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NAME OF AUTHOR/*NOM DE L'AUTEUR* Henry John Michalewski

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NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* Dr. H. Weinberg

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LATERALIZED CEREBRAL PROCESSING AND THE DEVELOPMENT OF HEMISPHERIC SLOW SCALP POTENTIALS--THE CNV

by

HENRY JOHN MICHALEWSKI

B.A., California State University, 1967
M.A., California State University, 1970

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Name: Henry John Michalewski

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Examining Committee:

Chairman: Lorne M. Kendall

Harold Weinberg
Senior Supervisor

A. Leonard Diamond

Paul Bakan

Christopher M. Davis

Roger Blackman

Morton D. Low
External Examiner
University of British Columbia, Vancouver

Date Approved: Aug. 12/75

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Author:

(signature)

Henry John Michalewski

(name)

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(date)

ABSTRACT

Three principal experiments were carried out in order to examine the lateral distribution of the contingent negative variation (CNV) during tasks designed to evoke differential hemispheric activity.

Monopolar scalp recordings were collected from homologous lateral sites from normal right-handed female and male subjects. Measures of average CNV activity included amplitude, density, ratio, and waveform (cross-correlation) indices. Experimental conditions were contrasted to a standard or control condition (SC) by variance analyses.

1. Tone analysis (TA), directed at right hemisphere functioning, required subjects to analyze tone sequences during the S_1-S_2 interval. Results indicated that homologous sites (F_4 vs F_3; T_4 vs T_3) were not asymmetrically distributed in TA. Along with a prominent scalloping effect that paralleled tone onsets, CNV amplitudes in TA were greatly increased compared to SC. In contrast to the vertex (C_z), resolution of the CNV at lateral sites corresponded with the subects' judgments (<u>same</u> or <u>different</u>) about the tone sequences. No sex effects were observed for either amplitude or waveform measures.

2. CNV activity over the area of Wernicke on the left

hemisphere was investigated by using conditions that required subjects to vocalize stimulus words after an S_2 signal. The stimuli were presented visually in either S_1 or S_2 positions. Although there was a significant conditions effect, homologous sites (W_1 vs W_2; F_3 vs F_4) were not asymmetrically distributed. Records indicated that pretrial shifting occurred when stimuli were presented in the S_1 position. No sex effects were observed for either amplitude or waveform indices.

3. Slow potentials over Broca's area on the left hemisphere were investigated in situations similar to (2) and which included a condition that required vocalization of a one-word association to stimulus words. Additionally, subjects were classified on lateral eye movement predisposition (LEMP) and ocular dominance (OD). The results indicated that homologous sites (B_1 vs B_2; F_3 vs F_4) were not asymmetrically distributed. No effects for sex, LEMP, or OD were observed for either amplitude or waveform indices.

Although overall lateralization effects were not found for the CNV, many individual records displayed sizeable slow wave asymmetries. The experimental tasks elicited hemispheric differences but not consistently enough to constitute an effect. The overall results for the three experiments are discussed in terms of the concepts of lateralization and the relationships of slow potential genesis to cerebral processing.

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Chapter 1

INTRODUCTION

The primary purpose of this paper is to explore the lateral distribution of the Contingent Negative Variation (CNV) over specific scalp sites during tasks designed to evoke hemispheric asymmetries.

The duality of structure reflected in the cerebral hemispheres of the human brain has stimulated workers to investigate the functional consequences of this split organization. The data that have emerged suggest that each hemisphere may have a dominance or predisposition to process particular types of stimulus information. As new information and techniques become available to study the brain, the further enlightenment between cerebral localization and cerebral asymmetries rests with the exploration and accumulation of relevant experimental data.

A great number of studies have been conducted that show differences in the way the two sides of the brain process information. Further, some of these investigations have been able to demonstrate behavioral differentiation with various gross cortical signs, e.g., alpha waves, evoked potentials, slow waves, etc., recorded from surface electrodes on the scalp. An attempt has been made here to correlate and extend the results from hemispheric functioning to the recording of slow scalp potentials. Although these slower potentials have been intimately linked to the workings of the cortex, their origin and function are only beginning to be explored in relation to overall behavior. For the present, the discussion here is limited to selected cognitive tasks which were incorporated into a general slow wave paradigm. Comparisons of the slow potentials between the hemispheres under these special situations were then examined. Based on our understanding of localization and cerebral functioning, these experiments should increase our knowledge of the nature and relevance of slow waves.

Chapter 2 presents a broad survey of the literature covering three major subject areas. The topics include the findings of hemispheric studies, scalp potentials (e.g., evoked potentials, ongoing EEG activity, alpha waves), and slow scalp potentials. In each of the subject areas, particular attention is directed to describing the methods that were used in the study in order to mark the limitations and the generality of the findings. Chapter 3 brings to focus some of the most recent studies in which lateralization effects have been observed in slow potentials, particularly the CNV. From pilot experiments, the effects of distraction on the distribution of the CNV are presented along with a discussion of the problems of assessing and quantifying lateralized slow wave activity. Chapter 4 presents a tone experiment that was designed to evoke right hemisphere asymmetries in the generation of the CNV potentials. Chapters 5 and 6 focus upon the language abilities of the left hemisphere with conditions that involve simple verbal processing and vocalization. A discussion of the results from each experiment is provided at the end of each chapter. Finally, Chapter 7 presents an overview of the three principal experiments and draws conclusions about lateralization effects and slow wave genesis from the common elements in each investigation.

Chapter 2

DIFFERENTIAL CEREBRAL PROCESSING, LATERALIZED EEG ACTIVITY, AND EVENT-RELATED SLOW POTENTIALS: THE CNV

The first two-thirds of this chapter is devoted to defining functional differences between the hemispheres as evidenced by representative experimentation conducted on cerebral specialization. As will quickly become apparent, examples of left-right differences come from varied and diverse sources. Experimental data derived from normal subjects as well as assorted clinical patients form a reciprocal relationship, sometimes complementary, sometimes incongruent, but always interesting. The focus of literature reports is such that relationships between variables take on a distinctiveness which may be more artificial than real. For this reason, no exaggerated attempt was made to shape the various findings into a mold that was not ready for casting.

The last third of this chapter presents details of a cortical slow wave phenomenon, the Contingent Negative Variation (CNV). Although related slow wave activity is briefly considered, the main intention of this section is to characterize the critical parameters importantly associated in the generation of the CNV. The combined readings from this chapter should provide the foundation and rationale necessary for the experimentation presented in later chapters.

Visually Related Asymmetries between the Cerebral Hemispheres

Experimenters have been able to take advantage of the discrete anatomical connections of the human visual system to examine selectively cerebral functioning. A clear hemispheric specialization has been demonstrated for particular stimulus materials presented very briefly or at short tachistoscopic exposures. Thus a visual right field or left hemisphere lateralization has been found for the recognition of words, letters, and digits. For example, Overton and Wiener (1966) tachistoscopically presented five-letter English words in several positions lateral to a central fixation point. The scoring technique used consisted of the number of correct recognitions out of 20 for each of the positions presented to each eye. The results indicated that word recognition was significantly better to the right of visual fixation than to the left. Further, posttest analyses indicated that the effect of visual field differences was due to the left eye; the right eye showed no advantage for left or right field presentations. Considering the lateral distances from fixation, right field recognitions were greatest for words presented at the extreme right field position, 2° in this case. No distinct effects were found for handedness or ocular dominance.

Kimura (1966) attributed field differences to an unequal processing of stimulus information between the cerebral hemispheres.

From her own experimentation, the right visual field displayed a definite recognition advantage over the left field for successively presented letter tasks. When considering certain methodological problems, Kimura commented that right field recognitions may be favored because of left-to-right reading habits, especially for stimuli presented simultaneously to the left and right of fixation. The effects of right field superiority and the familiar English practice of reading left-to-right were examined by Orbach (1967). This investigator tachistoscopically presented English and Hebrew words to native Hebrew readers (right-to-left) in left and right visual fields. The results indicated that English words were recalled more accurately from the right than left visual field; interestingly, Hebrew words showed no differences between the visual fields.

For both visual half-fields, Bryden (1965) found that single letters of the alphabet were recalled better in right-handed subjects than in left-handed subjects. The differences between subjects were greatest at shorter tachistoscopic exposure times (20 milliseconds); when exposure durations were increased to 25 milliseconds, no consistent field differences were found for either left- or right-handers. Hines and Satz (1971) examined digit recall in right-handed subjects using various presentation rates. In addition to finding a right field superiority for digit recognition, visual half-field asymmetry was most distinct at shorter presentation rates and for subjects without a history of sinistrality. Paralleling the field results for recognition tasks, significantly faster reaction times (RTs) were observed for letter displays presented to the right hemifield than to the left hemifield (Umilta, Frost, & Hyman, 1972). Hines, Satz, Schell, and Schmidline (1969) theorized that the capacity for processing verbal material was directly related to the connections of the right visual field to language centers in the left hemisphere.

McKeever and Huling (1971a) postulated that verbal material presented to the right hemisphere had to be transferred (via the corpus callosum) to language centers in the left hemisphere in order to be processed. The additional time and the additional neural elements involved in signal transmission may account for the right hemisphere's poor linguistic ability. In order to test the effects of cerebral pathways and transfer times, McKeever and Huling conducted a monocular recognition task. Common English words were bilaterally presented for 20 milliseconds duration; also, in order to assure fixation, subjects were required to report the appearance of a small numeral in the place of the fixation point at the time of stimulus presentation. The subjects were divided into separate left and right eye groups. The results indicated higher performance scores for the right visual field than for the left visual field for both subject groups. The investigators concluded that the right field results were due to the transmission fidelity of the primary pathways and shorter transfer times to the left hemisphere language centers.

In a logically more direct attack on the effects of interhemispheric transfer time, McKeever and Huling (1971b) presented stimuli that were either temporally ahead or temporally behind one or the other visual half-field. The tachistoscopic control of stimulus input allowed the following experimental times to be examined:

(a) simultaneous, (b) 6 milliseconds (a time considered reasonable for transcallosal transmission), and (c) 20 milliseconds (a time considered long enough to eliminate transmission effects). The results indicated that a right field superiority was maintained in every condition and for nearly every subject tested. Clearly leading left field words did not increase left field recognitions; clearly leading right field words did not increase recognitions beyond the level obtained for simultaneous onsets.

Using binocular stimulation, McKeever and Gill (1972) investigated masking effects in the visual fields of left- and right-handed subjects. A stimulus letter was tachistoscopically presented for 30 milliseconds followed .1 milliseconds (or 100 milliseconds) later by another but different letter for 30 milliseconds. The masking results disclosed that right-handed subjects recalled more starting letters in the right than left visual field. In contrast, left-handed subjects recalled more letters presented to the left than the right visual field. Speech centers for both left- and right-handers are generally found in the left hemisphere (Milner, Branch, & Rasmussen, 1964); as pointed out by Zangwill (1960) and Hécaen and Ajuriaguerra (1964), however, not all left-handers are uniquely lateralized to one hemisphere for language functions. An interesting clue regarding an individual's probable linguistic lateralization was provided by Kimura (1973). She found that hand gesturing during speech was opposite to the dominant or talking hemisphere for right-handers.

Presenting tachistoscopically paired digits, Sampson (1969) examined visual field effects in subjects that were right-handed and right eye dominant. Temporal and nasal occluders were placed on the subject that were rotated in position to allow stimulation of the appropriate visual fields. The subject's task was to call out the stimulus digits as soon as possible after the signal to respond. The results indicated the recall of digits projected to the nasal retinae was significantly better than when digits were projected to the temporal retinae. Also, digit information projected to the right eye was recalled better than information projected to the left eye. Sampson (1969) suggested that the field differences were due to faster processing times, especially for stimulation presented over primary pathways from the nasal hemiretinae.

Dimond and Beaumont (1971a) investigated hemisphere function for detection tasks of short and long duration. The stimuli presented to subjects consisted of four red lights and a central fixation point; the red stimulation lights were placed on the horizontal plane and were directed to specific retinal locations. The scoring technique used was based upon the mean percentage of detections and the mean frequency for false positives (defined as a response that occurred more than 10 seconds after the last signal). Over time, the results indicated a significant decrease in both detections and false positives over the four signal locations. During the later stages of the experimental situations, temporal hemiretinae showed superior performance over the nasal hemiretinae.

Investigating the relationship between intermodal processes and functional differentiation, Dimond and Beaumont (1971b) found that the left hemisphere was able to process more visual information during a simultaneous hand sorting task than the right hemisphere; however, visual stimuli presented to both hemispheres maximized performance over the stimulation of only one hemisphere. In another study, Dimond and Beaumont (1972a) found that hand performance was not disturbed by the simultaneous presentation of visual information. Also, experimentally induced fatigue was not transferred from one hemisphere to the other (Dimond & Beaumont, 1972b). Using paired-associate duograms to examine another facet of hemispheric specialization, Beaumont and Dimond (1973) discovered that visual stimuli presented to the left hemisphere resulted in a bilateral learning between the hemispheres, whereas stimulus duograms projected to the right hemisphere did not result in bilateral learning. Dimond (1971, 1972) suggested that due to the presence of the pyramidal tracts, transfer of movement was controlled by the specialization of each hemisphere according to situation demands.

McKinney (1967) isolated visual right field effects without the use of language dependent stimulus materials. This investigator observed that luminous figures viewed in a dark surround fragmented and faded much as stabilized retinal images. Since the dimly lit objects fragmented in an organized fashion, the break-up phenomenon was presumed to be the result of cortical activity. McKinney devised an apparatus which presented two faintly illuminated lines around a central fixation point. When the apparatus was placed at the correct distance, the parallel lines fell upon the left and right visual fields. The subjects were instructed to report which line faded first or whether both lines disappeared simultaneously; subjects received both binocular and monocular trials. For the binocular condition, the results indicated that the right visual field was significantly more stable than the left visual field. Handedness made no significant contribution to right field results, but the right field effect was more pronounced in subjects who were right eye dominant. In the monocular viewing condition, differences between left and right fields were found for the left eye but not for the right eye. Greater image stability was found for the temporal hemiretinae in both eyes; slightly more fragmentation was observed for the temporal hemiretina of the right than the left eye. McKinney (1967) asserted that the efficiency observed for the right visual field was not inconsistent with the general dominance of the left occipital lobe.

Schmit and Davis (1974) found a left hemisphere interference for tachistoscopically presented color stimuli and incompatible color names. The investigators hypothesized that the dominant hemisphere had to resolve the color and color name, whereas the nondominant hemisphere processed the stimulus only on the basis of the visual nature of the information.

Wyke and Ettlinger (1961) presented outline drawings of familiar objects, e.g., fork, cap, table, etc., for recognition. The successive binocular tachistoscopic presentations were flashed to the left and right visual fields. Exposure durations started at 10 milliseconds and increased, if necessary, until identifications were made. The results indicated greater recognition of objects presented to the right than left visual field. Similarly, when stimuli were bilaterally presented, recognition was better for the right than for the left visual fields. Drawing from the cortical work of Hubel and Wiesel, Wyke and Ettlinger (1961) suggested that right field superiority was the result of greater neural excitation to nasal projections, coupled with a possible right eye dominance over the left.

The left hemisphere's general capacity for processing verbal material is in distinct contrast to the right hemisphere's ability for processing nonverbal material. Kimura (1963) observed that patients with right temporal lobe damage were deficient on nonverbal recognition tasks. The patients exhibited inferior performance in (a) recognizing nonsense figures, (b) counting dots, and (c) a recurring figures task; they were not deficient however when more familiar stimuli were used. Using normal subjects, Kimura (1966) presented nonsense figures, nonoverlapping abstract forms, and dots for counting. With successive binocular presentation to either the left or right visual fields, dot recognition showed a left field superiority, whereas the recognition of nonsense figures showed no differences between the visual fields. In an experiment minimizing verbalization, Kimura (1969) demonstrated that a point was more accurately located when it was projected to the left than to the corresponding right field position. Umiltà, Rizzolatti, Marzi, Zamboni, Franzini, Camarda, and Berlucchi (1974) found that certain line orientations favored right field detections while other line orientations favored left field detections.

Postulating visual-spatial functions for the right hemisphere, Dunford and Kimura (1971) binocularly presented a three-dimensional arrangement of rods to visual left and right fields. The subject's task was to decide whether a central rod was closer or farther from the fixed group of rods. The results indicated a greater number of correct responses from the left than right visual field. However, monocular presentation of the stimulus arrangement revealed no field effects. Minimizing visual cues further, Dunford and Kimura stereoscopically presented (20 milliseconds) random dot stereograms (see Julesz, 1956) to either left or right visual fields. When the subjects named the objects they observed (e.g., raised triangle, square, etc.), left field scores were significantly higher than right field scores. Earlier, Carmon and Bechtoldt (1969) speculated on the right hemisphere's spatial integrating capacity during visual perception. They presented Julesz' stereograms to two patient groups with unilateral lesions of the left or right hemisphere. They found that patients with right hemisphere lesions made more errors in reporting the position of a small raised square than patients with left hemisphere lesions. Using normal subjects, Rizzolatti, Umiltà, and Berlucchi (1971) found a left field (right hemisphere) superiority for a task that involved the simple recognition of faces. Methodologically, the exposure of the stimulus faces before testing was not, in itself, interpreted as the basis for the observed visual field asymmetries (Berlucchi, Brizzolara, Marzi, Rizzolatti, & Umiltà, 1974).

Auditory Asymmetries between the Cerebral Hemispheres

Evidence for auditory specialization between the hemispheres has come largely from dichotic listening experiments. A number of studies have indicated a right ear (left hemisphere) advantage for the recall of dichotically presented words and digits (Curry, 1967; Curry & Rutherford, 1967). In contrast, a left ear (right hemisphere) advantage has been observed for dichotically presented nonverbal emotional stimuli, melodic patterns, and environmental sounds (Carmon & Nachshon, 1973; Kimura, 1964, 1967). The right ear superiority for verbal material was extended to nonsense words and dichotically presented synthetic vowel sounds and fricative consonants (Darwin, 1971). Reaction times for dichotic listening were also observed to be faster for right than for left ear stimulation (Levy & Bowers, 1974). Regarding the capacity for verbal processing, recent studies have found that the right hemisphere was not totally lacking in the ability to utilize speech or verbal material during perception (Blumstein & Cooper, 1974; Nebes, 1974). With simple clicks near fusion, Murphy and Venables (1970) found a significant detection advantage of the left ear over the right ear. Interjecting a burst of white noise contralateral to click presentation only accentuated the asymmetrical effect. Knox and Kimura (1970) dichotically presented verbal and nonverbal tasks to boys and girls (5 - 8 years of age). In addition to affirming right ear superiority for verbal materials, both males and females demonstrated a left ear superiority for nonverbal stimuli (e.g., identifying animal sounds). Considering the ages of the subjects, the investigators suggested that the lateralization of auditory functions may be present before five years of age. Using children for subjects, Bakker (1970) was able to elicit a lateralized right ear superiority for monaurally presented digits; a left ear advantage, with some restrictions, was also found for monaurally presented sound sequences. Bakker (1970) demonstrated that the degree of asymmetry produced by monaural stimulation was related to the capacity of the subject for ordered recall.

Clinical Evidence of Cerebral Specialization

The behavioral bases for differentiating hemispheric functions were largely derived from clinical observations of hemispheric dysfunction. For example, patients with unilateral left temporal lesions show impaired performance for the learning and retention of verbal material (Milner, 1968). regardless of the technique used to elicit responses (Blackmore & Falconer, 1967; Milner & Teuber, 1968). Patients with unilateral right temporal lesions have difficulty in the recall of visual and auditory stimuli, but they generally do not suffer verbal impairment (Milner, 1971). Using the Seashore Measures of Musical Talents, Milner (1962) found that left temporal patients exhibited no change in test scores before or after lobectomy procedures; right temporal patients following right temporal lobectomy, however, recorded an increased number of errors on timbre and tonal memory subtests. Similarly, dichotically presented melodies were impaired in a right temporal patient group, whereas dichotically presented digits were selectively impaired in a damaged left temporal patient group (Shankweiler, 1966). Using another type of perceptual task, Milner (1965) and Corkin (1965) both found that maze learning in patients following right temporal lobectomy was much more impaired than in patients following left temporal lobectomy.

In a dichotic listening task which used digits and synthetic syllables, Zurif and Ramier (1972) found that patients with right-sided lesions had a disrupted perception of speech sounds, whereas patients with left-sided lesions had trouble with the phonological processing of speech information. Bisiach and Faglioni (1974) found that patients with unilateral damage to the left hemisphere had difficulty in the delayed recognition of complicated shapes. Damage to the right hemisphere has also included impairment in the capacity for line orientation tasks (Warrington & Rabin, 1970), facial recognition (De Renzi, Faglioni, & Spinnler, 1968), and stereopsis (Carmon & Bechtoldt, 1969). Lesions of the parietal lobe of the dominant hemisphere have been accompanied by impairment in symbolic thought, general reading disturbances, and a diminished ability to perform arithmetic calculations (Alford, 1948; Critchley, 1969). Deficits in tactual abilities are often accompanied by right hemisphere damage (Carmon & Benton, 1969; De Renzi & Scitti, 1969). Boll (1974) found that patients suffering right hemisphere damage were more impaired on contralateral and ipsilateral tactile perception tasks than comparably damaged left hemisphere patients. When letters of the alphabet were presented tactually, Witleson (1974) found that the left hemisphere had no special advantage over the right hemisphere. Interestingly, blind children reading Braille were found to be more efficient when they used their left hand (i.e., right hemisphere) than when they used their right hand (Hermelin & O'Connor, 1971). Except for certain aspects of speech, deficits in frontal areas are usually more subtle to detect than for other brain areas. Milner (1971) however has found that patients with left or right frontal lesions are generally unable to modify ongoing behavioral activity in rapidly changing situations.

Using tests with medium and long delay periods (e.g., facial recognition tasks), Milner (1968) found that right temporal patients were impaired in the perception of complex patterns than when compared to left temporal patients. These left and right differences vanished however for the tests of shorter duration. Shai, Goodglass, and Barton (1972) tachistoscopically presented verbal and nonverbal stimuli to patients with unilateral brain damage. The damaged groups were comparable in extent of injury (arterial accidents, tumors) and were tested approximately 20 weeks after surgery. Left brain damaged patients were aphasic and occasionally suffered right hemiplegia; right brain damaged patients had either left hemiplegia or some sensory disruption on the left side of the body. Stimuli were monocularly presented at a threshold exposure plus a constant time period; the subject selected his answer from a stimulus array before him. A non-damaged patient group was included for comparison. The recognition scores for the left patient group showed that they performed better with both types of material presented in the left visual field. Scores for the right patient group demonstrated that both verbal and nonverbal materials were identified more correctly from the right than from the left visual field. The normal patient group showed the usual visual right field superiority for verbal material. There was also evidence that the field of a particular eye accounted for the major differences. For the normal group, it was the right field of the left eye that made the most significant contribution to correct responses. For the left brain damaged group, the left field of the right eye contributed most to correct scores; for the right patient group, the right visual fields of both eyes were the main contributors (for both verbal and nonverbal stimuli). The nondamaged patient group showed no field differences for the nonverbal stimuli.

