evoked Response Amplitude Values.

The evoked response amplitude values reflect the over-all amplitude of the whole evoked response measured during the 500 millisecond recording epoch, as opposed to the amplitude values measured at specific evoked response waveform components.

The very significant finding for differences in the stimulus condition in the main analysis of variance is further validated by the consistent and similar findings in each level of tests of significance of simple main effects and simple simple main effects. The evoked response amplitude values for the tone stimulus are consistently greater than the evoked response amplitude values for the word stimulus. This finding was not unexpected in that the two stimuli were intended to be different and were only crudely matched in terms of duration and intensity. The tone stimulus had a higher intensity (87 db versus 81 db and RMS value of 69.73 millivolts versus an RMS value of 46.67 millivolts) than the word stimulus. Since the main thrust of this study was not primarily the direct comparison of the effects of the tone and word stimulus conditions this finding does not have great value by itself but does assume more prominence in conjunction with findings to be stated below.

3. Discussion of Component Latency Values.

The discussion of component latency values will proceed with discussion of results of tests of simple main effects and simple simple main effects for each experimental condition across all event latencies. A discussion of the Pickup condition will be followed by a discussion of the Ear condition and then the Stimulus condition.

(a) Discussion of Simple Main Effects and Simple Simple Main Effects on Pickup for Component Latency Values.- The results of tests of simple main effects show that differences in latency values for left-side pickup and right-side pickup occur at both levels of the Ear condition. At event P_1 of the evoked response the left-side pickup obtains a greater latency value than the right-side pickup when the left ear is stimulated. In the two subsequent events, N_1 and

P_2, the right-side pickup obtains a greater latency value when the right ear is stimulated. All three results are consistent to a degree in that they are all instances of smaller latency values for the pickup condition contralateral to the ear stimulated. The result for event P_1 is inconsistent with the results for event N_1 and P_2 in that the direction of greater or lesser latency values for the two pickup conditions is reversed. This may reflect the initial sensorial input bias of the right hemisphere coupled with the bias for more efficient reception of contralateral influences. Freedman,[1] who studied the response of the two hemispheres to unilateral photic driving and found that the right hemisphere showed a greater following, suggested a classical dominance interpretation for his results, that the right hemisphere has a primarily sensorial non-specific orientation.

Thus, for event P_1, the right-side pickup has a significantly smaller latency value than the left-side pickup because it receives the input from the left ear, the ear contralateral to the right-side pickup, more efficiently than the left-side pickup. The reason this difference is significant at the left-ear stimulated level of simple main effects may be because of the primary sensorial non-specific

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[1] N.L. Freedman, "Bilateral Differences in the Human Occipital Electroencephalogram with Unilateral Photic Driving," Science, Vol. 142, 1963, p. 598-599.

orientation of the right hemisphere in the early part of the evoked response.

If we examine the direction of mean latency values for left-side pickup and right-side pickup in Tables XII, XIV and XVI we see that the general direction of differences is the same. That is, the mean latency values for contralateral influences tend to be shorter than the mean latency values for ipsilateral influences to the respective pickup conditions, but significant levels of differences are attained only at the level of left-ear stimulated in event P_1 and right-ear stimulated in events N_1 and P_2. Perhaps after event P_1 the primary sensorial orientation bias for the right hemisphere is no longer evident.

The result of the simple simple main effect for pickup latency values event N_1 where the right-side pickup has a significantly greater latency value than that of the left-side pickup for the level of word stimulus and right-ear stimulated is not readily interpretable.

(b) Discussion of Simple Main Effects and Simple Simple Main Effects on Ear for Component Latency Values.- The tests of simple main effects show that differences between latency values for the left-ear stimulated condition and right-ear stimulated condition occur at the level of right-side pickup condition in events P_1, P_2 and N_2. There was no significant finding for simple main effects at event N_1. This finding is in part consistent with the idea that stimulation of an ear should result in smaller latencies at the contralateral hemisphere. In fact, the mean latency values for P_1 in Table XII and for N_1 in Table XIV indicate that the mean latency values at the level of left-side pickup, left-ear stimulated, right-ear stimulated follow a pattern inverse to the mean latency values at the level of right-side pickup, left-ear stimulated, right-ear stimulated, but do not reach a significant level of difference. This may reflect the classical dominance interpretation cited by Freedman.[2]

The comparable mean latency values cited above for events P_1 and N_1 do not occur in the same direction for events P_2 and N_2.

Another significant result at event P_2 shows that the left-ear stimulated condition obtains a smaller latency value than the right-ear stimulated condition at the level of tone stimulus. This may be some very mild support to Knox and Kimura's[3] position that the left ear shows superiority in identification of non-verbal stimuli.

The results of significant tests of simple simple main effects follow the direction of the test of simple main

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[2] Freedman, <u>op. cit</u>., p. 598-599.