In an extensive discussion of the findings concerning sensorimotor deficits in patients with left, right, and bilateral lesions, Semmes (1968) suggested that the left hemisphere appeared to have a focal characterization in functioning, whereas the right hemisphere appeared to have a diffuse almost overlapping functional organization. She argued that the "concept of cerebral dominance is not helpful for it proposes nothing about mechanism" (p. 11) and sometimes offered little more than a label or statement of the results of hemispheric injury. As a consequence of the postulated compact ordering of functions in the left hemisphere, dysfunction for certain tasks might be related to very specific lesion sites. Further, the specific decrements in performance might be interpreted as dominance of that hemisphere for that particular task. In addition, the right hemisphere, with the proposed diffuse organization, may undergo discrete injury but without the overall traumatic performance decrement that might be observed for the left hemisphere; the diffuse functional patterning of the right hemisphere may serve spatial relationships better than either a focalized or centralized cerebral functioning. From some standpoints, Semmes' theory about cerebral functioning coincides with Bogen's (1964) earlier characterization of hemispheric activity. Based upon a large number of clinical observations, Bogen was able to generalize that each hemisphere was distinguished by a separate mode of thought processing; the left hemisphere exhibited an ability for symbolic or verbal analysis, whereas the right hemisphere appeared more suited for the integration of visual or image relationships. In an extreme consideration of one-sided functioning, Obrador (1964) reported cases of hemispherectomy in which some language and even higher motor activities were retained no matter which hemisphere was removed.

From studies with commissurotomized patients, Gazzaniga and Sperry (1967) found that the dominance of the left hemisphere was not always absolute; in fact, certain functions, normally attributed only to the left hemisphere, were also carried out in the right hemisphere (Sperry, 1973). Using commissurotomized patients, Nebes (1973) tachistoscopically presented special line-dot arrays to the left and right visual fields. When the subjects indicated their responses by finger movement, more accurate determinations of orientation were made with left than right field presentations. Milner, Taylor, and Sperry (1968) tested commissurotomized patients in a dichotic listening situation. Simultaneous input to both ears showed that the patients failed to report digits from the left ear. In contrast, a monaural control session showed 87% and 90% recall for digits presented to the left and right ears, respectively. Similarly, Sparks and Geschwind (1968) observed 100% extinction for left ear performance on dichotic listening tasks for a patient who underwent bisection. Milner and Taylor (1972) examined the ability of the minor hemisphere to match tactile nonsense forms to visually presented versions of the nonsense forms. Split brain subjects showed the left hemisphere was greatly impaired in tactual form perception than when compared to the right hemisphere. Similarly, Nebes (1972) reported a definite advantage for commissurotomized patients when they used their left hand (right hemisphere) to match tactually visual shapes presented in fragmented form. With commissurotomized patients, Gazzaniga (1970) reported that verb commands, e.g., laugh, tap, etc., flashed to the right hemisphere produced no response, whereas the left hemisphere showed no difficulty in executing the command response. When patients were to retrieve objects, this time indicated by noun forms, the right hemisphere had no difficulty in executing the task.

So far the specificity of function observed between the hemispheres does not find a parallel in the gross morphology of the brain. Carmon and Gombos (1970) noted at least one exception, however. The vascular blood supply to each hemisphere is served directly from the aortic arch, whereas the right hemisphere is supplied by a vascular trunk shared with the upper extremities. These investigators collected indirect blood pressure measurements in left-handed, right-handed, and ambidextrous patients. Arterial pressures were found to be higher on the right side for most right-handed patients; pressures were higher on the left side for most of the left-handed patients; ambidextrous patients had pressures that were approximately equal. Higher correlations between pressure and handedness were attained for systolic than for diastolic pressures.

Recently developed techniques for observing regional cerebral blood flow (rCBF) have shown different blood flow distributions according to task demands (Ingvar & Schwartz, 1974). Increased rCBF was observed in mid-rolandic areas with hand work. The production of spoken language showed rCBF increases in the dominant hemisphere which included anterior and posterior speech areas and rolandic areas. This pattern of blood flow distribution was changed when subjects engaged in abstract thinking and problem solving. For these latter situations, rCBF increases were observed in frontal and postcentral association areas.

Human Scalp Recorded Evoked Potentials and Hemispheric Processing

Based on the evidence of differential cerebral processing, R. Cohen (1971) biaurally presented selected stimuli in an effort to provoke lateralized electrical brain activity. The nonverbal right hemisphere stimulus was a simple 10-millisecond click (called "noise" by Cohen) delivered through headphones. For the left hemisphere, subjects listened to single syllable words ("cat," "bar," and "rat") of 150 milliseconds duration. Average auditory evoked responses (AERs) were recorded from the scalp by a left temporo-central and right temporo-central electrode configuration. The stimuli were presented at a rate of one per second for two different sweep rates and a varying number of summations. The AERs to click stimuli indicated that the right hemisphere led the left hemisphere with an initial positive wave. Both hemispheres then showed corresponding multiphasic waves for the rest of the sweep period. Compared to the right hemisphere averages, the left hemisphere records for click stimuli were generally of lower amplitude and were delayed. Average evoked responses to verbal stimuli produced initial synchronous negative activity over both hemispheres. The onset of negativity varied with the particular stimulus word but ranged from 30 to 50 milliseconds. Succeeding secondary waves were similar over both cerebral hemispheres. Of the 37 subjects tested, 20 showed AERs of approximately equal amplitude to the verbal stimuli; for the remaining subjects, however, larger amplitudes were found over the left hemisphere. The records from four left-handed subjects were comparable to the predominately right-handed group for both click and verbal stimuli. Cohen (1971) concluded that the clicks were initially processed in the right brain, whereas verbal material elicited greater cortical activity over the left brain. Earlier, Schafer (1967) recorded specific cortical responses to the spoken letters "t," "o," and "d" over left temporal areas and right sensorimotor scalp sites.

In a normative study of human visual evoked responses (VERs), Harmony, Ricardo, Otero, Fernandez, Llorente, and Valdes (1973) recorded electrical activity from homologous central, temporal, and occipital scalp locations. The measures used to evaluate the evoked responses included latency differences, amplitudes, waveform similarities, and derived left-right energy ratios. Aside from small differences, the comparisons between homologous placements indicated that the VER waveforms were very similar. However, an example of lateralized activity for simple stimuli has recently been published by Davis and Wada (1974). These investigators found that a frequency analysis of evoked responses revealed more coherence for click stimulation from the left than right hemisphere, whereas flash responses were more coherent from the right than from the left hemisphere.

Wood, Goff, and Day (1971) examined in more detail the neural concomitants (in the form of AERs) related to the linguistic processing of auditory stimuli. The experimenters hypothesized that if the left hemisphere was specialized for the extraction of verbal features, some corresponding electrical activity should be visible in the averaged records, especially when compared to nonverbal hemispheric processing. Their study involved the activity evoked by the same consonant-vowel syllable during two auditory discrimination tasks. The first task, called Stop Consonant, presented the subject with certain signal parameters in order to provide linguistic information. The syllables used were "ba"/low and "da"/low. The second task, called Fundamental Frequency, provided no linguistic information at the phoneme level but differed only in fundamental frequency; the stimuli for this condition were "ba"/low (104 Hz) and "ba"/high (140 Hz). The subjects were given each task separately; they were instructed to press a button as quickly as possible for the "ba" or "da" in the Stop Consonant condition, or press a button for "ba"/low or "ba"/high in the Fundamental Frequency task. The stimuli were computer generated with a duration of 300 milliseconds; each of the stimuli was clearly identifiable in pretrial testing. Monopolar scalp recordings were taken from temporal and central (T_3, C_3) locations over the left hemisphere and temporal and central (T_4, C_4) locations over the right hemisphere. The sampling epoch for averaging was 490 milliseconds; data collection started at the onset of the stimulus.

Average evoked potentials to the same stimulus were combined across subjects to obtain records based upon 1920 trials for each task and electrode location. Additionally, the final waveforms were divided into preresponse (approximately 200 milliseconds) and motor response intervals. Neural events, mirrored as AERs, should be the same if the brain makes no distinction between verbal and nonverbal parameters. The results indicated that the right hemisphere AERs were identical for both tasks, as measured during the preresponse interval. In the left hemisphere, however, statistically significant differences were found for the tasks that required linguistic and nonlinguistic analysis. The results of the motor response intervals indicated that differences for each hemisphere occurred during both experimental tasks. The investigators were able to rule out the effects of motor interval reaction times to preresponse differences in the AERs, but they were not able to say that reaction times had no effect on the motor interval. In summary, Wood et al. (1971) concluded that (a) time point differences occurred between the hemispheres during a task that required verbal and nonverbal analysis; (b) the differences occurred only over the left hemisphere; and (c) the differences were not due to subtlety of signal structure or motor response.

Morrel and Salamy (1971) collected cortical responses made to human speech sounds. Monopolar scalp derivations from homologous anterior (Broca's area) and posterior (Wernicke's area) sites tended to have a negative component that was larger over the left hemisphere than over the right hemisphere for the spoken nonsense words; a later positive component (150 milliseconds) was uniformly distributed over scalp sites.

In both verbal and nonverbal conditions, Matsumiya, Tagliasco, Lombroso, and Goodglass (1972) reported a study where the meaning of the stimulus was manipulated. In Condition 1 (called undiscriminated words), four monosyllabic words ("back," "tick," "back," and "cook") were randomly interspersed between nonspeech sounds. In Condition 2 (called undiscriminated sounds), four types of mechanically generated noises were interspersed among the words of Condition 1. In Condition 1, the subject's task was simply to total the number of words; in Condition 2, the subject totaled the number of noises. Condition 3 (called discriminated sounds) contained only the sounds of Condition 2 without words; the subjects were instructed to determine how many types of sounds they could distinguish. Lastly, Condition 4 (called meaningful speech) consisted of ten sentences delivered in a spaced pattern of speech. All stimuli were edited to a duration of 485 milliseconds. Scalp recordings were collected from each hemisphere and were summated for a 250-millisecond epoch from the onset of the stimulus.

The AERs for eight of the nine subjects (all right-handed) were larger over the left hemisphere in Condition 4 (spoken sentences) than over the right hemisphere. Although not as striking, larger left hemisphere amplitudes were found for Condition 3 (discriminated sounds) than for Condition 2 (undiscriminated sounds). For three subjects, average evoked potentials for Condition 1 (undiscriminated words) over the left hemisphere were generally larger than for Condition 2; three subjects, however, showed larger amplitudes over the right hemisphere for the same experimental conditions. The peaks that were measured had latencies in the range of 100 milliseconds; within that time, as the investigators noted, only about one-fourth of the stimulus word was heard. The scalp records probably do not reflect differences in the stimuli in that time. Instead, they were probably related to the perceptual set of the subject. Thus when the subject had to use the meaning of each word, as in Condition 4, larger amplitude asymmetries were produced than when the meaning of each word was minimal, as in Condition 1. In Conditions 2 and 3, where the sounds were physically the same, amplitude asymmetries were elicited by simply imposing different tasks or instruction sets on the subject. Matsumiya et al. (1972) concluded that the occurrence of asymmetries in the AER might include more than just the use of verbal and nonverbal stimuli; indeed, factors such as subject set or subject attention may play an important role in the observation of hemispheric asymmetries.

Factors Influencing Evoked Response Activity

Before proceeding further with studies investigating cognitive differences from scalp evoked potentials, certain factors influencing the cortical responses themselves should be discussed. For this purpose, several experiments dealing with visual, auditory, and somatosensory responses are briefly considered.

Visual evoked responses from the scalp were monitored by Garcia-Austt, Bogacz, and Vanzulli (1964) during sessions of forced attention or during sessions with injected interference. Interference stimuli consisted either of tones or clicks at 70 dB. The VER waveform during focused attention indicated a general increase in the number of VER components, i.e., P_1N_1, P_2N_2, P_3N_3, etc. When the subject simply counted the flashes during stimulation, there was an increase in the size of the VER, especially for the later components. Interference produced an overall decrease in the VER amplitude.

Satterfield (1965) conducted a study to determine the effects of attention on evoked cortical responses. Subjects were instructed to attend either to click or shock stimuli during the alternate presentation of clicks and shocks. The overall results indicated that averaged cortical activity was increased for the stimulus attended, whereas unattended stimuli were suppressed. In three different vigilance tasks, Spong, Haider, and Lindsley (1965) recorded visual and auditory evoked responses from occipital and temporal regions of the scalp. The experimental conditions included (a) attending to a brightness change, (b) a key-pressing task, and (c) a counting task. The stimuli were simple flashes and clicks alternately presented. For the brightness and key-pressing tasks, VERs in the occipital area were larger for flashes than for clicks. In the temporal area, subjects who attended clicks showed larger amplitude AERs than subjects who attended flashes. For the counting task, no similar trends in the evoked responses were observed. The investigators suggested that counting by itself may serve as a distraction damaging to the attentive state. Generally, perceptual discriminations that demanded close subject attention were paralleled by a corresponding change in cortical activity.

Considering the information delivered by simple stimuli, Sutton, Tueting, and Zubin (1967) reported on the significance of a large positive process in evoked potentials that occurred approximately 300 milliseconds after stimulus presentation. If a subject was required to make a response to a stimulus that resolved some uncertainty, this late component, or P300 wave, was generally of larger amplitude than when the response did not resolve any uncertainty, e.g., when the subject had prior knowledge of the forthcoming stimulus. In the latter situation of subject certainty, the stimulus only marked the time of its occurrence; in the former situation, however, the uncertain stimulus provided information in addition to the time of its occurrence. Further, if the information carrying stimulus was delivered externally, a larger positive component was observed than when the absence of an external event, in effect, delivered information.

John, Herrington, and Sutton (1967) demonstrated that VER waveforms were not only determined by simple receptor stimulation but were also affected by the perceptual context of the stimulus. Their data were collected from monopolar scalp recordings located on the midline 3 cm above the inion. Four pairs of stimuli were compared: (a) a blank field versus a field containing some geometric shape, (b) one geometrical shape versus a different shape of equal area, (c) two figures of the same shape but different areas, and (d) the words "circle" and "square" (equated for letter areas). The VER averages were expressed in terms of a descriptor, λ (Lambda), a ratio formed from the root mean square (rms) difference between waveforms. The VERs to blank fields and a geometrical form were different; also, the VERs were different for dissimilar figures of equal area. Figures of identical shape but unequal areas, however, produced VERs that were similar to each other. The VER results for different words indicated dissimilar waveforms. The evoked response records provided evidence of a physiological correlation to perceptual processing.

In a continuous vigilance task, the subject normally attends to all the stimuli that are presented (Ritter & Vaughan, 1969). Evoked responses that are recorded during a continuous vigilance situation, therefore, may not always register changes in subject attention. Citing from an earlier study, Ritter and Vaughan demonstrated that small stimulus changes, randomly embedded in a series of repetitive stimuli, evoked a prominent positive component (P300) in the averaged response. The appearance of this late component was considered the result of attentional shifts or orienting responses. In their 1969 investigation of attention and evoked response activity, both visual and auditory stimuli were used. In the visual condition, repetitive flashes, one every 3 seconds, were presented. Interspersed among the regular flashes at random times was a signal flash of slightly dimmer intensity. The subject pressed a key whenever he detected the signal. In the auditory condition, tone bursts of a standard level, 40 dB, were presented; embedded among the regular tones was a signal tone at 35 dB. Again the subject pressed a key to indicate his detection. The results from scalp averaged responses disclosed that the vertex and occipital sites exhibited a late positive component (latencies ranged from 300 to 500 milliseconds) to the detected signals. Averages for nonsignals (standard stimuli) or undetected signals did not display this late component. As soon as the discrimination task was made more difficult, a late component was found for both the signal and the standard stimuli. If, on the other hand, the discrimination was made easy, the late components for both the standard and the signal stimuli were at first present but then disappeared as the trials proceeded. The late component that was elicited under the different vigilance tasks was most likely dependent on central processing for the cognitive significance of the stimulus.

Hillyard, Squires, Bauer, and Lindsay (1971) performed a study to investigate the amplitude of the P300 during an auditory signal detection task. On each trial the subject decided whether auditory noise, presented at threshold levels, was detected (or not detected) against a background of continuously presented noise. A monopolar vertex electrode was used to obtain AERs to hits, misses, false alarms, and correct rejections. The AERs indicated that the P300 appeared only on the hit trials; the P300 was not evident or was greatly reduced in amplitude in the other trials. The size of the P300 during the hit trials was shown to increase over a range of signal intensities.

In another signal detection experiment, Paul and Sutton (1972) held the signal parameters or stimulation constant. Changes in the observer's criterion were manipulated by varying the a priori probability of the signal and by changing the payoff matrix. The observer's task was to indicate his detection (yes/no) during an observation interval. The interval consisted of a period of white noise where the signal, a click, was injected (or not injected). Auditory evoked responses were recorded for hits, misses, false alarms, and correct rejections. Three levels of a priori probabilities were used: (a) .25 (cautious), (b) .50 (unbiased), and (c) .75 (liberal). The late positive component (P300) for hit trials was largest for the unbiased condition and smallest in the liberal condition.

Velasco and Velasco (1972) investigated the psychological significance of stimuli and the amplitude of the average somatic evoked response (SER). The stimuli consisted of threshold levels of shock delivered to the left median nerve. Scalp recordings were collected from right somatosensory areas and the vertex. The significance of the stimuli were manipulated by instructing subjects (a) to ignore the stimulus, (b) to press a key after each stimulus, or (c) to attend another extraneous stimulus and ignore the shock stimulus. Results for the SER amplitudes indicated that the early components of the SER remained the same during the three experimental conditions. The late components of the SER, however, were at a maximum during attention and were at a minimum during distraction.

Cernacek and Podivinsky (1971) studied the development of handedness in infants with the development of an early negative component of the SER. The experimenters cited an earlier report where a correlation was found between handedness and the appearance of an ipsilateral SER. Cernacek and Podivinsky pointed out that handedness developed during infancy and was not present in the newborn. For their study of the development of the SER component, 29 infant subjects from 3½ to 48 months of age were tested. Infant handedness was determined by observing the grasping patterns that were made toward a desired object. The young subjects were stimulated on the left or right ulnar nerve at motor threshold levels. Average evoked potentials were collected from bipolar parietal locations over both hemispheres with a common vertex electrode. (The lateral parietal placements were intended to be positioned over hand projection areas.) The SER results were reported in age categories along with characterizations of the typical grasping pattern. Infants of 5 - 6 months displayed a negative peak (N_1) in the SER (20 - 30 milliseconds latency) over the hemisphere contralateral to stimulation; this age group did not show a preferred hand. The 6 - 8 month group, characterized by a significant number of bimanual graspings, showed a distinct N_1 wave on the contralateral hemisphere and a distinct negative wave on the ipsilateral hemisphere. The final group analyzed, 8 - 9 months, was classified into definite hand preferences--dextrals, sinistrals, and ambidexters. This oldest group of infants exhibited a prominent N_1 peak on the contralateral hemisphere; however, the ipsilateral N_1 peak was now greatly attenuated and delayed. Amplitude data indicated the right-handers had larger left hemisphere responses to left wrist stimulation than the right hemisphere. Records for ambidextrous infants indicated no differences between the hemispheres. Left-handed infants showed larger right than left hemisphere responses, but the differences were not to the same degree as that found for right-handers.

Eason and White (1967) reported a study that used visual stimulation over different parts of the human retina to investigate evoked response activity. Fourteen sites of stimulation on the horizontal plane of the right eye of one subject were chosen. The red stimulus flashes (presented at 1 cps) subtended a visual angle of 1°.

Visual evoked responses were recorded from one active monopolar electrode on the right hemisphere (approximately O_2) for 100 flashes. When symmetrical sites on the two retinal halves were compared, the results indicated that smaller VERs were found for stimulation of the nasal hemiretina.

The effects of retinal stimulation and evoked potentials were expanded in a follow-up study by Eason, Groves, White, and Oden (1967). The primary objective of this study was to investigate the relation between visual half-field stimulation and the corresponding cortical responses from the two hemispheres. A secondary objective of this study was to examine the influence of handedness upon the hemispheric responses. Monopolar recordings from left and right occipital lobes (2.5 cm above the inion and 2.5 cm to the left and right of midline) were collected. Evoked responses were summated for 100 or 200 binocular flash stimulations. The red or blue stimulus light subtended 1° of visual angle and had a duration of 10 microseconds. Ten retinal sites located 10° apart on the horizontal meridian were stimulated. In describing the visual field results, the lobe which first received impulses over direct classical pathways was considered primary, whereas the lobe that was not directly connected to primary pathways was considered secondary. For every retinal site and for the two left-handed subjects tested, larger evoked responses were recorded from the right hemisphere when it was considered primary than when it was considered secondary. For the single right-handed subject tested, no consistent differences between the hemispheres were observed. The response of the secondary lobe at a given site of stimulation paralleled that of the primary lobe. Additional left- and right-handed subjects were tested in order to examine further the effects of handedness on hemispheric responses. The VERs collected for left-handed subjects indicated that larger amplitude responses were evoked from the right hemisphere than the left hemisphere. No consistent differences in VER amplitudes were observed for the right-handed subjects.

Eason, Oden, and White (1967) considered three variables of retinal stimulation and the corresponding VERs. The variables investigated included (a) the site of retinal stimulation, (b) flash intensity, and (c) wavelength (red versus blue). Retinal stimulation was restricted to eight sites of the temporal retina of the right eye. Both red and blue VERs from the right occipital hemisphere showed deflections of larger amplitude when the retina was stimulated near the fovea. Decreasing amplitudes were observed as the flashes were directed at progressively more peripheral sites. For both colors, increased latencies in the major components of the evoked response were observed with greater distances from the fovea. For both high and low levels of stimulation, VER waveforms were essentially the same.

Lehmann and Fender (1967) studied the effects of target structure on the VER. They presented a flashing blank field stimulus to the right eye while the left eye observed fields of differing complexity. (Stimuli for the left eye included a blank field, a dot, a cross, and a grid.) Bilateral parieto-occipital scalp recordings were collected to form the VER averages. The results indicated a decrease in rms μV amplitude as the field structure for the left eye increased. Lehmann and Fender concluded that the VER in this case was "an index of the loading imposed on the visual areas by the structure of the steadily illuminated target seen by the contralateral eye" (Lehmann & Fender, 1967, p. 205).

Lehmann, Kavanagh, and Fender (1969) recorded visual evoked responses from a subject with a split optic chiasma (with resulting bitemporal hemianopsia). Monocular flashes were presented at 3.7 cps. The VERs from symmetrical parieto-occipital scalp locations showed similar waveshapes but inverted polarities. Compared to normal subjects, the split brain subject demonstrated that the VERs from the ipsilateral hemisphere were of normal polarity, whereas VERs from the contralateral hemisphere were inverted in polarity.

Lehmann and Fender (1969) attempted to test the amount of central interaction, in terms of VERs, to dichoptic stimulation from a subject with a traumatic split of the optic chiasma. Monocular stroboscopic flashes were presented to one eye while the other eye viewed steadily illuminated targets of varying complexity. Symmetrical parieto-occipital recordings from the scalp were collected. The VERs showed no evidence of interaction between the dichoptic stimuli. This is in distinct contrast to normal subjects where dichoptically presented stimuli altered the VER waveform, presumably due to the influence of central mechanisms.

Additional Experimentation Relating Evoked Response Activity and Hemispheric Processing

Buchsbaum and Fedio (1969) undertook a study to examine the hemispheric VER patterns to verbal and nonverbal stimuli recorded from the left and right hemispheres. Three types of computer generated stimuli were used. Verbal stimuli consisted of three-letter words (nouns, verbs, and articles); nonverbal stimuli consisted of a set of patterns constructed from an artificial alphabet made to resemble three-letter words; lastly, another set of nonverbal stimuli was generated into random dot designs. The stimuli were displayed to the subjects on a screen (8 × 10 cm) as blue dots on a black surround. Scalp recordings were collected from locations O_1 and O_2, referenced to ipsilateral ears. Visual evoked responses were recorded for words-random dots and words-designs. Stimuli were presented at 1-second intervals for either 40 milliseconds or 500 milliseconds.

The VERs recorded from the right hemisphere showed that the latency of the positive peak (P300) was shorter (24 milliseconds) for words than for either dots or designs; left hemisphere latencies were in the same direction but were not as great. The experimenters described a correlational index, ζ (Zeta), which discriminated VERs to words, random-dot patterns, and designs. Greater discriminability between stimuli was produced for the 40-millisecond than for the 500-millisecond stimulus presentation times. Further, the index differentiated word VERs from design VERs in the left hemisphere. The right hemisphere showed higher correlations for VERs to words, dots, and patterns than corresponding left hemisphere correlations. Contrasted with the left hemisphere, the right hemisphere processing was more uniform and much less differentiated.

Buchsbaum and Fedio (1970) extended their 1969 report to include verbal and nonverbal material presented to the left or right visual fields. The stimuli and experimental design were similar to the 1969 study. Visual evoked responses to verbal and nonverbal patterns produced different waveforms from the separate occipital hemispheres. Primary pathways discriminated words and forms better than secondary pathways. The largest differences between word and form stimuli were observed from the left hemiretina (right visual field) as recorded from the left hemisphere. Visual responses from the right hemisphere were more stable and appeared more uniform than those collected from the left hemisphere. Regardless of the field of retinal projection, both hemispheres recorded more stable VERs to nonverbal stimuli than to word stimuli.

Using a modulated light source as a stimulus, Pfefferbaum and Buchsbaum (1971) investigated the effects of sex, handedness, and hemispheric activity upon the average evoked response. Scalp recordings were gathered from vertex-ear and vertex-occipital derivations on the right hemisphere and vertex-ear and vertex-occipital derivations on the left hemisphere. Four depths of modulated light around a mean of 100 ftL were used: 11%, 24%, 34%, and 42%. The averaged VER waveforms were analyzed by Fourier analysis for the first (10 Hz) and second (20 Hz) harmonics. The vertex-occipital electrode configurations produced larger VERs than vertex-ear placements for both the first and second harmonics. From vertex-occipital records, left-handed subjects produced VERs that increased in amplitude for the first and second harmonics with increased depths of modulation. For right-handed subjects, however, symmetrical VER activity was obtained at all electrode configurations with increased depths of modulated light. No significant differences in VER amplitudes were found between males or females. However, left-handed subjects showed more asymmetric VERs for occipital locations than left-handed females or right-handed males (or females). Pfefferbaum and Buchsbaum concluded their discussion of the results by saying, "stimulus intensity as well as handedness must be considered when looking for hemispheric asymmetry in the AER [VER]" (Pfefferbaum and Buchsbaum, 1971, p. 239).

Generally, patients with left temporal damage have difficulty in tasks requiring the use of verbal memory; in distinction, patients with right temporal injuries display deficits for a variety of perceptual functions, e.g., impairments in tachistoscopic recognition of figures or in the discrimination of complex stimuli. In a recognition task of verbal and nonverbal material, Fedio and Buchsbaum (1971) tested a group of temporal patients with stimuli presented in the left and right visual fields. Eleven patients with either left or right temporal lesions and determined to be left hemisphere speech dominant served as subjects; the patient group was compared to 16 normal individuals from an earlier study. Visual field defects due to temporal lesions for all subjects were outside a 10° central field. Of the experimental group, all were right-handed and showed a right eye preference. Visual evoked responses were summated to verbal and nonverbal dot stimuli from the left (O_1) and right (O_2) hemispheres. The overall results indicated that word and dot stimuli produced more dissimilar VER waveforms when the material was presented along the primary pathways than secondary pathways. The largest differences for

VER waveforms were shown for stimuli flashed in the right visual field and recorded from the left hemisphere. Visual evoked response activity from left temporal patients to verbal stimuli was not different for either right or left field stimulation. For both cerebral hemispheres, VERs from patients with right temporal lesions produced greater differences to words than to dot figures; these patients also showed less VER stability to dot stimuli than the other patient groups. Generally, VER recordings were more stable from the lesioned hemisphere than from the normally functioning hemisphere.

Shelburne (1972) attempted to find a physiological basis for reading disabilities by recording responses evoked to words and nonsense trigram syllables. For each normal word presented, a corresponding nonsense trigram was generated. The trigram was formed from a stimulus word by changing the last letter. For example, the stimulus word "cat" was transformed into "caf." The trigram stimuli were presented one letter at a time with 1-second intervals between letters; the third letter in the trigram marked the end of a trial and signaled the subject to indicate his decision as to whether the CVC was a word or nonsense syllable. Auditory feedback was provided to the subject to indicate his correctness or incorrectness. The computer started data collection at the onset of each letter and sorted VERs to each letter position in a trial. Monopolar scalp recordings were taken from the vertex (C_z), left parietal (P_3), and right parietal (P_4) locations. The analysis of first and second position letters showed no differences between words and nonsense syllables. However, third position letters showed a late positive component that was different for words and nonsense syllables; no asymmetries were detected for the parietal placements for third position letters. A similar study conducted with children found the results in substantial agreement with adult findings (Shelburne, 1973)

Molfese (Note 1) recorded evoked potentials from infants, children, and adults in order to examine the development of lateralization effects. The types of stimulation included speech sounds, musical chords, single tones, and white noise. Scalp activity was recorded from left temporal (T_3) and right temporal (T_4) sites. For each of the age-groups, hemispheric differences were observed but not consistently. There was some evidence that larger asymmetries, when they occurred, were recorded for the earlier age groups.

Roemer and Thompson (1973) examined the relation between cortical activity and word meaning. In their study, the meaning of a word depended upon whether it was considered as a noun or as a verb, e.g., rock, duck, fly, etc. Following the auditory presentation of the stimulus, the subject was to rehearse the meaning of the word (according to the instructed context) until a click sounded, signaling the vocalization of the word. Scalp recordings from central (C_3, C_4) sites were averaged to the click presentation. A preliminary analysis of the results indicated significant differences for noun and verb contexts. There was also some indication that evoked potentials to nouns at the C_3 site were larger than those at C_4. In another preliminary report dealing with word meaning, Brown, Marsh, and Smith (1973) presented subjects with short sentences; the last word in each sentence had either a noun or verb context. Evoked potentials to the last word were recorded from the areas of Broca and Wernicke on the left hemisphere and compared to respective homologous sites on the right hemisphere. Correlations for left side placements showed lower values between noun and verb contexts than for right side electrode sites; the correlations between noun and verb responses were usually lower at Broca's area than at Wernicke's area.

Gott, Rossiter, Galbraith, and Saul (1974) studied evoked responses in commissurotomized subjects during the presentation of verbal and nonverbal stimuli. Monopolar recording areas included the vertex (C_z), parietal (P_3, P_4), and occipital (O_1, O_2) sites. For the verbal task, subjects were flashed a word to either the left or right visual fields; the subject's task was to determine whether or not the flashed word rhymed with a continuously presented word. Similarly, a matching task was used in the spatial or nonverbal condition. For this latter situation, the subject was presented nonsense figures to the different visual field positions; the subject's task was to determine whether or not the flashed shape matched a continuously presented random shape. For the verbal condition, subjects indicated a "yes" or "no" response with right hand button presses; in the nonverbal condition, subjects responded with left hand button presses. The data from five subjects indicated: (a) that evoked responses to verbal stimuli were larger than to nonverbal presentations, (b) that larger evoked responses were recorded from the hemisphere contralateral to the stimulus presentation, and (c) that responses to verbal stimuli were larger over the left than right hemisphere. The investigators observed that their results conformed to the known asymmetries between the cerebral hemispheres; further, by using commissurotomized subjects, the differences between the hemispheres were made more distinct.

Asymmetrical Cortical Rhythms

Extracted against a background of continuous EEG activity, the evoked response represents a relatively short and complicated processing period. With emphasis upon lateralized electrical events, the following section considers a few examples from experimentation that has examined features of ongoing EEG activity.

Lehtonen and Lehtinen (1972) studied alpha (8 - 13 cps) production under the following conditions: (a) provoked by a uniform visual field, (b) at different levels of subject vigilance, (c) with the effects of visual fixation, and (d) after repetitive photic stimulation. Monopolar scalp records were collected from O_1, O_2, T_5, and T_6 locations. Alpha activity was recorded during eyes-open and during eyes-closed conditions. Out of the 18 normal male subjects tested, nine displayed regular alpha production to the diffuse unpatterned visual field, seven subjects showed moderate alpha production, and the remaining subjects showed poorly developed alpha activity. Removing the diffuse visual field induced alpha desynchronization. Alpha production was greatest for the eyes-closed state; however, nearly the same amount of alpha was elicited from the uniform visual field. For most of the subjects tested, there was a slight tendency for more and larger alpha to be generated over the right than left hemisphere; no lateralized changes were observed in shifting from the closed to the open field condition. When a fixation point was introduced into the visual field, there was a transient desynchronization of alpha activity. When photic stimulation was counted by the subjects, the amount of alpha produced was not significantly changed. After photic stimulation, rhythmic after-activity (a periodic discharge in the alpha frequency range) was always greater in the eyes-closed than in the eyes-open condition. With a fixation point, rhythmic after-activity was greatly attenuated or nonexistent. The visual evoked potentials recorded during eyes-closed and eyes-open conditions were very similar in appearance; during counting, however, VER amplitudes were larger than those observed in other conditions.

In a recent study devoted to rhythmic after-activity (RAA), Lansing and Barlow (1972) found no consistent relationship between RAA offset and alpha return; RAA was of greater amplitude during the parallel periods of larger alpha background. The investigators contended that RAA was a true physiological response and was not a simple time-locked alpha return.

Looking at ongoing EEG activity, Morgan, McDonald, and Macdonald (1971) conducted an experiment to engage either the left or right hemispheres in particular cognitive tasks. The investigators hypothesized that different amounts of alpha would be produced depending on which hemisphere was processing information. Left hemisphere tasks involved verbalization (e.g., "recite a few words from a poem"); right hemisphere tasks were designed to invoke imagery without thinking (e.g., "picture a child swinging in a swing" [p. 463]). Bipolar activity from both hemispheres referenced to the vertex was recorded. Analysis of the data included an index that reflected the relative proportion of ongoing alpha produced from each hemisphere. Regardless of the experimental conditions, the results indicated that more alpha was emitted from the right than from the left hemisphere. However, more alpha activity was noted for the right hemisphere when the left was engaged in its verbal task. Congruently, the spatial tasks produced relatively less alpha in the right than left hemisphere. Following a similar experimental design, Morgan, Macdonald, and Hilgard (1974) found a greater percentage of alpha was emitted from the right than from the left hemisphere, particularly when the left hemisphere was actively engaged in an analytic task. Galin and Ornstein (1972) investigated EEG production from the left and right hemispheres with specialized cognitive tasks. The ratio of right over left was found to be greater for verbal tasks (writing or composing a letter) than in spatial (block design) tasks. Similarly, Butler and Glass (1974) reported an overall decrease in EEG amplitude over the left hemisphere during mental arithmetic calculations than over the right hemisphere for right-handed subjects.

Critical of recording methodology, MacNeilage (1966) reminded readers that motor responses have strong effects on the stability of the EEG; delicate cognitive features, if they occurred in the EEG record, could easily be masked by high rates of response. MacNeilage reported an experiment where subjects had separate tasks to perform but which involved the same physical stimuli and a similar type of motor response. By holding motor activity constant, it was theorized that the stability of the EEG might better reflect the influences of cognitive activity. The EEG signals from bipolar parietal locations were filtered and rectified to provide amplitude write-outs of the α (alpha) and β (beta) frequency bands. The tape recorded tasks included (a) the continuous addition of numbers in groups of four and (b) writing down every "7" and "9" played. The results indicated that there were no significant differences in overall amplitude levels for either α or β frequencies. The ongoing EEG amplitude records were not related to specific cognitive activities. MacNeilage (1966) concluded that the EEG measures collected were not sensitive enough to detect differences between the experimental tasks; however, palmar skin conductance and heart rate successfully distinguished between the test conditions. MacNeilage further observed that the widespread EEG changes reported for other studies might be more the product of mechanisms of response than the subtlety of information processing.

Liske, Hughes, and Stowe (1967) reported normative data for human alpha production. Electroencephalographic scalp recordings were collected from homologous P_3-0_1 and P_4-0_2 locations. A total of 42 male subjects participated; all were right-handed except for two subjects (hand preference was determined by history and motor demonstration). The subjects were placed in a sound attenuated room, supine, with eyes closed; they were instructed to remain alert but relaxed. High resolution EEG correlograms were generated that analyzed block epochs of 150 seconds. For 24 subjects, the results indicated that there was a definite phase lead in alpha production from the right hemisphere; the remaining 18 subjects demonstrated a definite left hemisphere lead in alpha production. The average phase shift was .83 milliseconds to the right; individual shifts ranged from 4 milliseconds from the left hemisphere and 7 milliseconds from the right hemisphere. For no subject did the left hemisphere ever lead by as much as the right hemisphere.

Hoovey, Heinemann, and Creutzfeldt (1972) performed auto- and cross-correlational analyses upon ongoing alpha activity. Two homologous scalp locations from O_1 and O_2 were digitized in bin widths of 1-millisecond for periods of 8 to 10 seconds. Data were reported from subjects with eyes closed. Results showed that the mean interhemispheric latency differences for peaks of alpha waves varied between ± 2.5 milliseconds. Individual differences ranged from +20 to -20 milliseconds. Correlations between the hemispheres ranged from +.14 to +.80.

Bakan and Svorad (1969) demonstrated a relation between the amount of hemispheric alpha produced and lateral eye movements. When a person was asked a question, a conjugate lateral movement of the eyes either to the left or to the right usually occurred. The consistency of eye movements in reflecting upon an answer appeared to show a shift of attention that was opposite to the activated hemisphere; the movement was consistent and characteristic for that individual. Persons that moved to the left, termed left-movers, were described as having tendencies to internalize subjective experiences, whereas persons that moved to the right, termed right-movers, were characterized as seeking an external focus of attention. In their study, lateral eye movements (LEMs) to 15 reflective questions were given to 15 subjects. Thirteen of the 15 subjects tested showed consistent LEMs to the left or right 72% of the time. Based on their eye movement responses, subjects were categorized as left-movers (7) and right-movers (4). Bipolar scalp recordings were collected from the frontal and occipital locations from resting subjects. Ongoing alpha activity of a minimum amplitude was used to drive a counter-timer for a period of 100 seconds. The first session simply registered the total seconds of alpha; a second session registered alpha production in eight separate periods (each of 100 seconds duration). Results for the first session showed that left-movers (right hemisphere dominant) produced 68.9% alpha in contrast to right-movers (left hemisphere dominant) who produced 28.1%. For the second session, left-movers averaged 51.9% and the right-movers averaged 20.4%.

Martinius and Hoovey (1972) investigated bilateral occipital alpha synchrony in children between the ages of 8 - 11 years. Comparisons of hemispheric activity were made for resting and attentive states. The children showed a synchronous distribution of phase differences that ranged in latency from 1 to 10 milliseconds. No consistent trends between age and phase synchrony were found. When compared to adult activity, children demonstrated a wider range of phase differences; the experimenters attributed this to the relative instability of alpha frequencies in this age group.

Westmoreland and Klass (1971) recorded alpha activity from 15 patients with temporal lesions. With eyes closed, an asymmetrical attenuation of alpha was observed during arithmetic calculations; with eyes open, 12 of the 15 patients showed bilateral decreases in alpha amplitude. The alpha attenuation effects were observed on the side involving the lesion.

With alpha ratios of 2:1 or more, Jaffe and Lusins (1971) examined the clinical correlates of patients exhibiting large hemispheric asymmetries. For the 38 cases studied, the amplitude asymmetries were found predominantly over the right hemisphere. There was also some evidence for a history of brain injury or dysfunction on the side exhibiting the greater amplitude.

B. D. Cohen, Noblin, and Silverman (1968) demonstrated hemispheric differences for verbal and nonverbal tasks after electroconvulsive shock treatment (EST). Neurologically normal right-handed female patients received either left, right, or bilateral EST. When performance scores were analyzed, patients that received left EST did less well on a verbal task (paired associate) than on a nonverbal (drawing geometrical forms from memory) task. In contrast, patients with right EST performed more poorly on the nonverbal than on the verbal task. Subjects that received bilateral EST showed the greatest performance decrement in both the verbal and nonverbal tasks.

Giannitrapani (1972) studied the EEG topographic distribution in left and right preferent subjects. A frequency analysis (1 - 34 cps) for subjects resting, listening, and performing arithmetic calculations showed that the temporal areas displayed the largest EEG differences. For all the frequencies tested, greater activity was found for left temporal areas in right preferent subjects and greater right temporal activity for left preferents.

An interesting note on the generation of alpha asymmetries was given by Leissner, Lindholm, and Petersen (1970). With ultrasonic techniques, these investigators examined skull thicknesses over the left and right hemispheres of 80 selected cases. The indirect measurements showed that the left side was thicker for 52 of the 80 cases than the right side; however, the remaining measurements indicated that skull thicknesses were larger on the right than left side. Leissner et al. (1970) suggested that the greater electrical resistance of the thicker skull parts may, in part, account for the EEG amplitude differences between the hemispheres.

Lansing and Thomas in 1964 investigated the laterality of photic driving during binocular, monocular, and visual half-field stimulation. Driving frequencies were above (16 - 20 cps), within (8 - 12 cps), and below (4 - 6 cps) the alpha frequency range. Scalp recordings were collected from left, right, and midline occipital locations from 24 male and female subjects. Effective driving was defined as a difference of 10% between the hemispheres. The results indicated that for most subjects photic driving was greater over the left than right hemisphere regardless of the mode of stimulation (binocular, monocular) or the frequency of stimulation. Further, the effects of photic driving and visual field stimulation were examined for eight subjects. From the data reported, no consistent trends between driving and field stimulation were observed. The investigators ascribed the earlier lateralized driving to intrinsic cerebral factors that were not connected with direct visual pathways.

Finally, Volavka, Feldstein, Abrams, Dornbush, and Fink (1972) investigated brain wave records of patients undergoing bifronto-temporal electroconvulsive shock treatment (B/ECT) and unilateral electroconvulsive treatment (U/ECT). In addition to slowing background

EEG activity, shock treatment is usually accompanied by a general deterioration in memory function. The transitory effects of B/ECT can be reduced by placing electrodes unilaterally over the nondominant hemisphere. Standard bifrontal electrodes were used for B/ECT and right temporo-parietal locations were used for U/ECT. Electroencephalographic recordings were collected from left F_7-C_z and right F_8-C_z scalp locations. The results indicated that B/ECT treatment caused a slowing in the EEG (delta range) which was manifested predominately over the left hemisphere. Right-sided U/ECT resulted in a slowing of EEG activity only on the right side. In agreement with earlier studies utilizing electroconvulsive shock therapy, the EEG slowing was found related to the number of ECT treatments administered.

Slow Scalp Potentials: The Contingent Negative Variation

Walter, Cooper, Aldridge, McCallum, and Winter (1964) provided the initial impetus for the experimental study of slow scalp potentials in man. In their original report, the expectancy wave (E-wave) or contingent negative variation (CNV) was recorded using DC or long time constant recordings in the interval (or empty period) of what appeared as a foreperiod reaction time (RT) task. The procedure used for eliciting slow potentials was simply a warning stimulus (S_1) followed by an imperative stimulus (S_2). As long as the subject was attentive and responding, the characteristic slow shifting pattern of the CNV was maintained. The genesis of CNV potentials appeared more dependent on the information delivered to the subject by the S_1-S_2 situation than particular stimulus parameters, sensory modality, or critical S_1-S_2 time interval. When S_2 was omitted after a series of S_1-S_2 pairings, a gradual diminution of the CNV resulted, but restoring S_2 returned slow potential activity to earlier levels. Equivocal presentations of S_2 showed the CNV amplitudes reduced in the overall records.

Walter (1967) found the CNV to be one of the most "consistent and predictable of human brain electogenesis" (p. 123). Amplitudes of the slow scalp recorded potentials averaged -20 μV (vertex referred to mastoid) with a standard deviation of 4 μV. Comparisons of these scalp recorded potentials with chronically implanted intracerebral and subdural electrodes showed only a twofold amplitude attenuation of the former over the latter. The distribution of the CNV was bilaterally symmetrical with maximum amplitudes recorded from the frontal and central regions. The negative shifting developed about .5 seconds after the onset of S_1 and was sustained for over 20 seconds in motivated subjects. Walter, Cooper, Crow, McCallum, Warren, Aldridge, Van Leewen, and Kamp (1967) were able to record slow potential activity from telemetered subjects outside the normal laboratory setting. Additional CNV data from subjects with implanted intracerebral electrodes were reported by Walter (1969).

The overall shape of the CNV can sometimes be distinguished for different individuals by the rising portion of the slow potential that immediately follows the S_1 stimulus. A quick rise in the negative wave, called a Type A CNV, has been contrasted to a slow or ramp-like growth of negativity, called a Type B CNV (Tecce, 1972). The slow potential is sustained between the S_1-S_2 interval until a response is made to S_2. The return or resolution of the CNV to prestimulation levels was reported to be bilaterally symmetrical even though a motor or mental response was sometimes required of the subject (Lombroso, 1969). Cooper, McCallum, and Papakostopoulos (Note 2) considered that the CNV situation represented a subject state of active involvement and was compared to passive or semiautomatic response states; they proposed the use of "scopeutic" and "categoric" to describe, respectively, these different and separate subject states.

Since the generation of a CNV normally involved a motor response by the subject, many experimenters thought that premotor and motor responses were essential components or actual elements of the CNV waveform. Slow potential activity has been recorded, however, in an S_1-S_2 interval even though no overt response was required from the subject at the imperative stimulus (Donchin, Gerbrandt, Leifer, & Tucker, 1973). When a correlational recognition technique was applied to CNV waveforms, normal slow potential activity was observed to occur even in the absence of S_2 (Weinberg, Walter, Cooper, & Aldridge, 1974). That an explicit task was not mandatory in generating a CNV was demonstrated by Järvilheto and Frühstorfer (1973). One experimental condition simply presented subjects with 80 dB tone bursts (1-second duration) at regular intervals; a reverse condition presented a continuous tone regularly interrupted by 1-second pauses. In both instances and without further instructions to the subjects, CNV-like activity developed for both tone bursts and tone pauses. Amplitude measurements could not distinguish between the two experimental conditions.

Response variables have been demonstrated to have an active influence on the CNV. For example, if S_2 was modified so that the subject's response terminated a series of repetitive flashes or clicks, the CNVs generated were generally of larger magnitude. The active termination of S_2 by the subject also produced faster reaction times. Peters, Knott, Miller, Van Veen, and Cohen (1970) theorized that the increased performance levels (e.g., RTs) may be, in part, the result of feedback information to the subject. In support of Peters et al., Karrer, Kohn, and Ivins (1973) found that if responding was ineffective in terminating an S_2 tone, CNV ampljtudes were reduced. When conditions promoted subject uncertainty by shifting to a situation where S_2 occurred only half the time, CNV amplitudes were increased. Wilkinson and Spence (1973) examined the resolution of the CNV after S_2 to determine if the return to baseline (or below) was the result of some overt movement response or some decision process. Neither the response nor decision process was found to be necessary in resolving the CNV to baseline levels.