[3] G. Knox and D. Kimura, "Cerebral Processing of Non-verbal Sounds in Boys and Girls," <u>Neuropsychologia</u>, Vol. 8, 1970, p. 227-237.

effects in that latency values for left-ear stimulated condition are of smaller value than those of the right-ear stimulated condition, with the exception of the result for latency event N_1 which is inverse. These results, however, are not readily interpretable.

(c) Discussion of Simple Main Effects and Simple Simple Main Effects on Stimulus for Component Latency Values.- The results of tests of simple main effects show that differences in latency values for word-stimulus and tone-stimulus occur only at event P_1 and at all four levels of the simple main effect. Thus, latency values for tone-stimulus are greater than latency values for word-stimulus at the level of left-side pickup, right-side pickup, left-ear stimulated and right-ear stimulated. This is an interesting finding from several points of view. The pervasiveness of this difference, at all four levels of simple main effects of event P_1, indicates that the difference between the two stimuli units in regards to latency values is very strong. However, this difference is present only at event P_1 and not at any subsequent events. This would suggest that in terms of latency measures, stimulus differences can be demonstrated in early components of evoked responses. The finding is not incompatible with the general statement that sensory processing is reflected in the early components of the evoked response, while more elaborative and associative processing is reflected in the later components of the evoked response.

At the level of simple simple main effects two significant values are found at event P_1, in the same direction as the results at the simple main effect levels, for the levels of left-side pickup and right-ear stimulated and for right-side pickup and right-ear stimulated. In addition to other things these findings may signify, they do indicate the pervasiveness of the stimulus differences reflected in latency measures at event P_1. No other simple simple main effects were found to be significant at any of the other evoked response events.

4. Discussion of Component Amplitude Values.

The discussion of component amplitude values will proceed with the discussion of results of tests of simple main effects and simple simple main effects for each experimental condition across all event amplitudes. A discussion of the Pickup condition will be followed by a discussion of the Ear condition and then the Stimulus condition.

(a) Discussion of Simple Main Effects and Simple Simple Main Effects on Pickup for Component Amplitude Values.- The results of tests of simple main effects show that differences in amplitude values for left-side pickup and right-side pickup occur only at event P_2 of the evoked response. The amplitude value of right-side pickup condition is greater than that of the left-side pickup condition at the level of tone-stimulus and also at the level of left-ear stimulated.

The differences in amplitude values found between left-side pickup and right-side pickup at the level of tone stimulus may be due to the differential treatment of the tone stimulus by two hemispheres which may differ in types of neurological processing. It is interesting to note that the word-stimulus mean amplitude values, although they do not reach a level of statistically significant difference, vary in the same direction as the mean amplitude values for tone-stimulus at events N_1, P_2 and N_2, as shown in Tables XXV, XXVII and XXIX. The increased amplitude differences found for left-side pickup and right-side pickup with tone stimulus and not for word stimulus may be due to acoustical parameter differences such as duration, frequency, composition, rise time, amplitude contour as well as speech or non-speech parameters.

The differences in amplitude values found between left-side pickup and right-side pickup at the level of left-ear stimulated appear to reflect the general findings that contralateral influences to a hemisphere produces a higher amplitude than ipsilateral influences. Although the amplitude values for left-side pickup and right-side pickup do not reach a significant level of difference at the level of left-ear stimulated in events P_1, N_1 and N_2 the direction of the difference is the same. One would expect that at the level of right-ear stimulated, differences in left-side pickup and right-side pickup would be the inverse of the results for left-ear stimulated. This was found only for event P_1. The results shown in Tables XXV, XXVII and XXIX indicate that there is no difference between the means of left-side pickup and right-side pickup for word-stimulus for event N_1, and a larger amplitude value, though not significantly larger, for right-side pickup for events P_2 and N_2. Thus, the results for the level of right-ear stimulated, rather than being generally inverse to the results of the level of left-ear stimulated, tend to parallel them in the last two evoked response events. This appears to provide some support for the classical dominance position that the right hemisphere has a primarily sensorial non-specific orientation.

The one significant finding for simple simple main effects of a greater amplitude value for right-side pickup than left-side pickup at the level of tone-stimulus and left-ear stimulated appears to result from the combining of the significant findings mentioned above for simple main effects.

(b) Discussion of Simple Main Effects and Simple Simple Main Effects on Ear for Component Amplitude Values.- The results of tests of simple main effects and simple simple main effects on Ear for component amplitude values indicated no significant results at any level of any effect. This means that the amplitude values for the condition of left-ear stimulated or right-ear stimulated were not significantly different at any level of pickup effect, stimulus effect or pickup and stimulus effect.

(c) Discussion of Simple Main Effects and Simple Simple Main Effects on Stimulus for Component Amplitude Values.- The results of tests of simple main effects and of simple simple main effects on stimulus conditions for component amplitude values were all in the same direction, namely, amplitude values for tone stimulus being greater than those for word stimulus. Significant results were found at two levels of simple main effects for event P_1 and at all levels of simple main effects for events N_1, P_2 and N_2. This, coupled with the results of tests of simple simple main effects on stimulus for component amplitude values which show no significant values for any level at event P_1, significant values for two levels at event N_1, significant values for three levels at event P_2, and a significant value for one level at event N_2 indicate that the most pervasive difference between amplitude values of stimulus conditions was found at event P_2. This was followed by events N_1, N_2 and P_1, respectively.