So far our consideration of the CNV has been in terms of adult age ranges. J. Cohen (1970) studied the development of the CNV for different maturational stages. Recordings from frontal, central, and posterior regions were collected from 65 children and adolescents ranging in age from 5 to 18 years. Compared to adult forms, slow potentials from an early age group were of lower amplitude and were not well developed. The amplitude of the CNV increased with age and reached a maximum by 16 - 18 years. In addition, the spatial distribution of the slow wave was more prominent in frontal and central regions with increased age levels. Low and Stoilen (1973) found well developed CNVs, vertex dominant, in children over 10 years of age; below 8 years, however, CNV activity was minimal or nonexistent. In the records that displayed EEG asymmetries, lower CNV activity was found over the abnormal side but not consistently. Papini and Zappoli (1973) found some children exhibiting a "tent-like" CNV at ages 5.5 - 7 years that changed at 8 years to include a brief plateau midway in the slow potential. Gullickson (1973) succeeded in recording CNV activity from three-year-olds with the use of novel and more interesting S_1 and S_2 stimuli. The warning stimulus (S_1) consisted of a glide tone (that moved from 500 - 1000 Hz in 1 second) followed by either a 2-second presentation of a two-color nonmoving visual pattern (S_2) or a 2-second presentation of a multicolor kaleidoscopic pattern (S_2). The young subjects showed more attention to the moving pattern and exhibited CNVs that resembled both adult form and amplitude.

J. Cohen (1973a) reported that CNV activity for children with learning disabilities was either greatly reduced or absent. Aphasic and dyslexic children were shown by Otto, Houck, Finger, and Hart (Note 3) to have greater positivity in an S_1-S_2-S_3 slow wave paradigm than normals in the same situation. The greater positivity was related to the generally deficient attention span usually attributed to aphasic children. When hyperactive children were given a stimulant, they produced CNVs similar to age-matched normals; off medication, however, hyperactive subjects displayed greatly reduced CNV activity (Andreasen, Peters, & Knott, Note 4). For a discussion of the various experimental findings investigating developmental stages and aspects of the CNV, a review was presented by J. Cohen (1973b).

The earlier reported bilateral distribution of the CNV was further examined in split brain subjects by Hillyard (1973) in collaboration with M. S. Gazzaniga. These investigators attempted to alter the normal symmetry of the CNV by flashing a warning stimulus (S_1) to only one hemisphere followed by another signal (S_2) to respond (or not respond). The results indicated that, no matter which hemisphere was warned, the CNV amplitudes over both hemispheres were the same regardless of which hand responded. Hillyard speculated that the bilateral nature of the CNV might be due to the connections of some diffuse brainstem mechanism, e.g., the thalamus, equally serving both hemispheres.

Interested in the real and extraneous generators of the CNV, Hillyard and Galambos (1970) deliberately introduced upward and downward eye movements between the S_1-S_2 interval to assess quantitatively the contribution of eye contamination to slow potential records. The experiment was designed so that the subject moved his eyes to either upward or downward positions in the S_1-S_2 interval. The investigators found that upward and downward movements produced unequal potential shifts at the vertex recording site. In effect, downward eye movements were superimposed on the CNV shift, whereas upward eye movements reduced CNV shifting. Additionally, in an eyes-closed condition, there was an involuntary rotation of the eyes downward during lever pressing that contributed about 23% or -6.4 μV to the CNV. McCallum and Walter (1968) have electrically referred the vertex to linked frontal-mastoids in order to compensate for ocular potentials during slow potential recording. Papakostopoulos, Winter, and Newton (1973) have used a mechanical transducer attached to the eyelid to determine the occurrence of eye movements. Most experimenters have adopted some plan or rationale to reject those CNV trials which are obviously contaminated by eye movement and/or ocular potentials.

As mentioned earlier, a necessary element in eliciting a CNV-type shift was the subject's response to S_2 or some equivalent. The readiness potential (RP), reported initially by Kornhuber and Deeke (1965), was recorded as a slow negative shift that preceded a motor response. Becker, Iwase, Jürgens, and Kornhuber (Note 5) have distinguished two types of RP based upon the kind of motor response required of the subject. For short ballistic movements or jerks, RPs were observed to start approximately .8 seconds prior to the actual movement; for slow movements, however, RPs preceded movement by approximately 1.3 seconds. When readiness potentials were recorded from the vertex, generally larger potentials were generated by the faster movements than by the slower movements. In addition to simple motor parameters, the amplitude of the RP has been varied by different motivational states (McAdam & Seales, 1969) and with experimental situations that required perceptual accuracy (McAdam & Rubin, 1971). Rubin and McAdam (1972) studied RPs from central, frontal, and temporal scalp sites in an experiment that involved recall. In a pretesting session, subjects were given a list of common English words to study. In the testing period, words from the list along with other words were tachistoscopically presented. The subjects simply decided if the words flashed during testing were on the word list or not; they classified their responses as "sure" (categories 7 - 9) or "not sure" (categories 4 - 6). When the subject decided on a category rating, a button was pressed to indicate the response; a few seconds later, the subject responded verbally. Baseline levels of scalp activity were determined over the period preceding stimulus onset. The RP was measured as the difference between baseline and the averaged amplitude of the signal before the button press. Results for the vertex recording site showed no significant RPs for either the sure or not sure ratings. When waveform deflections during the earlier middle third of the averaging interval were scored, however, there was a significant RP and positive RP difference between recognized and not sure categories. The frontal sites showed no differences between categories for either RPs, positive RPs, or between categories when RPs and positive RPs were pooled. The temporal electrode sites, however, demonstrated significant RPs for 7 - 9 responses (sure) but no significant positive RPs; significant RP and positive RP differences were found for 4 - 6 responses (not sure); lastly, significant RPs were found for 7 - 9 (sure) and 4 - 6 (not sure) responses. The investigators concluded that temporal scalp sites successfully distinguished between subjectively certain and uncertain events. Further, they ruled out the influences of motivation, activation, and attention on their results due to the following: (a) reaction times between categories did not differ, (b) pressure exerted in button pressing did not affect the RP amplitudes between categories, and (c) no significant response differences (RPs) were observed at the vertex. From an earlier study in which subjects initiated S_1 in a CNV discrimination task, it was found by the investigators that the RP preceding the S_1 button press was a reliable index of subsequent correctness or incorrectness. The CNVs, however, were of the same amplitude whether the subject was certain of his answer or correct but doubtful; CNV amplitudes were slightly reduced in subjects with no idea as to their performance.

Picton and Low (1971) were able to alter experimentally the shape of the CNV with a series of discrimination tasks that ranged in difficulty from easy to very hard. They discovered that CNV resolution at S_2 was witheld when feedback information concerning the correctness of the response was provided. The moment stimulus information was given, however, the slow shifting returned to previous baseline levels. When S_1 indicated to subjects that a difficult-to-detect S_2 was about to occur, a larger CNV was generated than when S_1 signaled an easier-to-detect S_2 (Rebert, McAdam, Knott, & Irwin, 1967). A pitch discrimination task that used the CNV paradigm was given to subjects by Delse, Marsh, and Thompson (1972). The experimental situation presented a tone burst at S_1 which was compared to another tone burst of higher or lower frequency at S_2. Recordings from the vertex indicated that females had larger CNV areas for the easy than for the close or difficult discrimination task; however, task difficulty had no effect on CNVs generated by the males.

McCallum and Papakostopoulos (1972) postulated that anomalies in the shape of the CNV might be attributable to the type of motor response required of the subject. To test the effects of motor activity on CNV genesis, subjects were tested on three methods of responding. In Condition 1, the subject pressed a button at S_2 to terminate flashes; in Condition 2, the subject pressed the button at S_1 throughout the interval until the occurrence of S_2; in Condition 3, the subject kept the button down all the time and released it only to terminate flashes at S_2. The amplitudes for the vertex (C_z) CNVs in Condition 2 fell substantially (about 50%) below Condition 1. The mean CNV amplitudes for Condition 3 were the same as for Condition 1 except that Condition 3 showed greater waveform variability. The investigators concluded that a sustained motor activity had no detrimental effect on the CNV, but a motor response in the S_1-S_2 interval (as in Condition 2) had the marked effect of inhibiting development of the CNV.

From the studies so far discussed, each particular investigator has had his own characterization of the critical ingredients involved in slow potential genesis. Many have thought that the CNV reflected a complex physiological state which included components of activation, mobilization-to-act, and preparation set. This latter construct, preparation set, was investigated by Low, Frost, Maulsby, and McSherry (1968). In their experiment, subjects were required to respond at S_2 with a specific force (hand plunger); the amount by which the subject was to respond was indicated at S_1. It was found that the slow shifting between S_1 and S_2 increased in magnitude (area measure) with the force required to make the response; the CNVs generated were additive with force but not linearly.

The similarity between the orienting response and the occurrence of the S_1 stimulus was brought to our attention by Kohn, Holy, Gullickson, and Griffith (1971). Thresholds, psychophysically determined, have been shown to decrease after a warning signal. Kohn et al. made monocular visual threshold determinations in and out of a CNV-type situation. Scalp recordings from F_z, C_z, O_1, and O_2 sites were taken during threshold tests. The overall results indicated that slow potential shifts were of small amplitude or were absent. Averaged waveforms showed no correlation of the CNV with threshold levels. It should be noted, however, that no significant threshold changes occurred during the testing periods. A pure tone of adjustable intensity was used for audiometric testing by Prevec, Lokar, and Cernelc-Dularjeva (1973). For the patients that were tested, CNVs developed only at those times when the tones were clearly perceived.

Based experimentally on varying S_1-S_2 intervals (.5, 1, 3, 6, & 15 seconds), Loveless and Sanford (1973) suggested that the CNV was composed of two separate phases: (a) a constant, orienting-type response which occurred after S_1 and (b) a second response unrelated by time to S_1 but which occurred in anticipation of S_2. After further experimentation, the distribution of the earlier response appeared to be frontally dominant (Loveless, Note 6). Blowers, Ongley, and Shaw (1973) compared the expectancies produced by S_1-S_2 intervals (1, 3, 5, 7, & 10 seconds) presented separately in massed blocks of trials against the random presentation of each of the time intervals. Although there was a significant intervals effect, averages from DC recordings showed no amplitude differences between the two presentation methods.

Somatic variables have been implicated in CNV generation. Gullickson and Darrow (1973) examined the influence of respiratory cycles on slow potential changes in a CNV paradigm. Slow potential trials were presented randomly during respiration cycles. From a vertex recording site, larger CNV-like shifts were observed when S_1 coincided with the starting phases of inspiration. In contrast, a positive shifting was observed with expiration at S_1 that lowered slow wave activity. At variance with the findings of Gullickson and Darrow were the results of Papakostopoulos and McCallum (1973). Multichannel recordings from various autonomic measures failed to show any relationship with CNV activity (except heart rate) including respiration. Lacey and Lacey (1973) found a phasic bradycardia or cardiac deceleration of 2 - 3 beats per minute with the intention to respond and indexed simultaneously by the CNV. Some accentuation of the dicrotic wave (as recorded by photoplethysmogram) has been noted paralleling a CNV situation (Zappoli, Papini, Cabras, Benvenuti, & Binazzi, 1973).

Pupillary Responses and the CNV

For the most part, early attention to autonomic activity was restricted to separating the CNV from other readily recorded and possibly contaminating events, e.g., GSR, skin potentials, etc. (see Low, Borda, Frost, & Kellaway, 1966). From the results of RT studies, Papakostopoulos (1973) was able to infer that there may be some relationship between pupil activity and the genesis of slow potentials. Indeed, some informal visual observations by this writer indicated mydriasis during CNV situations. Therefore, a brief experiment was carried out to verify the observed changes in pupil diameter during a typical slow potential recording session.

Pupillary apparatus. Pupil activity was recorded with a portable Sony videotape unit. A special camera attachment was constructed to capture the image of the pupil. A front-surfaced mirror and fixed magnifying lens were structurally supported 8 inches (20.3 cm) beyond the lens mount from an adaptor ring. The mirror arrangement was oriented diagonally to the optical axis of the camera so that an image of the eye could be "picked off" and not obscure the field of the left eye. A wide-angle Macro-Switar (26 mm) lens and extension tube enabled the focused image of the eye to fill the screen of the reflex monitor.

Subjects and recording methods. Four paid male volunteers served as subjects. Silver/silver-chlorided electrodes recorded scalp activity from the vertex (C_Z) referred to linked mastoids. Interelectrode impedances were reduced to 3.0K ohms by tapped skin abrasion. The EEG activity was amplified by an 8-channel Elema-Schönander Mingograf recorder with 5.0-second time constants and upper cutoff frequencies set at 30 Hz. Amplifier outputs were digitized on-line (1024 points/channel) by an HP 2116B computer. A data averaging program collected and displayed single trials before entering a permanent disc average. (The reader is referred to later chapters for a more complete description of the laboratory environment and data collection network.)

An average of 16 CNV trials was collected for each subject; pupil activity was recorded continuously throughout each of the experimental sessions. For the purpose of determining a baseline for the CNV trials, the manually issued start command began signal digitization 200 milliseconds before the onset of S_1; the total sweep time for each trial was 3.5 seconds.

After electrode preparation, the subject was escorted into a cubicle and placed on a bed adjusted to view a fixation point directly ahead. A pillow was used to make the final head adjustments while the camera apparatus was moved into place to record pupillary activity. Overhead fluorescent lighting provided sufficient illumination and picture contrast to record the iris of the eye but without the light of the room directly entering the subject's eyes. Eye movements by the subject were observed outside the chamber on a monitor linked to the recording camera.

Since all the subjects had participated in CNV experimentation and had displayed normal slow potential activity, only one condition was administered to each subject. A standard S_1-S_2 configuration consisted of a brief tone pip (S_1) followed 2.0 seconds later by clicks (S_2). The subject's task was to terminate the clicks by button press as soon as they sounded. The stimuli were delivered through loudspeakers at levels of approximately 65 - 70 dB re 20 $\mu N/m^2$. The audio track of the video recorder picked up the S_1-S_2 stimuli.

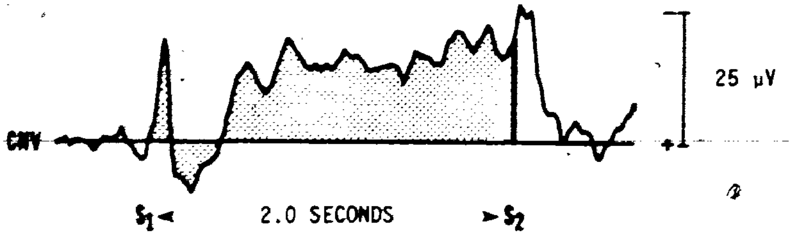
Pupil measurements, results, and discussion. After examining the tape results, it was decided to sample pupil diameters every 200 milliseconds starting at S_1 and continuing to a period 2.0 seconds after S_2 for each of the 16 accepted CNV trials. The original pupil activity was retaped with a brief flash (LED) marking the sampling periods and triggered from the original S_1 stimulus. Pupil diameters were then directly measured from a large screen monitor by manually advancing the tape to positions marked by the flash onsets. Additionally, five measurements estimating a 1-second period before the onset of S_1 were collected. Each of the separate data points was then averaged over the 16 trials. From the first five points an overall mean was calculated which served as the baseline for computing percentage changes in pupil diameters before, during, and after the S_1-S_2 interval. Pupil activity as well as the corresponding CNV are shown for subject J. L. in Figure 1. Clearly, the initial increases in pupil diameter after S_1 paralleled the upswing in negativity at the vertex. The relative dilation was maintained steadily until S_2, where further dilation can be observed following the button response. From the video recordings, pupil dilation gave way to the constriction of baseline levels but only after several seconds elapsed; the sustained dilation after S_2 is in marked contrast to the prompt return to baseline for the CNV. The other three subjects showed a similar dilation pattern. The pupil records suggest that the balance of sympathetic (dilation) and parasympathetic (constriction) activity was, at least in part, temporarily altered during and after the CNV interval. Any further interpretation of pupil activity in the CNV paradigm would have to include factors known to influence pupil diameters, e.g., fixation, lighting, motor responding, etc. (Hess, 1972).

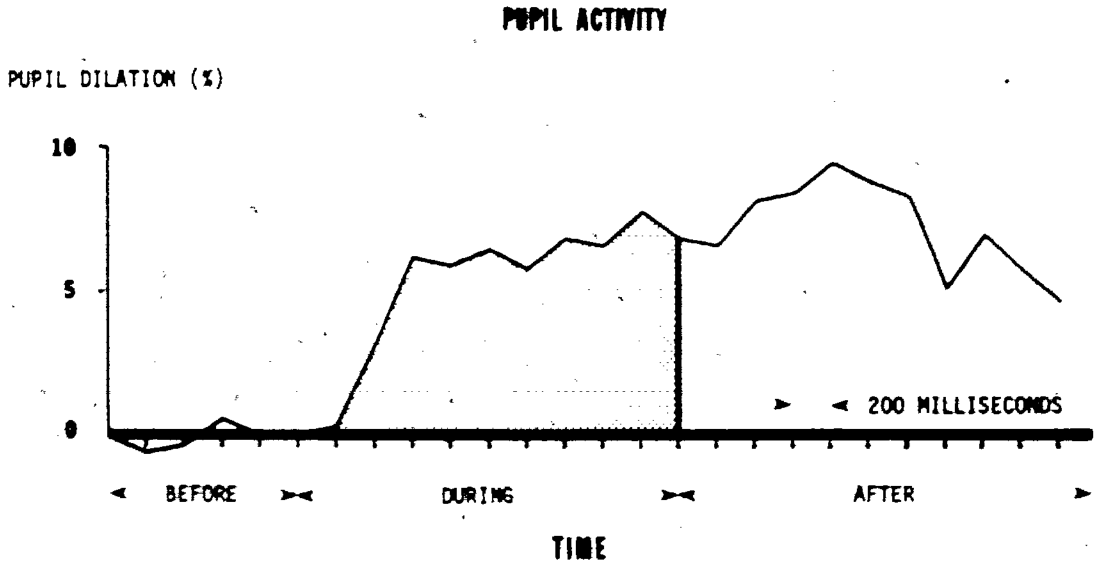
Cortical States and the CNV

The slow negative shifting exemplified in the CNV paradigm may be linked to a massive dendritic hyperpolarization covering large areas

Figure 1

Pupil Changes Recorded for Subject J. L. before, during, and after the S_1-S_2 Interval; the Corresponding CNV for J. L. Is Displayed Above


CNV
25 µV
S1
2.0 SECONDS
S2


PUPIL ACTIVITY
PUPIL DILATION (%)
10
5
0
200 MILLISECONDS
BEFORE
DURING
AFTER
TIME

of the cortex. Indeed, McAdam (1969) interpreted slow potential shifts as increased excitability in the central nernous system. McAdam tested this hypothesis by using the late components of the somatosensory evoked response to index excitability. Evoked response latencies to shock stimuli injected in the CNV interval were shorter than evoked responses recorded outside the paradigm. The faster resolution of the evoked response components was attributed to the increased cortical excitability during the period of increased scalp negativity.

In order to investigate further the cortical excitability theory, Bevan (1971) reported that the amplitude of the spontaneous EEG was greatly reduced in tests with deep sea divers. Congruently, initial negative and positive deflections of the auditory evoked response were greatly attenuated at deep diving depths. As a possible explanation for the differences in both the EEG and AER, Bevan theorized that signals from the reticular activating system (RAS) were either reduced or blocked under the abnormal pressure conditions. If the CNV was dependent upon the RAS, slow potentials under diving conditions may show attenuation effects similar to those found for the EEG and AER. The results from 13 divers indicated that no significant changes in the CNV occurred at deep sea pressures. Based on this evidence, Bevan suggested that generators of the CNV may not be directly dependent on the RAS. Naitoh and Johnson (1972) studied the effects of an altered cortical state on the CNV by depriving subjects of normal sleep patterns. A high or low tone (S_1) was followed 4 seconds later by a low tone (S_2). The subject's task was to terminate S_2 as quickly as possible if S_1 was a low tone. Subjects were tested after three consecutive nights of sleep deprivation (no REM or slow wave sleep), resting, and then tested after one night of total sleep deprivation. All subjects had stable and discriminable CNVs during control periods. After three nights of sleep deprivation there was a marked decrease in the amplitude of the CNV; after one night of total sleep deprivation there was an even further decrease in CNV amplitude. The CNV appeared to successfully distinguish different levels of wakefulness. However, it should be noted that slow negative shifts have been recorded from patients in coma (Dolce & Sannita, 1973) and during epileptic discharge (Bostem & Delaunoy, Note 7). The effects of amphetamine were found to increase CNV activity; however, for subjects that did not show the usual arousal from the drug, CNV activity was reduced (Tecce & Cole, Note 8). The intake of alcohol (.6 mg/l) had the marked effect of reducing CNV potentials; intake at higher levels (1.1 mg/l) abolished slow wave activity (Beaumanoir, Ballis, Nahory, & Genies, 1974).

Rebert, Berry, and Merlo (Note 9) observed that muscle tension has been used to alter experimentally the arousal level in subjects. They hypothesized that if induced muscle tension was introduced between CNV trials, the transient increase in arousal level might also enhance CNV activity. In their experiment, induced muscle tension consisted of lifting a hand carrier with either 0, 15, 30, or 45 pound weights; the lifting preceded a standard S_1-S_2 paradigm by 5 seconds. Amplitude measures of the CNV from the vertex (C_z) indicated no change at the 0 and 15 pound levels, but a marked increase in CNV activity was observed at the 30 and 45 pound levels.

The Reaction Time Paradigm

Hillyard (1969) investigated the relationship between RTs and CNVs over a long series of trials. Subjects terminated a tone (S_2) preceded by a solitary warning click (S_1). In computing CNV amplitudes, eye movement potentials were partialled out and a "true" or "tCNV" was obtained. The EEG activity from tape recorded sessions was averaged for the fastest RTs, next fastest, and so on. For half the subjects, tCNVs (vertex-mastoid) were inversely related with RTs; for the remaining subjects, however, the largest tCNVs were correlated with the fastest RTs. Obviously, no single process such as cortical priming or excitability by itself could account for the disparate results. The trial-to-trial variability from a host of situational variables (e.g., fluctuating effort or prolonged responding), however, might indiscriminately have had deleterious or unknown effects on the averaged records.

Waszak and Obrist (1969) utilized a disjunctive RT task to examine the relationship between motivational states and the generation of slow potentials. An analysis of vertex averages indicated that the fastest RTs were accompanied by the largest CNVs. Evoked potentials to S_1 under instructed high motivation were significantly greater than under instructed low motivation; however, CNVs between motivational conditions did not show amplitude differences. McAdam, Knott, and Rebert (1969) performed two studies in order to examine the effects of RT foreperiods on CNV amplitudes. The paradigm involved a single click as S_1 and a single click as S_2. Three different S_1-S_2 intervals were used and simple RTs to the onset of S_2 were measured. The CNV amplitudes for the 800- and 1600-millisecond intervals were significantly larger than for the 4800-millisecond interval; there was no statistical difference between the 800- and 1600-millisecond amplitudes. Behaviorally, subjects had faster RTs with the shorter intervals. Further, when subjects had to make a pretrial guess as to whether the interval between S_1 and S_2 would be either short or long, CNVs were complexly related to a function of the subject's own prediction, the actual outcome, and his level of certainty. For example, when subjects received an interval other than the one they predicted, RTs were significantly slower. When short but equally probable foreperiods (500 - 900 milliseconds) were used, Loveless (1973) found that CNV activity increased monotonically with foreperiod duration; RTs decreased with foreperiod duration. Gaillard and Näätänen (1973) concluded that overall CNV activity in a choice RT task paralleled the preparedness to react to S_2; in their study, however, amplitude measures made just prior to S_2 only approximated the RTs to S_2.