The component amplitude value differences found between the two stimulus conditions are very much like the evoked response amplitude value differences found for the stimulus condition except that the latter is even a bit more pervasive. Thus, the amplitude values indicated a consistent and considerable difference between word-stimulus and tone-stimulus. This is not surprising in view of the fact that the two stimuli were quite different, as noted above.

In comparing the results of tests of simple main effects and simple simple main effects of the component amplitude values for stimulus conditions and the component latency values for stimulus conditions several points are noted. Significant test results for latency values are restricted to the first evoked response event, P_1. The results are in the direction of tone-stimulus having a longer latency than word stimulus. The component amplitude values for evoked response event P_1 show significant differences at two simple main effect levels in the direction of tone-stimulus obtaining a higher amplitude value than word-stimulus. The differences in component amplitude values for the other two simple main effect levels are not significant but are in the same direction. Thus, although tone-stimulus component amplitude values in event P_1 are higher than those of word-stimulus, word-stimulus component latency values are smaller than those of tone-stimulus. This would tend to run contrary to the position by Davis et al.[4] that there is an inverse

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[4] H. Davis, T. Mast, N. Yoshie and S. Zerlin, "The Slow Response of the Human Cortex to Auditory Stimuli and Recovery Process," Electroencephalography and Clinical Neurophysiology, Vol. 21, 1966, p. 105-113.

relationship between stimulus intensity and latency magnitude. In other words, although the tone stimulus condition had a higher intensity and a higher component amplitude than word for individual events, the component latency for the tone condition was greater for event P_1. This could indicate that the stimulus qualities of the word stimulus condition beyond intensity are involved in differential processing of the word, at least in the early part of the evoked response.

From the summary tables of simple main effects and simple simple main effects on experimental conditions for latency and amplitude values it appears that variations in component latency values are found mainly in ear conditions and pickup conditions while variations in component amplitude values are found mainly in stimulus conditions and pickup conditions. This may have some importance in future research in terms of determining appropriate measures for selected experimental conditions.

5. Conclusions.

Results of tests of significance of EEG amplitude values indicated that the amplitude values of background EEG were similar for all experimental conditions.

Analysis of evoked response amplitude values indicated that the amplitude values for tone-stimuli were consistently larger than the amplitude values for word-stimuli. This finding was not unexpected because of the many differences between the two stimuli used in this experiment.

Analysis of component latency values of simple main effects and simple simple main effects on pickup conditions indicated that contralateral influences resulted in smaller latency values for the left-side pickup condition in the second and third evoked response event. In the first event, however, contralateral influences, left-ear stimulated, resulted in smaller latency values for the right-side pickup condition. This was felt to be due to greater efficiency of contralateral stimulation and an added bias due to the possible primary sensorial non-specific orientation of the right hemisphere.

Component latency value analysis of simple main effects and simple simple main effects on ear conditions indicated that contralateral influences to the right-side pickup resulted in smaller latency values than ipsilateral influences. Some mild support was also found for left-ear superiority in identification of non-verbal stimuli since the left-ear stimulated condition obtained a smaller latency value than the right-ear stimulated condition, for a tone stimulus.

Differences in latency values for stimulus conditions indicated a consistently smaller latency for the word-stimulus condition than for the tone stimulus condition in the first evoked response event. This was felt to be consistent with the general statement that the early components of the evoked response reflect more basic sensory processing while the latter components reflect more elaborative and associative processes.

Analysis of tests of component amplitude values on pickup indicated possible differential processing of tone stimulus by the two hemispheres. This finding was restricted to the third event of the evoked response. At the third event, it was found that the right-side pickup obtained higher amplitude values than the left-side pickup when the left ear was stimulated. This was felt to reflect the general finding that contralateral influences to a hemisphere produce a higher amplitude than ipsilateral influences. Also, further analysis of data suggested support for the position that the right hemisphere has a primary sensorial non-specific orientation.

Analysis of tests of simple main effects and simple simple main effects on ear for component amplitude values indicated that no differences were found between ear conditions at the levels of pickup effect, stimulus effect or pickup and stimulus effect.

Tests of effects on stimulus conditions for component amplitude values indicated that the most pervasive differences in stimulus conditions occurred in the third, second and fourth evoked response events, respectively. The findings were consistent with those of evoked response amplitude results and indicated that tone-stimulus condition obtained a higher component amplitude value than word stimulus condition. This was expected because of the makeup of the two stimuli used.

In comparing component amplitude values and component latency values for stimulus conditions it was seen that although tone-stimulus component amplitude values in the first event were higher than those for word-stimulus, word-stimulus component latency values were smaller than those for tone-stimulus. It was felt this indicated that the stimulus qualities of the word-stimulus condition beyond intensity were involved in differential processing of the word and tone stimuli, at least in the early part of the evoked response.

Finally, it appeared that variations in component latency values were found mainly in ear conditions and pickup conditions while variations in component amplitude values were found mainly in stimulus conditions and pickup conditions.

Suggestions for research following from the above conclusions would include further study of the contralateral and ipsilateral influences to the two hemispheres using either verbal or non-verbal stimuli. Another area which would appear to warrant further study is the apparent differential processing of word and tone stimuli during the early part of the evoked response. Lastly, a study which included both binaural and monaural stimulation conditions could serve to elucidate some of the similarities and differences in cerebral processing of the two types of auditory stimulation.

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APPENDIX 1

RAW DATA

Raw EEG Amplitude Values in Millivolts.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	68.71	81.17	109.17	84.55	90.91	89.20	101.26	96.88
2	302.85	244.62	309.95	241.71	304.48	303.07	298.13	279.18
3	116.40	174.32	157.80	169.67	214.04	241.78	201.95	246.48
4	93.12	80.33	92.98	76.08	92.55	162.06	92.60	166.01
5	158.47	173.11	164.57	162.68	170.37	179.20	181.25	190.56
6	58.32	106.07	57.86	118.59	150.64	131.41	155.35	137.62
7	95.62	103.99	95.61	104.51	131.31	134.93	133.52	140.45
8	156.66	195.94	145.93	178.82	208.96	217.18	184.97	220.06
9	102.85	125.51	98.20	126.99	153.36	175.31	138.27	175.26
10	113.04	90.82	116.44	92.00	167.58	150.27	173.38	143.47
11	148.36	168.95	161.15	180.50	170.88	186.07	184.12	204.16
12	110.07	102.30	120.08	99.75	170.89	170.22	173.74	164.99
13	186.45	185.09	194.95	208.64	208.59	211.62	216.41	218.81
14	139.88	137.05	139.97	143.39	103.59	103.43	104.61	109.59
15	179.23	179.07	183.83	163.54	218.61	224.88	210.89	210.59
16	165.28	200.31	176.18	200.85	292.65	126.48	309.41	135.04
17	119.24	130.89	130.13	137.37	112.84	107.81	115.04	113.35
18	121.09	147.56	119.10	139.57	101.98	148.84	110.19	139.57
19	183.70	251.96	197.85	261.35	180.76	222.49	184.44	234.51
20	325.75	370.93	315.74	340.75	271.98	317.74	275.24	295.27
21	87.48	98.44	89.99	103.05	79.52	87.81	75.83	86.51
22	142.25	145.48	134.69	133.62	138.24	134.64	150.98	129.74
23	225.37	220.62	245.99	222.02	182.01	177.09	177.68	203.00
24	301.20	288.89	297.42	286.40	252.45	231.42	249.54	228.30
25	218.00	191.65	196.13	190.07	151.30	119.22	129.96	132.99
26	106.91	126.97	111.19	122.60	127.67	171.20	129.09	177.42
27	145.24	158.58	150.04	151.47	120.28	125.54	116.19	140.03
28	119.50	161.17	117.96	142.47	118.07	147.56	120.67	142.85
29	67.96	73.73	68.43	83.36	82.08	90.34	82.54	86.52
30	174.15	177.58	175.93	187.03	185.23	175.20	180.47	191.80

APPENDIX 1

Raw Evoked Response Amplitude Values in Millivolts.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	17.33	14.95	23.20	12.00	24.59	17.65	44.84	20.78
2	57.24	26.91	69.13	33.84	59.69	39.28	68.15	50.79
3	19.03	18.79	25.76	24.77	24.17	17.16	20.12	24.75
4	16.79	13.50	22.74	21.59	13.07	19.64	19.26	22.88
5	35.57	52.97	40.55	52.61	41.68	58.02	84.48	81.82
6	8.40	15.77	8.45	12.61	20.64	24.28	20.97	20.55
7	12.24	16.17	17.54	18.23	27.92	24.33	31.36	23.64
8	19.45	32.46	32.04	32.43	41.40	37.95	64.42	59.89
9	28.57	30.92	27.43	38.94	26.29	34.05	34.08	39.38
10	32.60	23.73	19.01	22.56	32.24	32.54	25.37	26.95
11	28.78	35.30	50.22	69.78	40.19	41.04	59.37	73.69
12	14.24	12.51	19.98	14.02	24.76	29.68	29.62	33.36
13	28.88	25.40	35.37	26.97	24.40	29.45	32.65	36.42
14	32.55	27.72	30.28	25.02	31.83	24.52	35.41	37.05
15	40.83	32.58	60.54	44.51	46.57	42.79	40.10	25.78
16	25.10	33.04	45.64	38.81	68.18	22.81	112.66	35.03
17	16.78	25.82	32.24	33.82	20.81	26.90	28.12	32.64
18	19.01	25.94	16.77	20.96	29.09	27.21	33.78	32.91
19	18.88	50.24	36.49	75.17	38.87	53.81	62.77	82.33
20	60.04	43.74	40.64	42.47	38.68	41.34	41.21	34.61
21	24.86	25.25	26.56	28.73	24.03	21.10	24.74	27.31
22	31.91	27.19	32.76	31.65	23.27	13.99	24.28	29.08
23	33.35	32.54	33.74	44.28	19.48	25.39	29.99	30.46
24	33.31	29.59	64.61	35.14	33.44	26.00	35.98	26.35
25	33.40	42.17	53.04	72.10	28.80	24.03	40.12	44.86
26	15.07	28.81	25.24	29.10	14.47	31.70	23.48	31.99
27	28.48	29.77	31.57	42.47	26.07	28.30	29.59	29.42
28	24.00	15.57	25.31	29.67	17.06	14.03	16.75	19.87
29	25.31	29.68	29.23	37.93	36.01	36.89	39.71	45.20
30	27.47	24.59	26.57	38.28	35.92	29.96	36.09	34.58