Tueting and Sutton (Note 10) manipulated subject certainty and uncertainty in a RT task. The experimental conditions were created by stimulus configuration and instructions to the subject. With uncertainty, the P300 (at choice stimulus) and the CNV (prior to choice stimulus) amplitudes were larger than with certainty of the situation. In recording EEG and pupillary responses, Friedman, Hakerem, Sutton, and Fleiss (1973) found larger pupillary dilations for experimentally produced uncertainty than for experimentally produced certainty. Karrer and Ivins (Note 11) varied the S_1 stimulus in a CNV paradigm to be either auditory, tactual, or both auditory and tactual. Administered to two groups of children, RTs were greatest for the compound S_1 warning signal. In contrast, the auditory signal at S_1 gave larger CNVs than either the tactual or the compound (auditory and tactual) presentation. McCallum and Papakostopoulos (1973) found that neither a single trial analysis nor an averaged analysis of CNV amplitudes indicated any consistent relationship with RTs. Citations in the literature of both positive and negative correlations between the CNV and RTs were provided by Rebert and Tecce (1973).

Donchin and Smith (1970a) observed that the conditions necessary for eliciting a CNV were similar to those eliciting the P300 wave in the averaged evoked potential. Further, information and subject expectation of results suggested that CNV resolution and the late positive responses of evoked potentials may be related (Donchin & Smith, 1970b). In the latter report, resolution of the CNV after S_2 was found to be approximately 300 milliseconds. By manipulating the P300 with different subject tasks, Donchin and Smith found that relevant stimuli and late positivity were indeed related to the temporal resolution of the CNV. A corresponding temporal relationship was suggested for S_1, since the slow potential does not begin to develop until approximately 400 milliseconds after the onset of the warning stimulus (Rebert & Knott, 1970). From patients with chronically indwelling subdural electrodes, Papakostopoulos and Crow (Note 12) verified the cerebral origin of the P300 and the CNV; in addition, the two phenomena were found to originate from separate neuronal systems. They also concluded that P300 phenomena represented a brain indicator of inhibitory activity. Independent of any preparatory set, the P300 appeared to reflect only the processing invoked by stimulus presentation (donchin, Ritter, Tueting, Kutas, & Heffley, Note 13).

Animal Studies of Slow Potential Shifting

The first evidence of CNV-like slow potentials in animals came from monkeys (Low, Borda, & Kellaway, 1966). Rebert (1971) subjected macaque monkeys to a foreperiod reaction time task with recordings taken from various subcortical structures. Areas demonstrating slow potential changes that paralleled the behavioral paradigm were generated in the caudate nucleus, midline thalamus, premotor and motor cortex. Rebert (1972) recorded slow potential shifts in six macaque monkeys in a preparatory task with juice reinforcement. Slow potential changes were recorded from several nonspecific nuclei (negative shifting) and subcortical nuclei (positive shifting). The changes that occurred during training appeared more rapid in nonspecific than in specific projection nuclei. From more recent reports by Rebert (1973, Note 14), recordings from stumptailed monkeys showed negative, CNV-like potentials from the premotor cortex, midline thalamus, midline reticular formation, and hypothalamus; simultaneously, positive potentials were recorded from the caudate nucleus, preoptic area, cingulate gyrus, and inferior thalamus.

Under conditions that altered a physiological drive state, Borda (1970) manipulated appetitive motivation in a group of rhesus monkeys. The animals pressed a lever to receive a food pellet after a warning signal. At least two slow negative shifts were observed over frontal and central sites during the interval between the signal and the lever press. With overtraining, central shifts maintained their amplitude, provided the subject sustained a high level of performance. Borda, Hablitz, and McSherry (Note 15) suggested that slow potentials reflected both excitatory (depolarization of apical dendrites) and inhibitory (hyperpolarization of cell somas) activity. Non-neural elements, e.g., vascular and glial, might also be involved. When monkeys were used as subjects, Hablitz (1973) showed that a significant relation existed between the slow wave distribution of cortical potentials and the type of reinforcement used. With cats, Skinner (1971) recorded slow negative shifts from frontal and central sites in the early phases of a sensory-sensory conditioning paradigm. In the later phases of the paradigm, cryogenic blockade in the inferior thalamic peduncle either completely abolished or greatly attenuated the slow shifting potentials. For a literature review and theoretical discussion of the work relating slow potential activity to the various animal studies, the reader is referred to Borda (1973).

Cognitive Aspects of Human Slow Potential Shifting

With the exception of a few notable cases, human sex differences do not appear to affect slow wave activity. With suitable experimental manipulation, however, sex differences in the CNV can be produced (Knott & Peters, 1973). Knott and Peters (Note 16) reported that females, in an experimentally induced stress situation, developed a significant decrease in CNV activity on response trials and increased

CNV activity on nonresponse trials; for males none of these CNV changes under stressful conditions were observed. In a preliminary report, Peters and Knott (Note 17) found post-S_2 negativity was greater in females than males on those trials where feedback was given and anticipated.

The effects of cognitive styles and slow potentials were investigated by Knott, Cohen, Van Veen, Miller, and Peters (1972) Field dependent (FD) and field independent (FI) subjects were subjected to a low and high stress reaction time paradigm recording vertex (C_z) CNVs, heart rates, and GSRs. It was hypothesized that anxiety levels would be correlated with aspects of CNV generation. Under the conditions tested, FD subjects did not show CNV increases for low or high stress levels, whereas FI subjects did show an increase. The other measures (heart rate, GSR) were not able to differentiate between FD and FI classifications.

Subject stress and anxiety may well affect arousal level. Tecce and Hamilton (1973) attempted to demonstrate that slow wave activity, in terms of CNVs, was inversely related to arousal. Support for this line of reasoning comes from the fact that distraction in the S_1-S_2 interval has been shown to reduce CNV amplitude. It was assumed that the additional attentional load imposed by the processing of these extra stimuli also accounted for the increased RTs to S_2. Along another line, other studies have demonstrated that lowered CNV activity was associated with heightened autonomic arousal. For their study, Tecce and Hamilton required subjects to add 7's aloud during S_1-S_2 trials. In addition to reaffirming the earlier mentioned effects of distraction, the arithmetic task decreased CNV amplitudes and increased RTs.

When normal subjects were used, McAdam and Whitaker (1971a) demonstrated that readiness potentials recorded from the scalp were localized during language production. Electrodes were placed over Broca's area on the left hemisphere and contrasted to a homologous location on the right hemisphere. For one condition, right-handed subjects vocalized a set of three-letter words that started with the letter "k" or "p"; in a control condition, subjects initiated muscular gestures that only imitated vocalization. The FM recordings of EEG activity allowed analysis of electrical events that occurred 1.5 seconds before the response and .5 seconds through the response. The averaged responses to spoken words indicated that larger activity was recorded over Broca's area than over the comparison site on the right hemisphere; the control gestures, on the other hand, produced bilaterally symmetrical records. Some of the slow potentials in the speech task were observed to occur as much as one second before the actual response. Morrel and Huntington (1971) have criticized the McAdam and Whitaker report on the bases of the imprecisness of voice triggering and the possible contamination of EEG potentials by EMG activity. A reply was given by McAdam and Whitaker (1971b) standing by their earlier results. Leford, Laffont, Sauvage, and Jusseaume (1973) found voluntary movements made after a stimulus were followed by a long latency negative wave that resembled the CNV. A bilateral distribution of the slow wave was found for movements that included fist clenching, tongue-cheek movements, and word evocation.

J. Cohen (1971) reported that singly presented semantic or pictorial stimuli were followed by a slow wave shifting. In a CNV paradigm, Cohen visually presented a word or object that was named by the subject. There was no difference in CNV shape or magnitude when the subject anticipated words or objects at threshold exposures. Cohen also noted that the amplitudes of the CNVs were significantly greater for correctly identified words or pictures.

CNV and Clinically Related Patient Groups

A few clinical reports have demonstrated the potential usefulness of the CNV in differentiating levels of verbal comprehension. For example, Burian, Gestring, Gloning, and Haider (1971) reported a single case where recovery from aphasia corresponded with a simultaneous reappearance of the CNV. In another example, Fenelon (1968) reported the case of a six-year-old dyslexic child and the generation of slow potentials. Using CNV trigrams to elicit associations to real words, no CNV was detected in the S_1-S_2 interval for the dyslexic subject. For mental retardates, Karrer and Ivins (Note 18) reported differences in the timing of the slow potential and in slow potential topography.

When patients with known brain lesions were used as subjects, McCallum, Walter, Winter, Scotton, and Cummins (1970) recorded clear asymmetries in the form and amplitude of the CNV. The most general observation made from the patients was that there was a marked decrease in the amplitude of the CNV over the area of the lesion. The investigators noted that for some of the cases showing a clear CNV asymmetry, no obvious focus or asymmetry was visible in the normal EEG record. Subcortical lesions have also been implicated in the production of asymmetrical CNVs (McCallum & Cummins, 1973). Negative shifts recorded at the scalp do not necessarily imply positive shifting at lower brain levels. When patients with implanted electrodes were used as subjects, McCallum, Papakostopoulos, and Griffith (Note 19) reported that both positive and negative shifting occurred in midline and brainstem structures in a CNV situation. Low (Note 20) observed that patients with intracerebral lesions could produce CNV activity provided the areas of dysfunction did not include the diencephalon or paracentral cortex. Informally, this writer attempted to record slow potential activity from an area between the hard and soft palate of a few practiced, normal subjects. While a monopolar vertex (C_z) electrode recorded a normal CNV in an S_1-S_2 paradigm after 16 trials, the palate electrode showed no sign of slow wave activity. Evoked responses in the CNV to S_1 and S_2 stimuli (tone-clicks) were not observed from the palate site with the small number of trials taken. In patients with frontal lesions, Zappoli, Papini, Briani, Benvenuti, and Pasquinelli (Note 21) found that negative shifts, if they occurred, were usually at the vertex; from patients with unilateral frontal lesions, electrode derivations F_3-T_3 and F_4-T_4 showed no consistent asymmetries in a conventional RT-type task.

A number of studies have included clinical examination of slow potential activity in psychiatrically hospitalized patients. Timsit-Berthier, Koninckx, Dargent, Fontaine, and Dongier (1970) surveyed CNV amplitude and waveform in 160 patients. The patients were classified as normal (45), neurotic (70), and psychotic (45). The CNV amplitude alone could not statistically distinguish between the three categories; however, there was a relationship between categories and the persistence of the negative potential after S_2. Only 9% of the patients classified as normal had displayed the persistent or sustained negativity after S_2, whereas 34% of the neurotics and 91% of the psychotics demonstrated that the prolonged CNV was associated with the severity of the psychotic disturbance. In another study of neurotic and psychotic patients, Timsit-Berthier, Delaunoy, Koninckx, and Rousseau (1973) considered three parameters (amplitude, morphology, and duration) of CNV activity. Neurotics and psychotics produced small amplitude CNV activity; morphology, in terms of Type A or Type B classification, was equally represented in the normal and patient groups; however, duration, or post-S_2 negativity, again appeared more often in the psychotic grouping. Types of post-S_2 resolution and the problems of interpretation of this resolution were discussed by Timsit-Berthier, Delaunoy, and Rousseau (Note 22). Timsit-Berthier, Delaunoy, and Rousseau (1973) also observed a different-from-normal motor potential among psychiatric patients.

Using a discrimination-type CNV task, Weinberg (1973) was able to induce experimentally rebound phenomena or post-S_2 negativity from normal subjects. The prolonged negativity was observed to depend upon the occurrence of feedback to the subject about the correctness or incorrectness of his response. Instead of being a sign of psychiatric illness, post-S_2 negativity may only reflect the subject's continued concern about his response.

Abraham and McCallum (1973) investigated the relationship between the duration of the Spiral After Effect (SAE) and the amplitude of the CNV. The experimenters tested schizophrenic patients on the SAE after CNV recording sessions. They found that longer SAE times were directly related to lower CNV amplitudes and severity of diagnosed condition. The results coincide with the characterization of schizophrenics being hyperactive and having, therefore, limited capacity for extra stimulation. Abraham, McCallum, and Gourlay (Note 23) studied four CNV features (amplitude, distraction amplitude, prolongation, and parietal spread) in diagnosed schizophrenic patients. The first two measures appeared consistent and not related to any particular type of patient classification. In contrast, reliable prolongations, i.e., post-S_2 negativity, were found for patients with manic-depressive syndromes. The measure referred to as parietal spread (defined as the μV difference between the C_z and P_z sites) was linked with one group of the patients. For the future, the successful use of the CNV in the clinical setting requires the judicious use of recording techniques coupled, of course, with the imposed limitations of the hospitalized patient. A recent paper on the interpretation of post-imperative negative variation was presented by Dubrovsky and Dongier (Note 24).

Chapter 3

HEMISPHERIC SLOW WAVE ACTIVITY, DISTRACTION PROCESSES, AND THE EVALUATION OF LATERAL SLOW POTENTIAL TOPOGRAPHY

Investigators are now examining the relationship between hemispheric processing and the distribution of slow potentials over the cerebral hemispheres. The problem of combining the two areas is an interesting one. If the brain is truly responsible for the functional differences outlined in Chapter 2, a cortical phenomenon such as the CNV should reflect hemispheric activity. The CNV paradigm lends itself to an examination of cognitive set by presenting a stimulus sequence that may require processing at either S_1, S_2, or both S_1 and S_2 stimuli. By paying special attention to the stimuli used and the response required, investigators are able to evaluate the effects of hemispheric processing on slow wave distribution.

This chapter is divided into three parts. The first section records recent experimentation dealing with hemispheric processing and slow potential asymmetries. From pilot work, the second section explores the effects of selective stimulus distraction and the generation of left side and right side slow potentials. The third section considers the logical problems involved in demonstrating lateralized slow potential activity.

Investigations of Lateralized Slow Potentials

Otto and Leifer (1973) examined the topographical distribution of the CNV during a sustained motor task and a delayed motor task. In a so-called double response condition (DR), subjects pressed a button at S_1 until the occurrence of S_2. The single response condition (SR) followed the same stimulus sequence but required only a single button press at S_2. The subjects were separately tested under both experimental conditions using their preferred hand and nonpreferred hand; additionally, subjects were given feedback in both DR and SR conditions. Monopolar scalp activity was collected from left and right motor thumb areas and midline (F_Z, C_Z, P_Z) sites. Slow wave activity was evaluated from area measurements computed between the waveform in the CNV interval and a 1-second pretrial baseline level. In addition to the effects of feedback and pretrial shifts that occurred in the DR condition, the investigators reported hemispheric differences between the dominant hand and the nondominant hand. Maximum negativity was recorded from the hemisphere contralateral to the hand that responded. Importantly, right-handed subjects exhibited larger negative activity over the contralateral (left) hemisphere regardless of the hand that responded. For left-handed subjects, maximum negativity was recorded over the contralateral (right) hemisphere no matter which hand responded. It should be noted, however, that the laterality effects reached significance only when the data were pooled over DR, SR, and across feedback conditions. The investigators entertained the idea that individual dominance may override the impulse activity of contralateral connections.

The evaluation of cerebral activity is not limited to measures of magnitude only. For example, Weinberg and Papakostopoulos (Note 25) used a correlational recognition index (RI) to examine the relationship between slow potentials recorded from the vertex (C_z) and other scalp locations (F_{p1}, F_{p2}, C_3, C_4, P_3, & P_4). A standard S_1-S_2 paradigm was used to elicit slow wave potentials. The subjects simply terminated an S_2 tone with either their left or right hand. The results indicated that the vertex (C_z) correlated highly with all other electrode sites except for F_{p1} and F_{p2}. Regardless of which hand responded, the correlations between the vertex (C_z) and the lateral placements were not affected. An amplitude analysis of the recorded potentials disclosed that there were no differences between experimental conditions and no hemispheric differences. The vertex (C_z) amplitudes were larger than either frontal, central, or parietal sites; in addition, the two frontal sites were smaller than either the central or parietal locations. The investigators speculated that frontal placements may be more involved in discrimination and time estimation, whereas central and parietal placements may be more involved in response control and output.

In discussing the topography of the human motor potential (RP), Vaughan, Costa, and Ritter (1968) found that the distribution was larger over the hemisphere contralateral to limb movement. Although four distinct components of the motor response have been identified, the initial negative wave preceded movement by as much as .5 to

2.0 seconds and ranged from 5 μV to 25 μV in amplitude. From the maximum response at the rolandic line, motor potentials have exhibited a gradient of decreasing magnitude both anteriorly and posteriorly. Recording CNV potentials from hand sensorimotor areas of both hemispheres, Syndulko and Lindsley (Note 26) found that larger slow scalp activity was generated by the side contralateral to the responding hand. Recordings from bipolar frontal (F_3, F_4), parietal (P_3, P_4), and occipital (O_1, O_2) sites did not display this asymmetry. Similar motor activity was observed for both left- and right-handers.

Donchin and Kutas (Note 27) reported preliminary findings on the effects of response parameters and the generation of readiness potentials. Subjects operated a hand dynamometer at 25%, 50%, and 75% levels of a maximum force that was determined prior to testing. The subjects viewed a continuously illuminated square with a superimposed circle; they were able to make the circle disappear by exerting one of the above force levels. Visual inspection of the averaged data (at all force levels) for right-handed subjects appeared to indicate larger left-motor than right-motor activity during right-handed operation. When right-handed subjects used their left hand, the motor asymmetries between the hemispheres were no longer observed. Interestingly, the force levels did not appear to alter the RP amplitudes. In a later and more extensive analysis, Donchin and Kutas (Note 28) found that right-handers exhibited a contralateral asymmetry of the RP that depended upon which hand responded. For left-handers, however, a contralateral asymmetry was found for right-handed responding, whereas no differences were observed between the hemispheres for left-handed responding.

Wilke and Lansing (1973) investigated the relationship between different levels of forearm exertion (1 & 3 pounds) and the corresponding generation of motor potentials. Bipolar scalp recordings were collected from rolandic sites referred to parietal locations. For a period 100 milliseconds prior to arm movements, no cortical activity was detected. However, during movement a surface negative-to-positive activity was observed that was larger for the 3 pound exertion than for the 1 pound exertion. The movement potential was larger over the hemisphere contralateral to the limb that responded. The amplitude differences ranged from 1.5 μV to 2.0 μV for both the force levels and for the laterality effects; the averages were based on a minimum of 350 voluntary arm movements.

In a preliminary CNV report, Donchin, Johnson, Hernong, and Kutas (Note 29) presented subjects with a series of rules for determining the outcomes of particular stimulus sequences. These rules were presented on separate days for the following situations: (a) guess (subject attempted to predict the outcome of a trial prior to S_1), (b) reaction time (subject responded with either the left or right hand following the choice stimulus), and (c) reaction time (same as b except with catch trials). Area measurements were computed for both the P300 (at S_2) and the CNVs. The results indicated that the experimental conditions affected the distribution of the P300 and CNV potentials. The vertex (C_z) was larger than most laterally placed electrodes. The lateral placements in the two RT conditions produced larger P300 and CNV areas on the right than on the left hemisphere; for the guess condition (no response required), activity recorded from the left hemisphere was larger than for the right hemisphere. (Averages were based upon 64 trials.)

Butler and Glass (1971) reported the production of asymmetrical CNVs with a cognitive task. The investigators hypothesized that solving arithmetic problems is heavily dependent upon the functioning of the dominant hemisphere. Bilateral recordings (fronto-parietal) were collected while subjects performed arithmetic operations mentally. The subjects were presented a warning stimulus (S_1) followed by a tachistoscopically flashed arithmetic problem (S_2). The results for right-handed subjects indicated that the amplitude of the CNV was significantly greater over the left than right hemisphere; a single left-handed subject demonstrated the lateralized effect but over the right hemisphere. The investigators interpreted the data as evidence that the hemisphere principally responsible for processing also produced the most activity. It is important to note that subjects were not performing the arithmetic operation in the S_1-S_2 interval. This writer attempted a similar study with subjects performing mixed arithmetic operations tachistoscopically presented at S_1 or S_2. If the problem was presented at S_1, the subject verbally reported the answer at the S_2 signal; if the problem was presented at S_2 after the S_1 warning signal, the subject solved the problem and responded verbally as quickly as he could. Visual inspection of monopolar recordings indicated large CNV amplitude differences between experimental conditions; frontal sites (F_3, F_4) were not differentiated either when the subject performed the operation in the S_1-S_2 interval or when the subject only expected the arithmetic operation.

In a continuous vigilance situation, McCallum (Note 30) presented subjects with a digit display that changed numbers at a rate of one per second. The subject's task was to respond whenever a sequence of three odd numbers had been observed. Amplitude measures showed increasing negativity to number sequences as a series approached the criterion for response. Scalp recordings from lateral placements F_3, F_4, C_3, C_4, P_3, and P_4 were symmetrically distributed during stimulus presentations.

Marsh and Thompson (1973) investigated the effects of verbal and nonverbal psychological set on the hemispheric distribution of CNV potentials. An S_1-S_2-S_3 stimulus sequence was used to elicit slow potentials; S_1 signaled the start of a trial, S_2 was a 5 - 8 letter word presented to either the left or right visual fields, and S_3 signaled the subject to verbally report the word observed at S_2. For the nonverbal condition, subjects viewed different line orientations (at S_2) that were randomly presented to either the left or right visual fields. The subject made his response from an array of possible orientations shown at the end of a trial. Monopolar scalp electrodes were placed at T_3 and T_4 locations along with bilaterally placed electrodes over left and right angular gyri. The results for the behavioral data indicated a right field superiority for word detections; for the line orientation task, however, subjects made an equal amount of errors for both the left and right visual fields. The CNV amplitudes showed that no differences occurred between the hemispheres for either the temporal or parietal placements. The investigators reported parietal amplitudes ranged from 4 μV to 5 μV; temporal locations recorded no slow potential activity. Further, no significant left or right differences were found when trials were separately tested by condition for correct or incorrect responses. In an additional experiment, Marsh and Thompson (1973) modified the experimental design so that S_1 signaled not only the start of a trial but also indicated whether the trial was verbal or nonverbal. Vocalization was eliminated in the nonverbal condition. The results from 14 subjects showed that hemispheric asymmetries were produced for both temporal and parietal sites on correct trials. The CNV amplitudes were smaller for the hemisphere presumed to be primarily engaged in the task. Overall amplitudes were still small. From a recent report, Marsh, Poon, and Thompson (Note 31) observed that left-right differences for frontal electrodes occurred only when correct trials were averaged.