APPENDIX 1

Raw Latency Values in Milliseconds for Event P_1.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	80	(86)[a]	96	78	68	62	70	96
3	126	(86)	116	122	122	126	120	122
4	78	80	82	(95)	80	94	86	78
5	76	72	80	78	76	80	78	86
6	84	86	126	92	98	92	120	96
7	98	92	118	128	72	78	78	94
8	114	120	118	120	82	76	116	118
10	116	100	128	78	(84)	96	84	108
11	94	84	86	88	88	94	84	114
12	98	114	84	124	116	114	114	114
13	(87)	84	126	128	122	92	76	112
14	40	82	80	86	82	88	80	90
15	74	82	80	84	80	86	76	88
17	68	74	104	88	104	104	94	92
18	86	84	86	100	74	68	78	94
19	106	82	94	(95)	90	94	(90)	82
20	(87)	88	88	118	86	94	90	92
21	76	80	88	82	74	80	78	86
22	78	68	82	68	58	60	(90)	92
24	110	98	100	72	108	104	70	136
25	96	66	48	74	54	98	92	90
26	86	76	82	76	64	74	(90)	68
28	104	112	(97)	74	70	(91)	96	106
29	90	60	74	68	64	91	70	74
30	124	116	126	130	110	114	124	126

[a] Values in brackets are column means used for missing latency values.

APPENDIX 1

Raw Latency Values in Milliseconds for Event N_1.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	116	104	160	112	146	142	118	150
2	154	106	166	68	130	106	108	114
3	144	124	212	154	152	154	220	168
4	130	124	122	116	134	134	116	98
5	130	142	144	108	130	142	112	112
6	148	138	146	118	160	136	146	164
7	140	134	150	156	124	128	116	140
8	160	166	158	158	148	148	152	156
9	92	92	96	94	98	102	100	102
10	140	124	160	162	134	140	110	168
11	110	104	108	106	108	112	108	114
12	140	144	150	148	132	140	150	156
13	106	116	178	194	150	168	200	158
14	110	112	114	112	114	146	116	144
15	102	102	114	108	108	100	106	118
16	132	118	152	156	146	158	148	154
17	162	120	156	134	158	154	142	150
18	136	128	136	138	132	134	132	138
19	146	194	138	138	136	204	132	140
20	118	128	138	140	124	138	140	140
21	138	128	148	134	130	130	138	136
22	106	104	108	110	110	104	136	140
23	104	108	108	112	106	102	102	152
24	136	124	174	118	(132)[a]	150	160	182
25	144	120	154	140	134	146	150	148
26	146	142	108	128	92	120	106	100
27	142	180	130	124	158	108	172	180
28	140	140	152	140	168	152	130	134
29	128	138	120	134	108	144	112	148
30	164	166	168	176	152	160	150	178

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[a] Value in brackets is column means used for missing latency values.

Raw Latency Values in Milliseconds for Event P_2.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	206	182	206	264	204	200	212	222
2	200	234	236	226	198	230	218	214
3	198	170	268	260	212	260	252	270
4	170	166	170	166	170	178	172	168
5	190	196	188	202	188	196	188	182
6	196	208	192	142	196	216	216	206
7	172	188	286	264	176	184	172	176
8	206	224	222	222	204	220	212	218
9	144	130	136	130	178	188	188	186
10	248	226	208	202	208	230	224	264
11	138	136	142	142	136	142	140	146
12	194	192	198	212	168	260	200	218
13	272	242	252	244	218	224	258	274
14	152	174	164	172	194	218	192	222
15	168	160	164	164	194	202	172	188
16	196	210	192	220	202	220	202	258
17	252	214	222	200	202	218	208	208
18	162	226	206	208	176	170	196	208
19	232	262	230	232	212	266	188	242
20	192	194	202	192	190	182	198	192
21	194	170	206	190	194	174	202	194
22	174	180	176	170	170	158	176	176
23	178	148	146	174	178	156	146	184
24	182	170	208	218	(193)[a]	234	206	216
25	193	180	208	198	206	200	204	206
26	226	214	246	246	204	260	170	210
27	196	208	152	152	192	200	220	220
28	204	188	212	190	216	208	182	160
29	188	192	184	194	200	202	186	200
30	214	204	204	276	220	220	198	276

[a] Value in brackets is column means used for missing latency values.

Raw Latency Values in Milliseconds for Event N_2.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_2S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_1S_2E_1$	$P_2S_2E_2$
1	284	270	310	326	292	316	298	300
2	282	260	300	324	280	344	314	330
3	302	280	320	314	(279)[a]	286	(277)	304
4	332	330	308	304	(279)	294	328	(286)
5	316	316	292	300	242	340	284	296
6	262	292	246	228	318	352	288	326
7	238	230	330	(279)	242	282	244	238
8	298	(278)	276	282	272	260	278	276
9	222	210	216	206	234	256	298	294
10	328	330	316	328	326	322	308	332
11	176	178	180	184	172	178	180	186
12	234	304	324	314	318	324	304	310
13	336	324	308	358	334	336	316	348
14	286	276	214	290	288	284	292	278
15	256	252	214	226	246	256	202	236
16	254	290	298	292	284	304	298	306
17	328	310	326	306	316	312	298	292
18	196	324	238	264	284	268	258	278
19	(277)	338	300	310	308	338	290	310
20	318	246	278	244	326	242	288	244
21	306	270	304	254	316	328	292	252
22	240	236	238	226	244	258	240	246
23	218	212	206	218	246	226	232	238
24	216	212	256	282	214	286	266	284
25	284	330	268	272	282	336	272	282
26	298	306	296	302	298	310	292	300
27	248	258	180	174	248	250	264	268
28	336	320	296	318	268	248	222	280
29	310	294	308	308	310	310	312	314
30	328	262	246	330	306	328	284	332

[a] Values in brackets are column means used for missing latency values.

Raw Amplitude Values in Millivolts for Event P_1.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	12.02	(31.17)[a]	20.75	15.40	16.94	15.90	37.28	26.22
3	7.32	(31.17)	36.44	36.33	30.93	25.52	57.42	68.30
4	25.69	17.46	14.04	(38.75)	19.25	10.97	6.96	2.21
5	40.62	79.53	84.74	104.59	72.99	88.52	113.13	150.05
6	93.38	11.58	4.43	32.24	36.80	19.04	20.81	17.71
7	23.64	0.90	40.63	40.21	42.74	3.30	28.04	16.56
8	28.95	43.32	51.04	67.69	55.33	33.67	59.44	59.62
10	27.04	(31.17)	43.06	21.12	(32.70)	21.47	1.01	26.95
11	30.77	19.77	4.64	(38.75)	30.73	9.50	35.07	30.29
12	(30.64)	14.96	23.10	20.01	9.33	24.11	25.01	32.72
13	(30.64)	49.91	49.77	31.34	11.03	31.41	75.98	23.17
14	26.48	13.22	56.21	24.19	16.45	10.78	45.42	19.89
15	96.48	16.50	23.53	5.27	78.09	1.37	92.94	32.39
17	29.18	14.99	26.32	49.86	17.09	17.80	50.47	55.04
18	33.58	22.88	46.83	21.71	33.88	12.48	71.23	19.75
19	51.37	45.15	33.98	(38.75)	14.54	37.41	(43.96)	11.94
20	(30.64)	80.29	(38.80)	64.29	38.45	70.74	35.28	40.95
21	28.02	41.26	28.66	39.59	16.90	46.39	34.94	31.88
22	12.71	20.48	22.00	23.82	18.42	30.85	(43.96)	8.01
24	20.64	33.37	83.94	44.97	33.34	37.00	43.84	22.09
25	35.55	12.00	38.68	19.96	24.92	13.18	9.37	30.27
26	33.23	31.23	12.21	23.53	93.39	1.92	(43.96)	30.06
29	9.24	5.66	15.18	21.52	17.51	(25.79)	27.08	22.33
30	25.37	36.51	70.18	106.63	(32.70)	25.72	25.60	80.18

[a] Values in brackets are column means used for missing amplitude values.