Low, Wada, and Fox (Note 32) investigated the possibility that the localization for language production was reflected in slow potential scalp activity, particularly in the CNV. In epileptic patients, the investigators observed that larger negative shifts occurred over the dominant than nondominant hemisphere (language dominance was verified by carotid amytal tests). In normal left- and right-handed subjects, area measurements from the temporal locations of both hemispheres generally showed greater negativity opposite to the subject's handedness. Preliminary data from normal children (6 - 12 years) indicated that temporal activity preceding speech production was asymmetrical. In a later report, Low, Wada, and Fox (Note 33) found some individuals that showed a negative shift over the dominant frontal hemisphere and a positive shift over the nondominant hemisphere during a language task.

Zimmermann and Knott (Note 34) reported preliminary slow potential data from stutterers and normal speakers. The subjects were presented a stimulus word at S_1 followed by a signal (S_2) to verbalize the word. In addition to the vertex (C_z), monopolar recordings were collected from left-inferior-frontal and right-inferior-frontal scalp locations. Normal subjects exhibited essentially a normal CNV distribution during the CNV task. Stutterers not stuttering displayed some vertex (C_z) activity but almost no frontal activity. When stuttering, however, stutterers produced almost no vertex (C_z) potentials; the left frontal site displayed a marked increase in negativity while the right frontal site was slightly positive.

In a recent conference report by Grözinger, Kriebel, and Kornhuber (Note 35), the production of asymmetric activity from time-reversed averages was linked to the particular speech-related task performed. When readiness potentials were collected over speech areas (Broca), one subject showed that the left hemisphere was more active than the right hemisphere prior to articulatory movements; prior to humming, however, the right hemisphere was found to be more active. When the lateralization of slow wave activity (RPs) over speech areas occurred, the asymmetries were not always negative or positive.

The Effects of Distraction on Slow Wave Generation

The apparent transient fluctuations in the amplitude of the

CNV led McCallum (1969) to study the effects of simple and complex distraction on slow wave production. Small decreases in CNV amplitude were observed when the subjects listened to simple tones, listened to music, or listened to the experimenter talk. When a subject was asked to increase voluntarily his concentration during a task, the CNV was increased by a small amount. When distracting stimulation in the same sensory modality as S_2 was introduced, CNV activity increased; however, intermodal distraction has been demonstrated to reduce CNV activity (Miller, Van Veen, Sandman, & Knott, 1973).

Tecce and Hamilton (1973) studied the effects of distraction on CNV amplitudes. In one experimental condition, subjects were presented with a standard S_{flash}-S_{tone} sequence. For the distraction condition, subjects added 7's aloud in the S_1-S_2 interval. An analysis of the results disclosed that a significant reduction in CNV amplitudes was caused by the adding of numbers. Heart rate during distraction was elevated. In order for the distraction to be effective in reducing the CNV, the investigators suggested that the interference must be demonstrably processed (e.g., longer RTs) and interrupt the primary task of responding to S_2.

The Effects of Simple Distraction in the S_1-S_2 CNV Interval

The experimentation on distraction suggested to this writer that particular stimulus materials known to effect differential hemispheric processing might also differentially influence CNV genesis. A number of practiced subjects with known CNVs participated in various conditions in which interfering stimulation was injected into the S_1-S_2

interval. A comparison condition usually consisted of a single click (S_1) followed by clicks (S_2). The subject's task was to terminate the clicks by button press as quickly as possible. For the distraction conditions, subjects were informed of the general nature of the injected stimulation but were to respond to S_2 as before. The overall design of the experiments was attractive because the period of distraction was relatively long (i.e., compared to EPs) and the instructions to the subject were minimal. Scalp activity was collected on-line using long time constant (5.0-second) recordings. The number of trials that comprised an average ranged from 10 to 16. Monopolar recordings (referred to linked mastoids) were gathered from the vertex (C_z) and homologous electrode placements. Upward and downward eye movements were monitored from bipolar electrodes placed around the right eye. Subjects were placed on a bed that was located in a sound attenuating chamber. A visual inspection of the data was carried out; baseline levels for data plots were based around the mean voltage level prior to S_1 stimulation. A more complete description of the laboratory environment and data collection network is presented in later chapters.

In a distraction series using simple stimuli, electrodes were placed at the vertex (C_z), C_3, C_4, T_3, and T_4 sites. Four right-handed male subjects were tested. The data plots that are shown for subject N. A. in Figures 2, 3, 4, and 5 summarize the distraction findings and represent the data collected from the other subjects. White noise was injected into the CNV interval; the distraction was biaurally presented at levels that approximated the S_1-S_2 stimuli (65 - 70 dB re 20 $\mu N/m^2$).

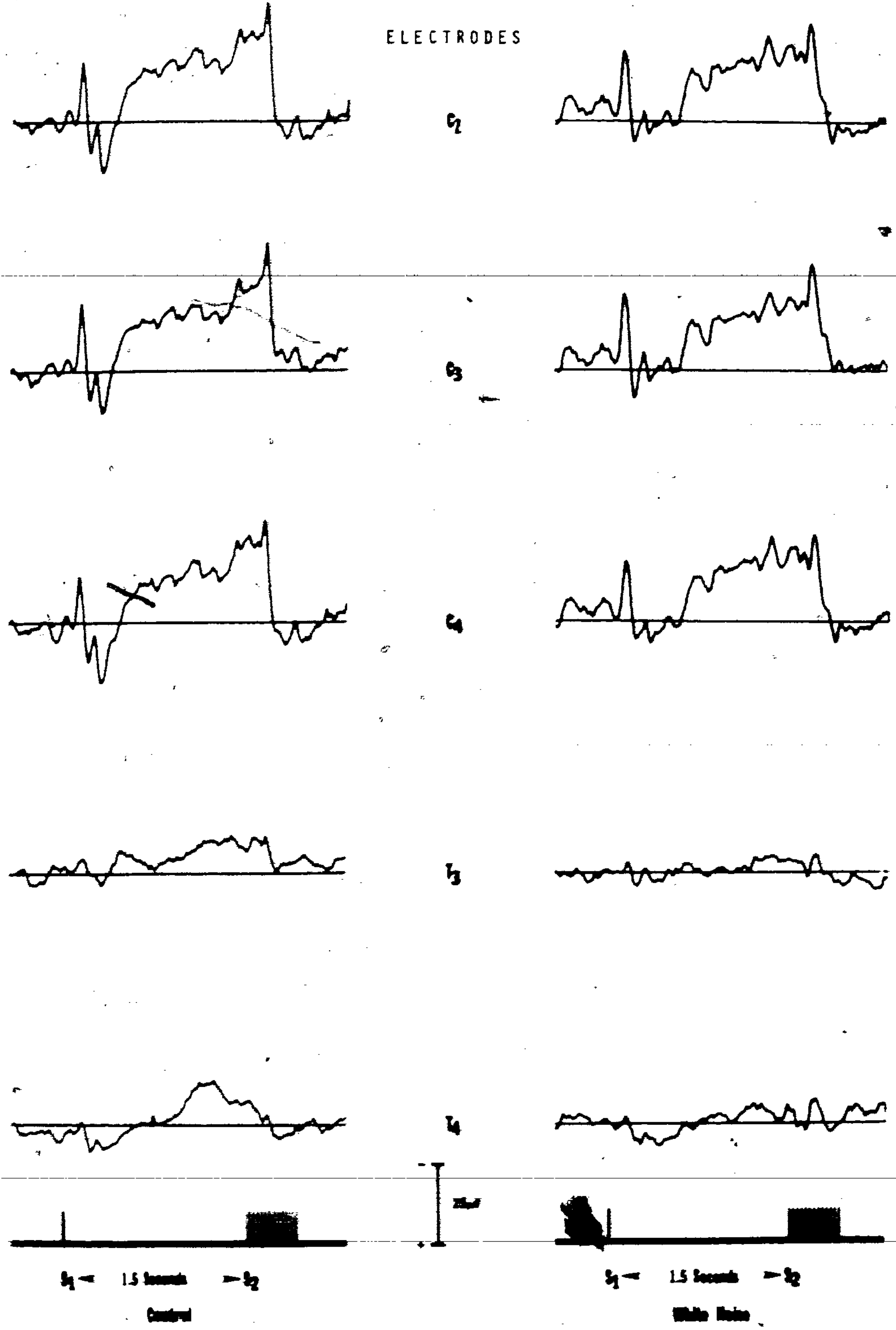
When compared to the control condition, overall CNV activity was decreased during the white noise presentation (Figure 2). This was especially evident at the onset of the noise injection. Homologous C_3 and C_4 sites were not differentially affected by the noise presentation. The temporal sites showed a minimum of slow wave activity. Visual distraction was introduced into the CNV interval by presenting blank flashes to the subject. The flashes were generated by a Grass Photo-Stimulator (intensity 2) and were binocularly observed from a distance of 1 meter. Compared to the control condition, flash stimulation reduced CNV activity by a slight amount (Figure 3). Homologous C_3 and C_4 placements remained symmetrical during flash presentations; temporal sites remained at baseline levels.

Slightly more complicated stimulus injections included a condition where subjects silently shadowed numbers on a TV monitor. Presented binocularly, unsynchronized single digits (1 - 9) appeared at a rate of two per second in the S_1-S_2 interval. The records from the digit injection showed the effects of attenuation for all electrode sites; no differential activity was observed at the homologous sites (Figure 4).

Spoken digits (1 - 9), randomly ordered and presented biaurally at a rate of two per second, were injected into the S_1-S_2 interval from a prerecorded tape (at a level of 65 - 70 dB re 20 $\mu N/m^2$). The numbers were silently shadowed by the subject for each of the CNV trials. The results indicated a slight slow wave reduction at all sites with no differential activity evident (Figure 5). There was evidence presented by McKee, Humphrey, and McAdam (1973) that right hemisphere alpha

Figure 2

Average ($\underline{n}$ = 10) CNV Records for Subject N. A. during the Control and Interjected White Noise Distraction Conditions


ELECTRODES
C2
C3
C4
T3
T4
S1 ← 1.5 Seconds → S2
Control
S1 ← 1.5 Seconds → S2
White Noise

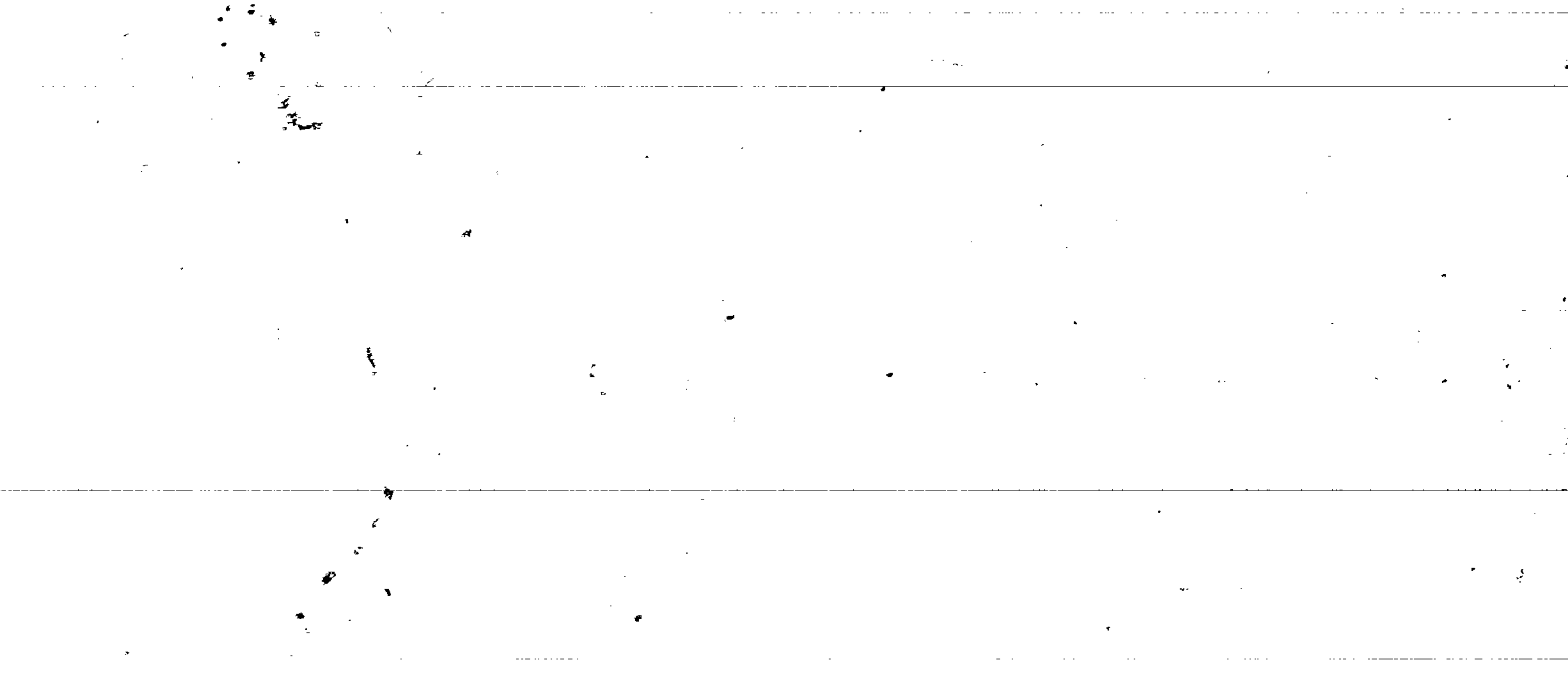


Figure 3

Average ($\underline{n}$ = 10) CNV Records for Subject N. A. during the Control and Interjected Blank Flashes Distraction Conditions

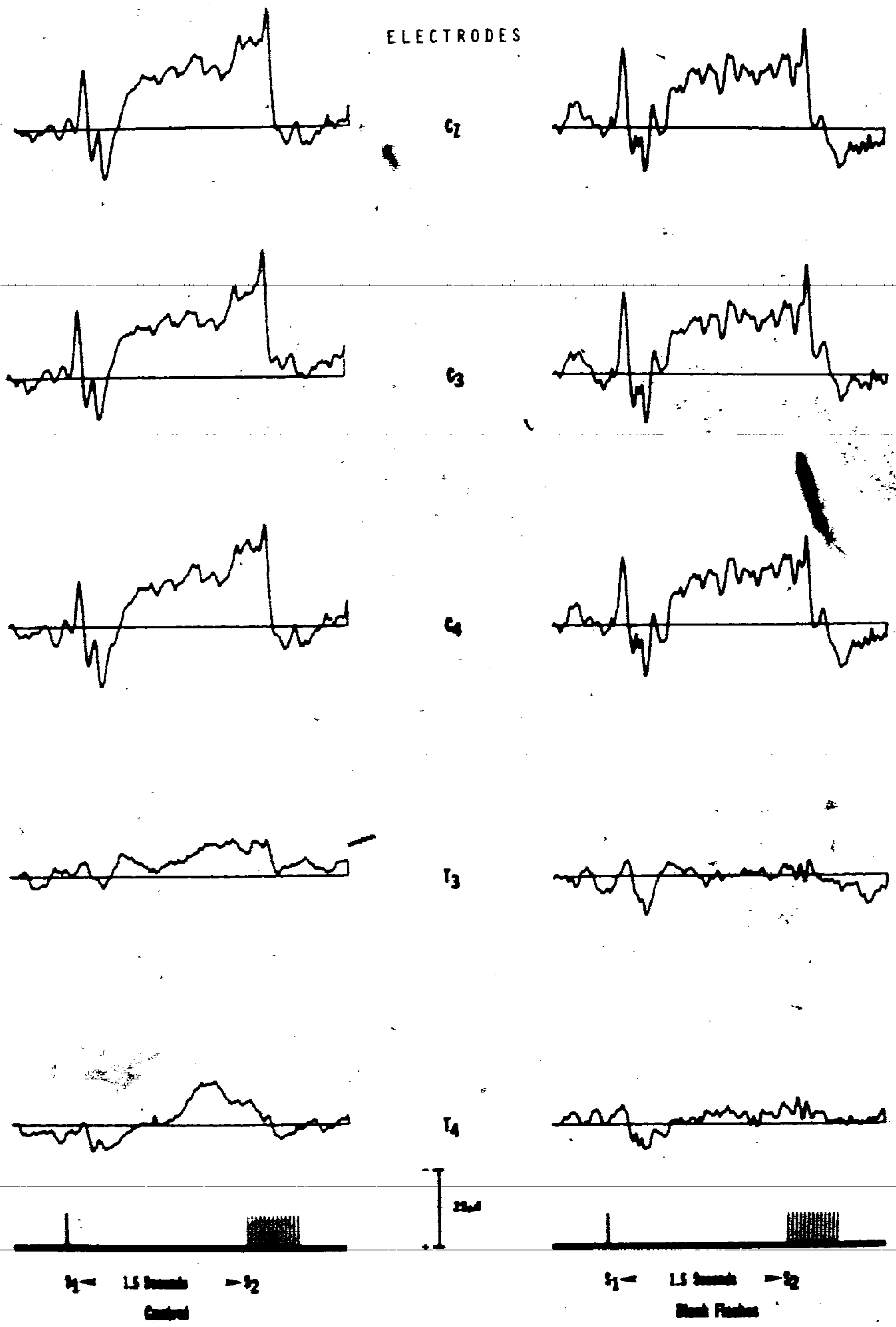

ELECTRODES
C_Z
C_3
C_4
T_3
T_4
25µV
S_1 ← 1.5 Seconds → S_2
Control
S_1 ← 1.5 Seconds → S_2
Blank Flashes

Figure 4

Average (n = 10) CNV Records for Subject N. A. during the Control and Visually Interjected Numbers Distraction Conditions

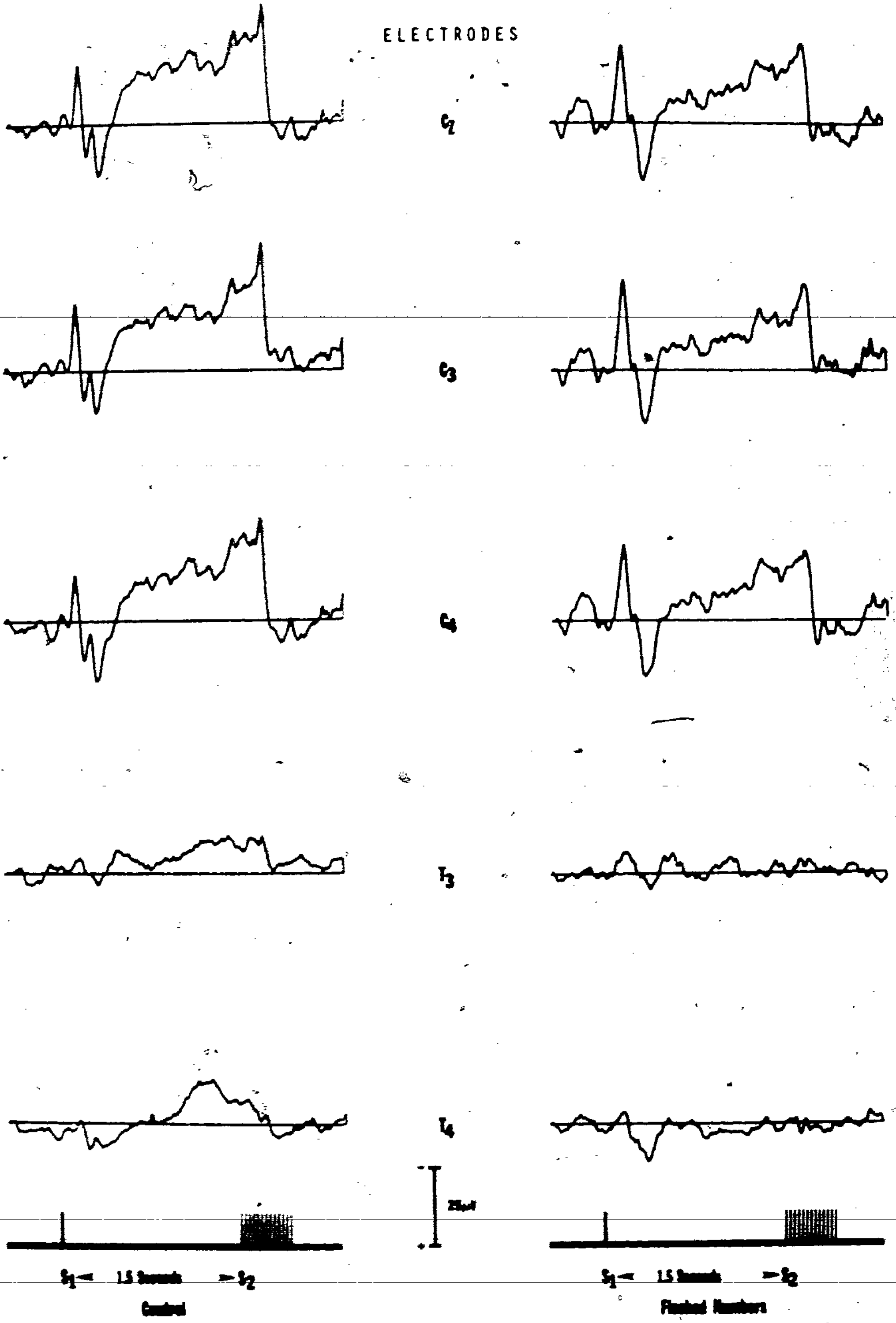
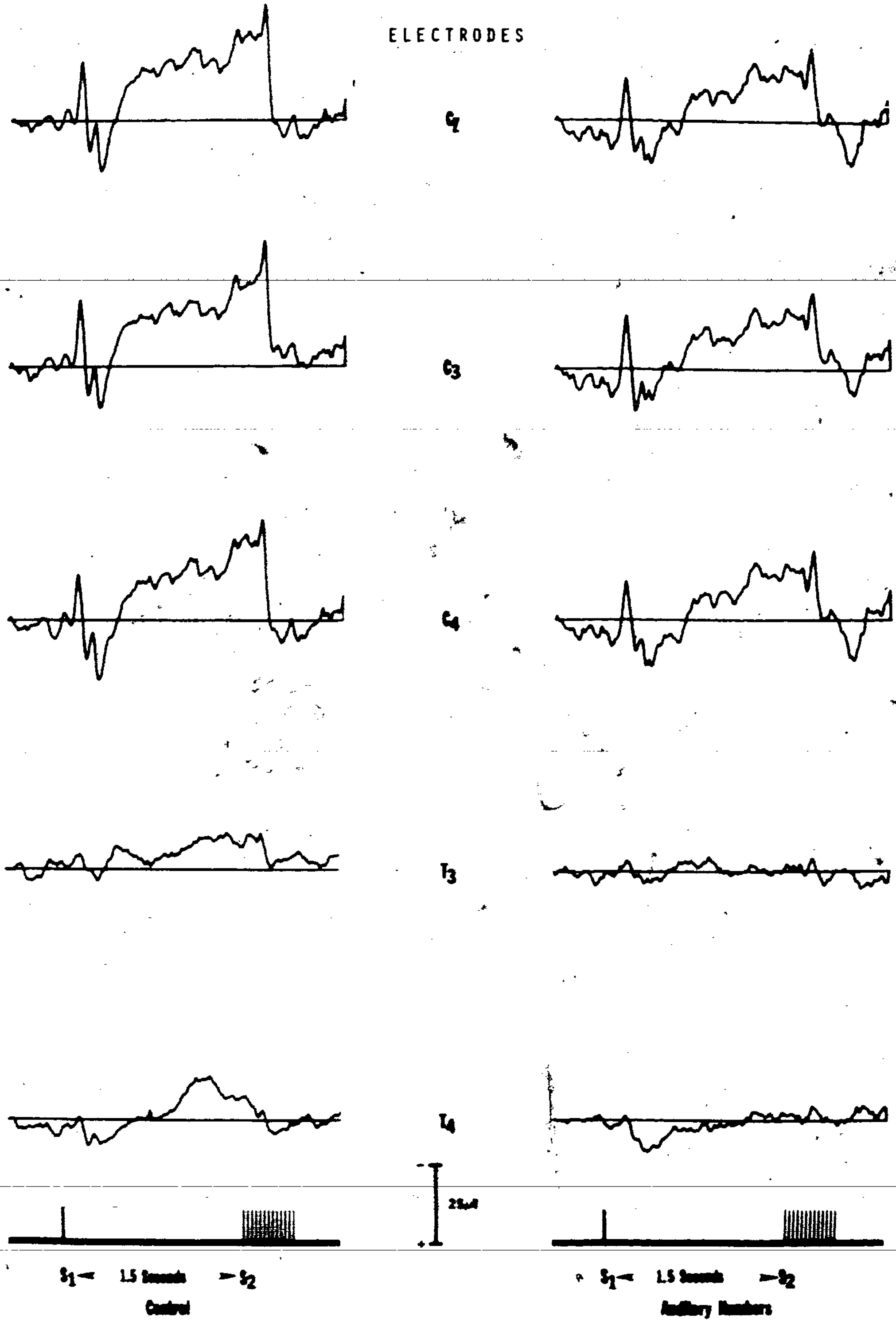

ELECTRODES
Cz
C3
C4
T3
T4
25µV
S1 ← 1.5 Seconds → S2
Control
S1 ← 1.5 Seconds → S2
Flashed Numbers

Figure 5

Average ($\underline{n}$ = 10) CNV Records for Subject N. A. during the Control and Injected Auditory Numbers Distraction Conditions


ELECTRODES
Cz
C3
C4
T3
T4
25µV
-
+
S1 ← 1.5 Seconds → S2
Control
S1 ← 1.5 Seconds → S2
Auditory Numbers

activity was altered during a musical task. Although not shown in the records of subject N. A., orchestral music interjected in the CNV interval reduced overall slow potential activity; however, homologous sites were not differentially influenced.