APPENDIX 1

Raw Amplitude Values in Millivolts for Event N_1.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	23.97	19.50	19.25	16.60	31.06	28.09	30.72	25.78
2	95.54	84.06	128.29	42.10	59.43	71.63	69.88	70.66
3	0.68	13.85	51.56	15.67	17.07	6.48	38.58	27.70
4	38.31	34.54	53.96	34.37	24.75	25.03	45.04	33.79
5	75.38	68.46	75.26	131.41	67.01	111.48	138.87	145.95
6	18.61	20.42	3.57	15.76	23.20	32.96	15.19	18.29
7	16.36	27.10	27.37	27.79	69.26	55.30	43.96	15.44
8	39.05	76.68	96.96	92.31	100.67	100.33	164.56	108.38
9	22.36	41.84	19.63	50.39	32.03	51.28	49.75	45.44
10	16.96	31.34	8.93	38.88	19.45	58.52	29.00	47.08
11	10.76	24.23	55.36	53.44	17.27	18.50	76.93	69.71
12	22.63	50.41	44.90	15.99	14.67	43.89	74.99	51.28
13	34.39	30.09	50.23	52.66	24.97	52.59	40.02	64.83
14	41.52	50.78	43.79	35.81	43.55	29.22	42.58	44.11
15	83.52	19.50	32.47	62.73	45.91	34.63	71.06	43.61
16	41.05	49.98	18.21	38.96	83.26	32.13	117.62	61.51
17	50.82	45.01	41.68	54.14	42.91	30.20	53.53	64.96
18	22.42	45.12	25.17	62.86	58.12	63.52	76.77	56.25
19	32.63	50.85	34.02	82.46	45.46	18.59	72.08	48.06
20	68.35	63.71	92.72	(51.71)[a]	77.55	61.26	108.72	59.05
21	43.98	46.74	47.34	44.41	27.10	57.61	33.06	44.12
22	51.29	55.52	46.00	60.18	21.52	17.15	23.65	23.99
23	19.41	60.46	71.18	71.46	39.73	44.65	46.85	45.61
24	19.36	93.74	84.06	59.03	(42.75)	7.00	68.16	25.91
25	60.45	52.00	97.32	80.04	31.08	38.82	58.63	69.73
26	30.77	40.76	77.90	31.53	10.66	46.08	38.47	41.94
27	26.39	21.94	12.87	54.94	89.41	12.90	74.52	30.51
28	44.00	29.16	37.82	33.88	20.44	24.67	25.74	12.71
29	26.76	28.68	44.82	46.48	34.49	57.33	64.92	61.67
30	58.63	31.49	33.82	93.37	67.53	54.28	18.40	91.82

[a] Values in brackets are column means used for missing amplitude values.

Raw Amplitude Values in Millivolts for Event P_2.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	36.02	28.50	28.75	19.40	40.94	19.91	69.28	38.22
2	88.46	19.94	127.71	57.90	96.57	40.37	94.12	77.34
3	31.32	22.15	68.44	60.33	22.93	17.52	29.42	44.30
4	33.69	37.46	46.04	53.63	27.25	26.97	58.96	74.21
5	60.62	99.53	72.74	112.59	92.99	108.52	181.13	158.05
6	17.84	35.58	24.43	20.24	16.80	51.04	28.81	41.71
7	19.64	40.90	28.63	28.21	54.74	64.70	76.40	56.56
8	40.95	23.32	59.04	71.69	83.33	35.67	147.44	147.62
9	45.64	37.16	72.37	101.61	51.97	52.72	54.24	30.56
10	43.04	36.66	39.06	41.12	48.55	65.47	50.99	36.92
11	54.77	87.77	128.64	158.56	90.72	81.50	191.07	246.29
12	25.37	22.96	43.10	24.01	41.33	52.11	73.01	64.72
13	53.61	33.91	97.77	55.34	39.03	55.41	51.98	47.17
14	34.48	41.22	36.21	32.19	40.45	42.78	53.42	55.89
15	76.48	80.50	127.53	113.27	74.09	89.37	56.94	48.39
16	74.95	98.02	73.79	33.04	180.74	55.87	190.38	42.49
17	21.18	30.99	58.32	53.86	57.09	65.80	66.47	79.04
18	25.58	46.88	30.83	45.71	49.88	40.48	51.23	79.75
19	35.39	73.15	45.98	73.54	66.54	69.41	91.92	87.94
20	147.65	20.29	67.28	88.29	70.45	42.74	87.28	92.95
21	60.02	37.26	68.67	55.59	50.90	38.39	50.94	59.88
22	64.71	48.48	50.00	71.82	38.42	18.85	64.35	68.01
23	36.59	63.54	60.82	68.54	28.27	43.35	61.15	58.38
24	28.64	61.37	59.94	60.97	(57.41)[a]	25.00	63.84	34.09
25	55.55	60.00	11.47	175.96	56.92	45.18	93.37	98.27
26	21.23	51.24	28.21	31.53	13.34	57.92	37.53	42.06
27	25.61	14.06	11.13	1.06	39.06	19.10	45.48	65.49
28	52.00	34.84	42.18	50.12	43.56	27.33	10.26	15.29
29	45.24	39.32	59.18	69.52	61.51	46.67	67.08	86.33
30	57.37	12.51	26.18	54.63	84.47	1.72	49.60	48.18

[a] Value in brackets is column means used for missing amplitude values.