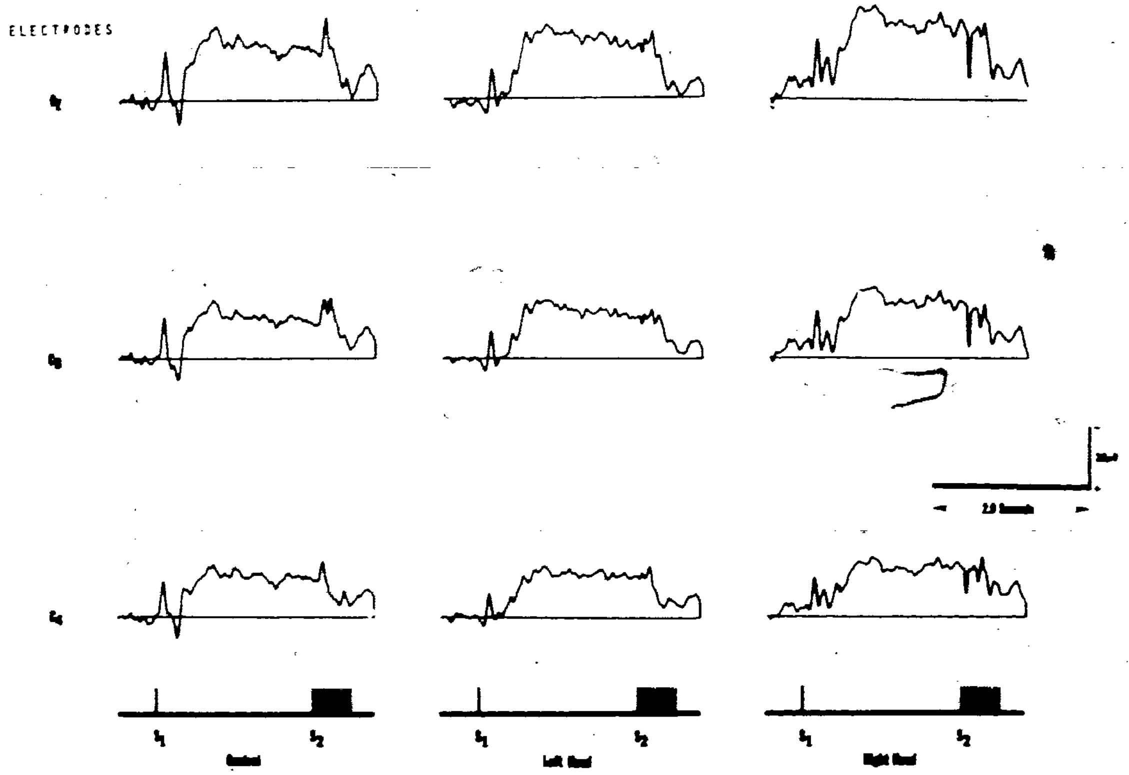
The effects of tactile distraction on CNV genesis were investigated by separately stimulating each hand with a Vibrometer vibrator. Slow potentials were elicited with a standard S_{tone}-S_{clicks} paradigm. In the tactile conditions, the vibrator was turned on during the 2.0-second S_1-S_2 interval. The subject's task for both the control and tactile conditions was to terminate the S_2 clicks by button press. In the control condition, the button was placed in the subject's right hand; in the vibrator conditions, the button was operated by the hand opposite to the tactile stimulation. Four right-handed females served as subjects. Monopolar electrodes (referred to linked mastoids) were placed at the vertex (C_z), C_3, and C_4 scalp sites. The averaged records for subject D. B. are shown in Figure 6 and were representative of all the subjects tested. Compared to the control condition, visual inspection of the records indicated a slight increase in CNV activity during the injected vibrator periods (baseline levels were determined around a mean voltage 500 milliseconds prior to S_1). Placement of the vibrator in either the left or right hand did not appear to change the overall balance of the C_3 and C_4 placements.

Discussion of the Results of Simple Distraction

In considering the overall results for all the distraction experiments, several points should be observed. For some of the

Figure 6

Average ($\underline{n}$ = 16) CNV Records for Subject D. B. for the Control Condition and Conditions of Left and Right Hand Tactile Stimulation


ELECTRODES
S_1
S_2
Control
S_1
S_2
Left Hand
S_1
S_2
Right Hand
2.0 Seconds

conditions, the central electrode sites were not appropriate. In the control conditions, the right hand button press did not appear to alter the symmetry of the C_3 or C_4 sites, nor did the distraction conditions appear to influence the press in this balance. Except for the fact that injected material was at the same intensity level as the S_1 and S_2 stimuli (in the auditory conditions), there was no assurance that the distracting stimulation was actively processed by the subject. For example, reaction times between control and experimental conditions were comparable.

Quantitative Aspects of Assessing Lateral Slow Wave Activity

Before proceeding to the experiments conducted in Chapters 4, 5, and 6, it is necessary to consider the assumptions made about hemispheric processing and the methods used in evaluating lateralized slow wave activity. Since the experimentation relied so heavily on verbal instruction to the subject, selection of an experimental condition free from lateralized effects was difficult to find. Instead, the notion of a control or standard condition was adopted. Subjects were given a typical S_1-S_2 CNV situation in order to verify the presence of slow wave activity and establish a slow wave distribution between the hemispheres. It was accepted that lateralized differences in the standard condition (as well as the experimental conditions) might be due to factors other than those designed for the situation. These included such things as the type of motor response required of the subject, the uneven placement of homologous electrodes, and the fact that the S_1 and S_2 stimuli themselves may not be altogether neutral in terms of hemispheric processing. Given the distribution status of the lateral placements in the standard condition, other conditions were administered in order to alter this balance in the direction of the left or right hemisphere. The shift in the lateral distribution of the CNV from the standard condition was considered necessary to any claim of hemispheric slow wave processing.

It was anticipated that amplitude measures of slow wave activity would form the initial basis for the analysis of CNV distributions. It also seemed reasonable to assume that the hemisphere most active in the processing of information would yield the largest slow wave activity, although other possibilities were not excluded from consideration. Results from pilot experimentation indicated that the magnitude measures were not the only relevant dimension that might be used to evaluate slow wave distribution. Cross-correlations have provided a convenient index to the similarity between waveforms (Cooper, Osselton, & Shaw, 1969). It was decided to use cross-correlations to evaluate the waveforms generated by the cerebral hemispheres. The cross-correlations used here were calculated by the Pearson Product-Moment technique using the averaged data points of each waveform. In order to investigate slow wave activity apart from the aspects of amplitude, four correlational comparisons of lateral CNV potentials were considered. These included correlations across particular electrode sites (I), between the vertex (C_z) and each of the lateral placements (II), between homologous pairs of electrodes (III), and between intrahemispheric electrode positions (IV). Considered with the amplitude measures, the cross-correlations formed a complementary analysis network directed at detecting distribution changes between the hemispheres for the different conditions.

The basis for evaluating the various indices of electrical brain activity rested in a general application of the factorial analysis of variance design (fixed effects) with repeated measures (Winer, 1962). In addition to providing information about subjects, electrodes, and experimental conditions, critical interactions of electrodes by conditions provided the cell means necessary to assess lateralized slow wave activity. Most interaction means were evaluated by level for the principal purpose of investigating the relative electrical activity of a lateral electrode site and its homologous counterpart. Additionally, specific nonsignificant interactions were examined in order to supplement the information of the various sites between the different experimental conditions.

In summary then, the experimentation of the following chapters attempts to alter the distribution of the CNV between the hemispheres in normal subjects with tasks derived and designed from the theories of differential cerebral processing. Specifically, the task situation in Chapter 4 seeks to evoke nonverbal right hemisphere activity, whereas the tasks in Chapters 5 and 6 look broadly at verbal processing and language production in the left hemisphere. It is assumed that the CNV represents a complex network of electrical phenomena which may or may not serve as a suitable index to cerebral processing. Eliciting asymmetries in the CNV however would establish a psychological and electrophysiological basis to specialized cognitive activity.

Chapter 4

RIGHT HEMISPHERE PROCESSING AND THE LATERAL DEVELOPMENT OF THE CNV: EXPERIMENT 1

This chapter endeavors to incorporate some of the special knowledge of right hemisphere functioning with the lateral development of the CNV. One of the more intriguing findings for differential cerebral functioning came originally from Milner (1962) who associated the right hemisphere with tonal memory and timbre. The work of Shankweiler (1966) with right temporal lobe patients and Kimura's (1964, 1967) work with normal subjects have further supported the right hemisphere's apparent musical or melodic predisposition. The ratio of ongoing alpha activity over the right hemisphere has been altered during a musical task (McKee, Humphrey, & McAdam, 1973) along with more transient forms of cortical activity, i.e., evoked potentials (R. Cohen, 1971; Molfese, Note 1). Earlier, Penfield and Rasmussen (1950) found that the temporal cortex was involved with memory functions and the ability to make comparisons between past and present sensory perceptions. Electrical stimulation of temporal regions in humans produced a variety of hallucinations including some that were musical in nature. The frontal areas have also been implicated in situations that require a continuous assessment of ongoing behavior (Milner, 1971).

A simple tone analysis situation was designed to fit the slow potential or CNV format. The tone presentations were continuous throughout the slow wave interval. The activity from lateral electrode placements over both cerebral hemispheres was used to assess CNV genesis during a control condition and a series of tone sequences.

Methods

Subjects

The subjects were five right-handed males and five right-handed females. The subjects were recruited from the university community as paid volunteers. Handedness was checked by requiring each subject to copy a short paragraph. The subjects' ages ranged from 18 to 26 years; except for two individuals, all subjects were experimentally naive regarding electroencephalographic methods and procedures. The subjects had no abnormal hearing deficits.

Recording Techniques

In accordance with the International 10-20 System of placement (Jasper, 1958), monopolar scalp electrodes (Ag-AgCl) were placed at the vertex (C_z), left frontal (F_3), right frontal (F_4), left temporal (T_3), and right temporal (T_4) locations. The active electrode sites were referenced to linked mastoids. A ground electrode was placed on the subject's forehead. In order to monitor ocular potentials, Beckman Biopotential electrodes were placed periorbitally above and below the right eye to record upward and downward movements, and electrodes were placed near the external canthus of each eye to record lateral eye movements. Skin sites were lightly cleaned with acetone before electrode application. After injection of the jelly electrolyte (Beckman), electrode impedances were measured and equated at 3.0K ohms by tapped skin abrasion.

The EEG activity was amplified and recorded on an 8-channel Elema-Schönander Mingograf recorder. Amplifier sensitivity was adjusted to 50 µV/cm for active electrode sites; time constants were set at 5.0 seconds with upper cutoff frequencies set at 30 Hz. A single recorder channel was normally reserved for use as an event marker. Outputs from the recorder were directed to a Hewlett-Packard 2116B computer for signal digitization and storage. Analog records of output signals were taped by a Precision Instrument 6200 FM recorder.

On-line data acquisition was accomplished with a data averaging program designed for slow potential recording. After a start command, normally issued manually, eight channels of 1024 points each were digitized and stored on disc. Individual trials (or sweeps) were displayed on an oscilloscope prior to being accepted (or rejected) for the data average. After a predetermined number of trials, the disc average was computed and displayed. If accepted, the average went into permanent storage under a designated file name. In addition, digital data from accepted trials were stored on magnetic tape. A teletype was used to enter program parameters and log accepted trials. Stored data averages were later retrieved for filtering, plotting, and further analyses. The reader is referred to Appendix A for a schematic layout of the laboratory environment.

Stimulus Construction

A tone tape was prepared for presenting tone sequences to the subject. A dual Marconi AF oscillator generated the four tones placed on an Uher tape recorder. The duration of each tone was 750 milliseconds for a total tone period of 3.0 seconds. The first tone pair differed in frequency by at least 200 Hz; in random order, the second tone pair was either the <u>same</u> or <u>different</u> from the first pair; if different, only one tone of the pair was allowed to be divergent. The tone frequencies were selected from a range of 600 to 6000 Hz; intensities for the various frequencies were equalized to effect an even playback level.

Before each tone set, a pulse from an Uher Dia-Pilot II was added to automatically trigger the start of a trial. Tone sets were separated for periods that ranged from 18 to 30 seconds. Grason-Stadler 1200 Series programming modules assured the precise sequencing of the trigger pulse, tone switching, and tone durations.

Procedure

Before the start of each experimental session, a calibration signal (25 μV) was placed in parallel across amplifier inputs to verify the equality of the final amplifier outputs throughout the data collection network.

After initial electrode preparation, the subject was placed in an electrically shielded, sound attenuating cubicle. The subject lay in a bed adjusted for viewing a closed-circuit TV monitor. The monitor projected a fixation point during experimental conditions; overall screen brightness was adjusted to 0.5 ftL (1.713 cd/m^2) and was essentially the only source of lighting in the cubicle.

A preliminary 15 - 20 minute period at the start of a session allowed the subject to relax momentarily, permitted the electrodes to stabilize, and provided the opportunity for a quick equipment inspection.

Each subject was presented with two experimental conditions. The standard condition (SC) consisted of a 150-millisecond (1000 Hz) tone pip (S_1) followed 3.0 seconds later by clicks (S_2). The subject's task was to terminate the clicks as quickly as possible with a right hand button press. If the button was pressed before the clicks sounded, the clicks were automatically inhibited and the subject was reinstructed on the procedure. Several practice trials were given to the subject to acquaint him with the mode of stimulus presentation. In addition to proper eye fixation, subjects were instructed to adopt a pattern of motor responding that was compatible with recording small electrical signals.

In the tone analysis condition (TA), the subject was instructed to listen to the prerecorded tone sets and to decide whether the second tone pair was the <u>same</u> or <u>different</u> from the first tone pair. When the clicks sounded at the end of a tone set, the subject pressed a button to indicate his decision and to terminate the clicks. The <u>same</u> or <u>different</u> responses were represented on a two-button box that was operated with each hand; the positions of <u>same</u> or <u>different</u> were randomized between subjects. Several practice trials were given to assure that the subject understood the tone task and responded correctly. (Correct or incorrect responses to the tone sets were observed but not recorded.)

For both SC and TA conditions, subjects listened to stimuli from loudspeakers located under the bed. Sound levels measured at the subject's head ranged from 65 - 70 dB; clicks were generated from a Grass S-4 stimulator at a rate of 15/second and were delivered at a level that ranged from 65 - 70 dB re 20 μN/m^2. The standard condition was always administered first.

An average of 16 trials for each condition was collected for each subject. Trials obviously contaminated by eye movement or EMG activity were rejected. For baseline purposes, data collection was started 100 milliseconds before stimulus presentation; the total sweep duration was 3.5 seconds. For both SC and TA conditions, the time between trials ranged from 18 to 30 seconds.

Data Treatment

The data averages collected for each subject were plotted (Houston Instrument Omnigraphic X-Y plotter) for each experimental condition and for each of the electrode sites. Individual data averages were digitally filtered prior to plotting (see Appendix B for filter characteristics) and were centered around a mean baseline voltage determined from the 100-millisecond prestimulation period.

Amplitude measures. Each CNV average was divided into four segments corresponding to the four tone periods. In the tone analysis condition, direct (calipered) vertical measurements were made from a baseline level to a point on the slow wave 50 milliseconds prior to the offset of each tone in the four tone sequence. The same temporal bounds were also used in measuring CNV amplitudes in the standard condition.

A four-factor (2 × 2 × 5 × 4) analysis of variance design with repeated measures on the last three factors was used to evaluate the amplitude measures. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C) by times (D). The analysis of variance computations were carried out using BMD08V of the Health Sciences Computing Facility, UCLA.

Ratio indices of asymmetry. In order to assess the relative proportion of right (R) hemisphere activity to left (L) hemisphere activity, ratios of the form $\underline{R}/(\underline{R} + \underline{L})$ were formed. Ratios were separately derived for homologous frontal, $F_4/(F_4 + F_3)$, and homologous temporal, $T_4/(T_4 + T_3)$, electrode averages for both SC and TA conditions. The CNV activity at an electrode site was estimated by a mean derived from the four vertical measures of amplitude. Ratios that exceeded .50 indicated larger right than left hemisphere activity; ratios below .50 indicated larger left than right hemisphere activity.

A three-factor (2 × 2 × 2) analysis of variance design with repeated measures on the last two factors was performed on the calculated ratios. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations I. Cross-correlations for all subjects were performed between the right frontal (F_4) site in the standard condition and the right frontal (F_4) site in the tone analysis condition;

similarly, cross-correlations between SC and TA were carried out for left frontal (F_3), right temporal (T_4), and left temporal (T_3) locations. (Each cross-correlation value was based on the total averaged waveform, n = 1024.)

A t-test for related measures was used to evaluate differences between right and left frontal correlations; similarly, a t-test was used to evaluate differences between right and left temporal correlations.

Cross-Correlations II. Separate cross-correlations were performed for each subject comparing the vertex (C_z) of the standard condition to each of the lateral electrode placements in SC; likewise, cross-correlations were performed between the vertex (C_z) of the tone analysis condition and each of the lateral placements in TA.

The resulting correlation values were entered into a three-factor (2 × 2 × 4) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations III. Separate cross-correlations were performed for each subject between homologous frontal (F_3 vs F_4) and homologous temporal (T_3 vs T_4) electrode sites for both SC and TA conditions.

The correlations that were obtained were entered into a three-factor (2 × 2 × 2) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations IV. Separate cross-correlations for each subject were performed between right side intrahemispheric placements (F_4 vs T_4) and left side intrahemispheric placements (F_3 vs T_3) for both SC and TA conditions.

The correlation values were entered into a three-factor (2 × 2 × 2) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Results

The analysis of overall treatment effects relied on the analysis of variance. Individual tests of main effects were carried out using Duncan's Multiple-Range Test for significant $\underline{F}$ ratios (Edwards, 1968). Significant interactions were also analyzed using Duncan's Multiple-Range Test among the means at selected levels. In the calculation of the critical ranges, it was the α-level of the significant $\underline{F}$ ratio that normally determined the particular tables entered.

Amplitude Measures

The overall effects between females and males were not significantly different ($\underline{F} < 1$, $\underline{df} = 1/8$, $\underline{p} > .20$). The standard and tone analysis conditions were different at the $\underline{p} < .01$ level ($\underline{F} = 11.38$, $\underline{df} = 1/8$). Significant main effects were found for electrodes ($\underline{F} = 19.70$, $\underline{df} = 4/32$, $\underline{p} < .001$) and for times ($\underline{F} = 9.91$, $\underline{df} = 3/24$, $\underline{p} < .001$). Interactions reaching significant levels included conditions by times ($\underline{F} = 5.29$, $\underline{df} = 3/24$, $\underline{p} < .01$), electrodes by times ($F = 7.93$, $df = 12/96$, $p < .001$), and conditions by electrodes by times ($F = 7.89$, $df = 12/96$, $p < .001$). A summary of the analysis of variance for amplitudes is provided in Appendix C, Table C1.

In order to provide some initial information on the magnitude of the slow potentials that entered the amplitude analysis, overall cell means (converted into μV) for Factors A, B, C, and D were assembled in Table 1.

A pictorial representation of the overall amplitude (Factor B) differences between the standard and tone analysis conditions is shown in Figure 7. The overall CNV activity at each electrode (Factor C) site is shown in Figure 8. The vertex (C_z) was larger than any of the other recorded sites ($p < .001$); and although F_4 and T_4 locations were slightly larger than their homologous counterparts, the differences between frontal (F_3 and F_4) and between temporal (T_3 and T_4) sites were not significant ($p > .05$). The Duncan range tests among the means of Factor C are shown in Appendix D, Table D1.

The overall mean amplitudes for each of the separate time periods (Factor D) are illustrated in Figure 9. Time periods 1 and 2 were both larger than Time 4 ($p < .001$); however, Times 1 and 2 were not different from each other ($p > .05$). The Duncan range tests among the means of Factor D are shown in Appendix D, Table D2.