APPENDIX 1

Raw Amplitude Values in Millivolts for Event N_2.

Subj.	$P_1S_1E_1$	$P_1S_1E_2$	$P_1S_2E_1$	$P_1S_2E_2$	$P_2S_1E_1$	$P_2S_1E_2$	$P_2S_2E_1$	$P_2S_2E_2$
1	27.98	15.50	31.25	24.60	47.06	24.09	78.72	45.78
2	87.54	20.06	108.29	70.10	107.43	51.63	129.88	90.66
3	24.68	37.85	31.56	67.67	21.07	34.48	(71.23)[a]	27.70
4	30.31	14.54	25.96	38.37	(57.14)	5.03	29.04	(70.78)
5	43.38	60.46	87.26	83.41	63.01	59.48	150.87	113.95
6	10.16	32.42	11.57	19.76	35.20	44.96	35.19	54.29
7	12.36	15.10	35.37	(66.90)	17.26	31.30	59.96	35.44
8	39.05	(49.59)	28.96	28.31	60.67	28.33	100.56	112.38
9	42.36	54.84	47.63	74.39	44.03	35.28	61.76	41.44
10	84.96	47.34	40.93	54.87	63.45	54.52	57.00	75.08
11	85.22	104.23	139.36	137.44	117.27	126.50	180.93	173.71
12	2.63	13.04	24.90	19.99	46.67	51.89	26.99	28.72
13	34.39	54.09	58.23	36.66	56.97	68.59	48.02	80.83
14	65.52	46.78	35.79	47.81	71.55	49.22	62.58	80.40
15	75.52	75.50	140.47	106.73	113.91	110.63	31.60	43.61
16	33.05	57.98	94.21	90.96	119.26	48.13	201.62	73.51
17	14.82	61.01	69.63	62.14	26.91	58.20	45.53	40.96
18	26.42	37.12	25.17	42.29	38.12	43.52	48.77	48.25
19	(45.96)	118.85	98.02	198.46	73.46	122.59	148.08	216.06
20	80.35	87.71	72.32	15.71	53.55	93.26	40.72	31.05
21	43.98	38.74	35.34	44.41	43.10	21.61	49.06	40.12
22	59.29	31.52	62.00	68.18	41.58	21.15	59.65	75.98
23	39.41	64.46	55.18	95.46	11.73	24.65	54.85	25.61
24	91.36	38.63	144.06	47.03	74.65	51.00	28.16	41.91
25	56.45	80.00	97.32	160.04	55.08	38.81	90.63	93.73
26	14.77	64.76	43.79	76.47	22.66	50.08	38.48	89.94
27	66.39	25.94	24.87	26.93	80.94	60.90	38.52	66.51
28	36.00	29.16	61.82	53.88	32.44	20.67	33.74	32.71
29	58.76	68.68	72.82	87.48	78.49	73.33	84.92	101.67
30	45.66	41.66	41.66	61.66	39.53	81.66	50.40	(70.78)

[a] Values in brackets are column means used for missing amplitude values.

APPENDIX 2

ABSTRACT OF

A Study of Auditory Asymmetry Using Auditory Evoked Response

APPENDIX 2

ABSTRACT OF

A Study of Auditory Asymmetry Using Auditory Evoked Response[1]

Studies of asymmetric auditory functioning have varied greatly in approach and level of study. They range from anatomical research, through dichotic listening and speech production studies to various electrophysiological investigations. The end-point of study has been physical parameters, memory and perceptual functions, motor functions and, to a limited extent, afferent functions.

This study proposed to extend investigation at the afferent level of functioning using auditory evoked responses. The end-point of study was afferent functions of the brain in response to monaural stimulation, as reflected in some auditory evoked response parameters.

A sample of thirty male subjects with reported normal hearing, negative history of ear pathology and neurological involvement and reported right-hand preference was used. Auditory evoked responses to word and tone stimuli presented to the left and right ears were recorded from bilateral symmetrical leads on the two sides of the head. The evoked

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[1] Jerry V. Kroetsch, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, 1972, viii-135 p.

brain activity was computer analysed and statistically treated using a triple classification repeated-measures factorial design.

Analysis of results indicated that contralateral influences resulted in smaller latency values for left-side pickup condition in some latter parts of the evoked response events and for the right-side pickup condition for the first event.

For ear conditions, results indicated smaller component latency values for right-side pickup for contralateral influences than for ipsilateral influences.

Differences in latency values for stimulus conditions indicated a consistently smaller latency for the word-stimulus condition than for the tone-stimulus condition in the first evoked response event.

Differences in component amplitude values on pickup for the third event indicated that for right-side pickup, contralateral influences produce a higher amplitude than ipsilateral influences.

Amplitude values for tone stimulus were consistently higher than those for word stimulus. This was expected because of the makeup of the two stimuli used.

Variations in component latency values were found mainly in ear conditions and pickup conditions, while variations in component amplitude values were found mainly in stimulus conditions and pickup conditions.