In order to assess the lateral distribution of slow wave activity during the standard and tone analysis conditions, the non-significant conditions by electrodes (B × C) interaction was analyzed. The means (μV) involved in the interaction are shown in Table 2. In the standard condition, no differences were found between frontal

Table 1

Overall Cell Means from the Analysis of Variance for CNV Amplitude Measures

Factors	Amplitude (μV)
A (Sex)	
A1 (Female)	14.46
A2 (Male)	14.49
B (Conditions)	
B1 (Standard)	8.26
B2 (Tone Analysis)	20.68
C (Electrodes)	
C1 (C_z)	23.74
C2 (F_3)	12.30
C3 (F_4)	14.24
C4 (T_3)	10.49
C5 (T_4)	11.59
D (Times)	
D1 (Time 1)	18.24
D2 (Time 2)	15.93
D3 (Time 3)	15.42
D4 (Time 4)	8.30

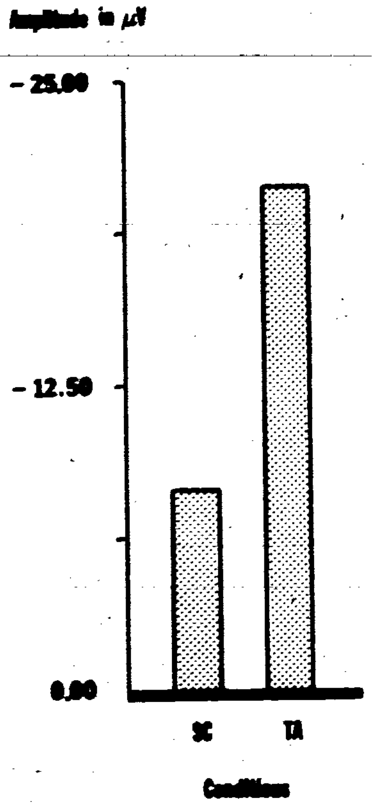


Figure 7

Overall Mean CNV Amplitudes for the Standard and Tone Analysis Conditions

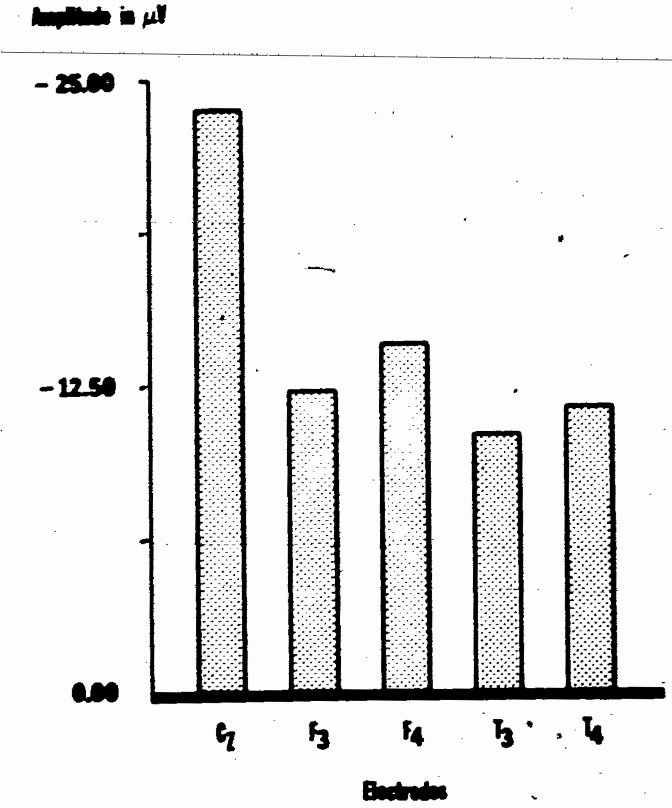


Figure 8

Overall Mean CNV Amplitudes at Each of the Active Electrode Sites

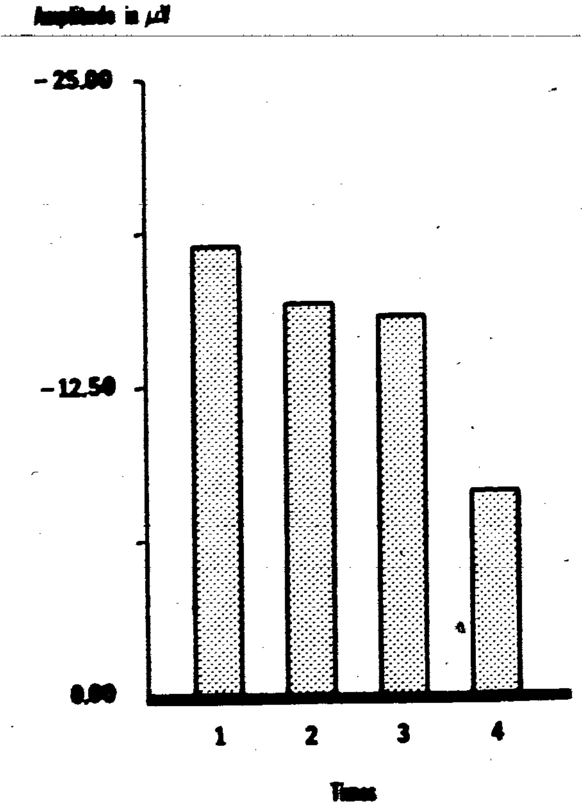


Figure 9

Overall Mean CNV Amplitudes for Each of the Separate Time Periods

Table 2

Mean CNV Amplitudes for the Nonsignificant Conditions by Electrodes Interaction

Experimental Condition	Electrode Site (Amplitude in μV)				
	C_z	F_3	F_4	T_3	T_4
Standard	16.58	5.59	6.39	5.55	7.16
Tone Analysis	30.87	19.00	22.08	15.42	15.99

(F_3 and F_4) or temporal (T_3 and T_4) electrode sites ($p > .05$); in tone analysis, no amplitude differences were found between frontal (F_3 and F_4) or temporal (T_3 and T_4) sites ($p > .05$). The vertex (C_z) site for both SC and TA conditions was larger than any of the lateral sites ($p < .05$). In TA, the right frontal (F_4) site was larger than either the left temporal (T_3) or right temporal (T_4) electrode locations ($p < .05$). The Duncan range tests among the means for the standard condition (B = 1) and the tone analysis condition (B = 2) across electrodes are shown in Appendix D, Tables D3 and D4, respectively.

The mean amplitudes involved in the conditions by times (B × D) interaction are illustrated in Figure 10. In the standard condition, the separate time period amplitudes decreased during the CNV interval; however, none of the time periods were different from each other ($p > .01$). In the tone analysis condition, the first three time period amplitudes were of approximately the same magnitude; however, each were separately different from the last (D = 4) time period amplitude ($p < .01$). The Duncan range tests among the means for the standard condition (B = 1) across times and the tone analysis condition (B = 2) across times are shown in Appendix D, Tables D5 and D6, respectively.

The mean amplitudes involved in the electrodes by times (C × D) interaction are illustrated in Figure 11. For the vertex (C_z) location, D = 1, 2, and 3 were separately larger than D = 4 ($p < .001$); For the left frontal site (F_3), D = 1 was separately larger than D = 2, 3, or 4 ($p < .001$); D = 2 and D = 3 were separately larger than D = 4 ($p < .001$). For the right frontal site (F_4), D = 1, 2, and 3 were separately larger than D = 4 ($p < .001$); D = 1 was also larger than

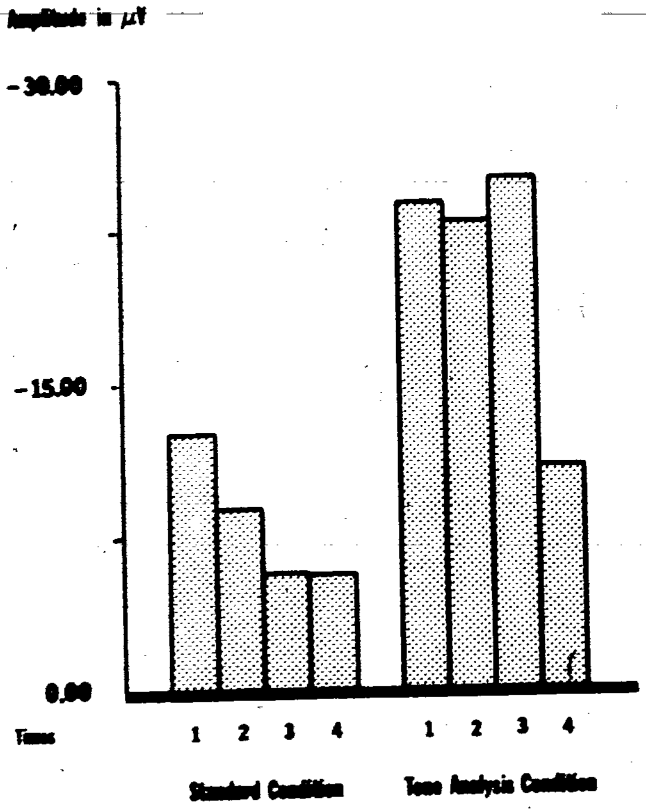


Figure 10

Mean CNV Amplitudes for Each of the Time Periods in Both the Standard and Tone Analysis Conditions

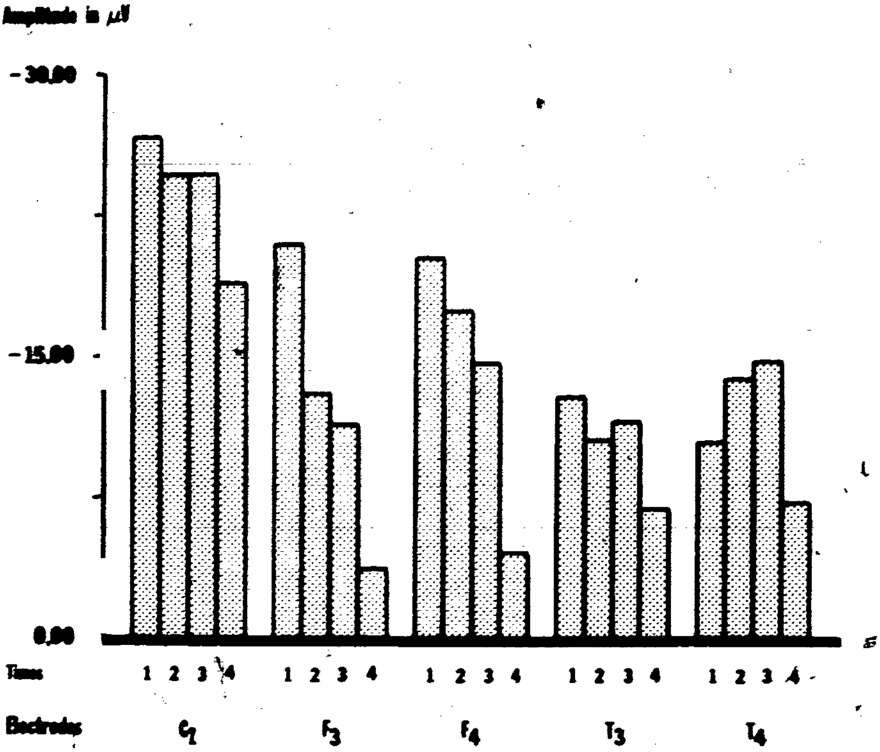


Figure 11

Mean CNV Amplitudes for Each of the Time Periods at Each of the Active Electrode Sites

D = 3 ($p < .001$). In the left temporal (T_3) records, D = 1 was larger than D = 4 ($p < .001$). In the right temporal (T_4) records, D = 2 and D = 3 were separately larger than D = 4 ($p < .001$). The Duncan range tests among the means for the vertex (C_z), left frontal (F_3), right frontal (F_4), left temporal (T_3), and right temporal (T_4) sites across times are shown in Appendix D, Tables D7, D8, D9, D10, and D11, respectively.

The significant B × C × D interaction further separated conditions, electrodes, and times. The mean amplitudes involved in the interaction are illustrated in Figure 12. For the vertex (C_z) site in the standard condition, D = 1 was separately larger than D = 2, 3, or 4 ($p < .001$); also, D = 2 was larger than either D = 3 or D = 4 ($p < .001$). For the left frontal (F_3) site in SC, D = 1 was larger than either D = 2, 3, or 4 ($p < .001$). For the right frontal (F_4) site in SC, D = 1 was larger than D = 3 or D = 4 ($p < .001$); also, D = 2 was larger than D = 4 ($p < .001$). For the left temporal (T_3) site in SC, only D = 1 was larger than D = 3 ($p < .001$). For the right temporal (T_4) site in SC, no signigicant differences were found among the time periods ($p > .001$). The Duncan range tests among the means in the standard condition for the vertex (C_z), left frontal (F_3), right frontal (F_4), left temporal (T_3), and right temporal (T_4) sites across times are shown in Appendix D, Tables D12, D13, D14, D15, and D16, respectively. For the vertex (C_z) in the tone analysis condition, D = 3 was larger than either D = 1, 2, or 4 ($p < .001$). For the left frontal (F_3) site in TA, D = 1 was larger than either D = 2, 3, or 4 ($p < .001$); also, D = 2 and D = 3 were both larger than D = 4

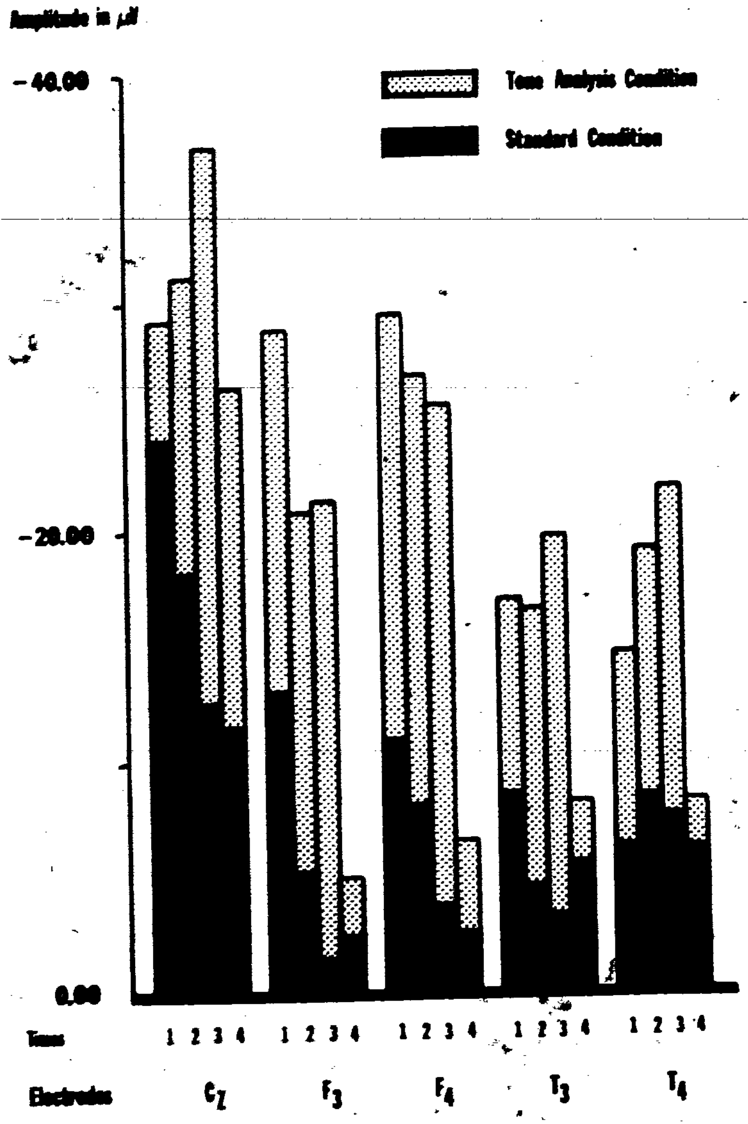


Figure 12

Mean CNV Amplitudes for Each of the Time Periods at Each of the Active Electrode Sites for Both the Standard and Tone Analysis Conditions

($\underline{p} < .001$). For the right frontal (F_4) site in TA, D = 1, 2, and 3 were separately larger than D = 4 ($\underline{p} < .001$). For the left temporal (T_3) site in TA, D = 1, 2, and 3 were separately larger than D = 4 ($\underline{p} < .001$). For the right temporal (T_4) site in TA, D = 1, 2, and 3 were separately larger than D = 4 ($\underline{p} < .001$); also, D = 3 was larger than D = 1 ($\underline{p} < .001$). The Duncan range tests among the means in the tone analysis condition for the vertex (C_z), left frontal (F_3), right frontal (F_4), left temporal (T_3), and right temporal (T_4) sites across times are shown in Appendix D, Tables D17, D18, D19, D20, and D21, respectively.

The superimposed plots of averaged slow wave activity for each active electrode site for all the subjects in the standard condition are illustrated in Figure 13. Similarly, the superimposed plots of averaged slow wave activity for each active electrode site for all subjects in the tone analysis condition are illustrated in Figure 14. In order to provide an overall pattern of slow wave activity, averages were pooled across each electrode site for all subjects in the standard condition; the pooled averages for each active site in SC were plotted and are illustrated in Figure 15. Likewise, averages were pooled across each electrode site for all subjects in the tone analysis condition; the pooled averages for each active site in TA were plotted and are illustrated in Figure 16. (Pooled averages were not filtered prior to averaging or plotting.)

The prominent undulating pattern of the slow wave averages during tone analysis was also quite prominent in the raw EEG record. As an example, two trials that separately extended over an 8.0-second

Figure 13

Overlayed CNV Averages for Each Subject at Each Active Electrode Site in the Standard Condition

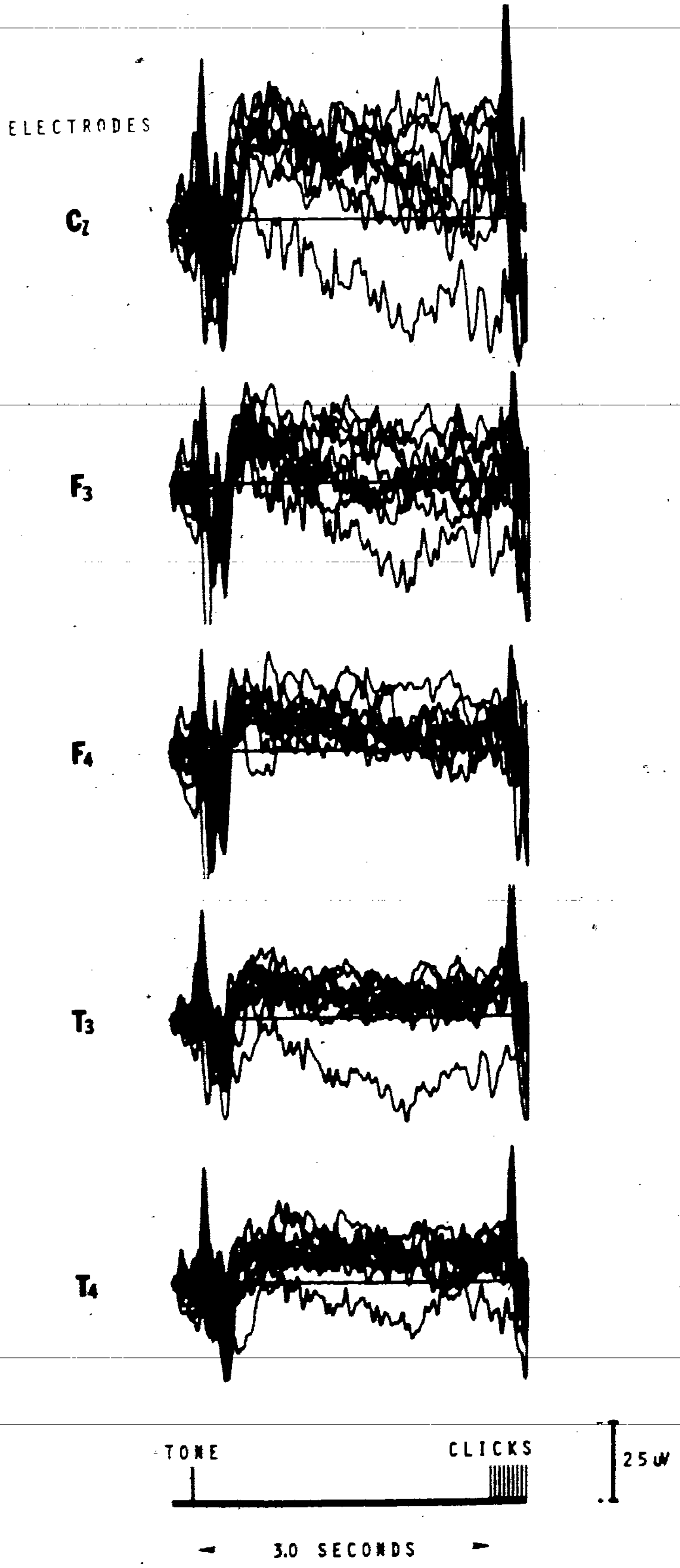

ELECTRODES
C_z
F_3
F_4
T_3
T_4
TONE
CLICKS
25 µV
3.0 SECONDS

Figure 14

Overlayed CNV Averages for Each Subject at Each Active Electrode Site in the Tone Analysis Condition

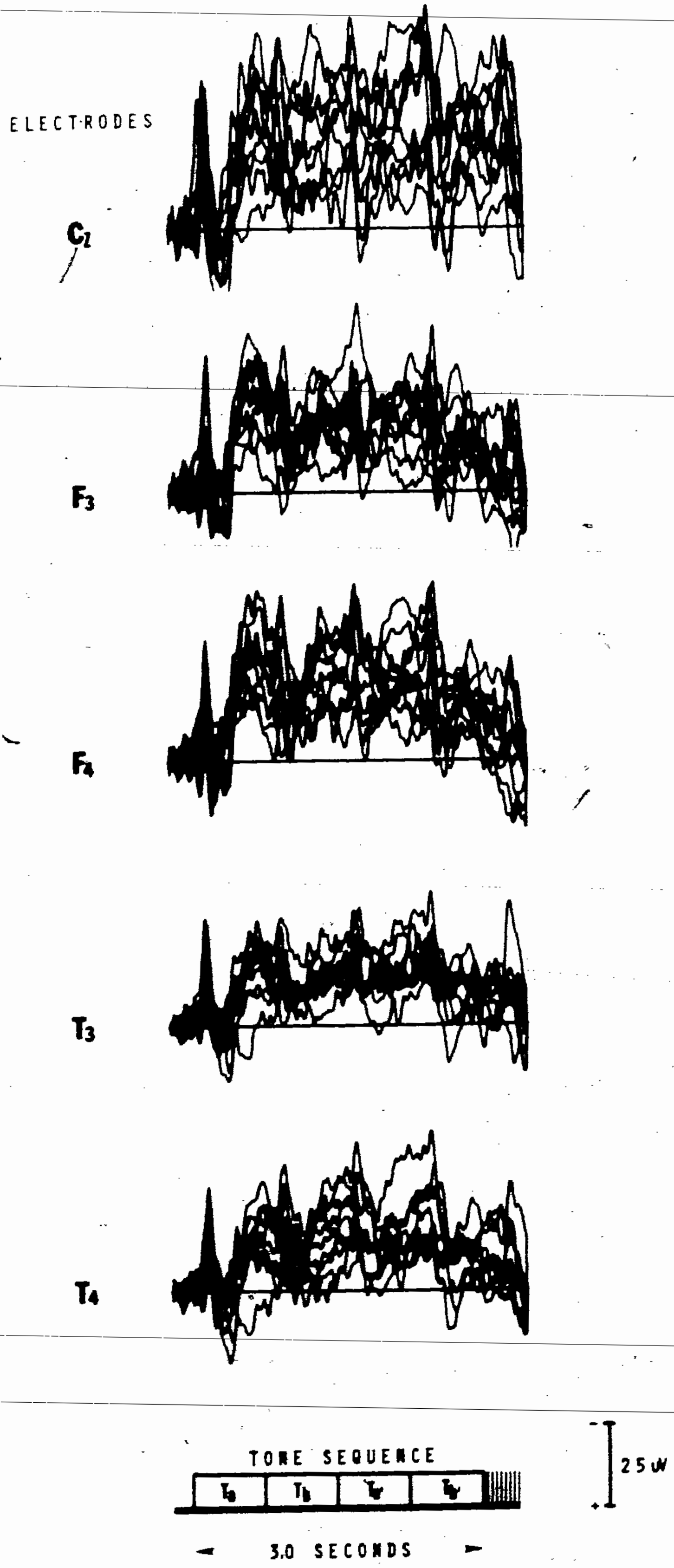

ELECTRODES
Cz
F3
F4
T3
T4
TONE SEQUENCE
Ta
Tb
25 uV
3.0 SECONDS

Figure 15

Pooled CNV Averages for Each Active Electrode
Site in the Standard Condition

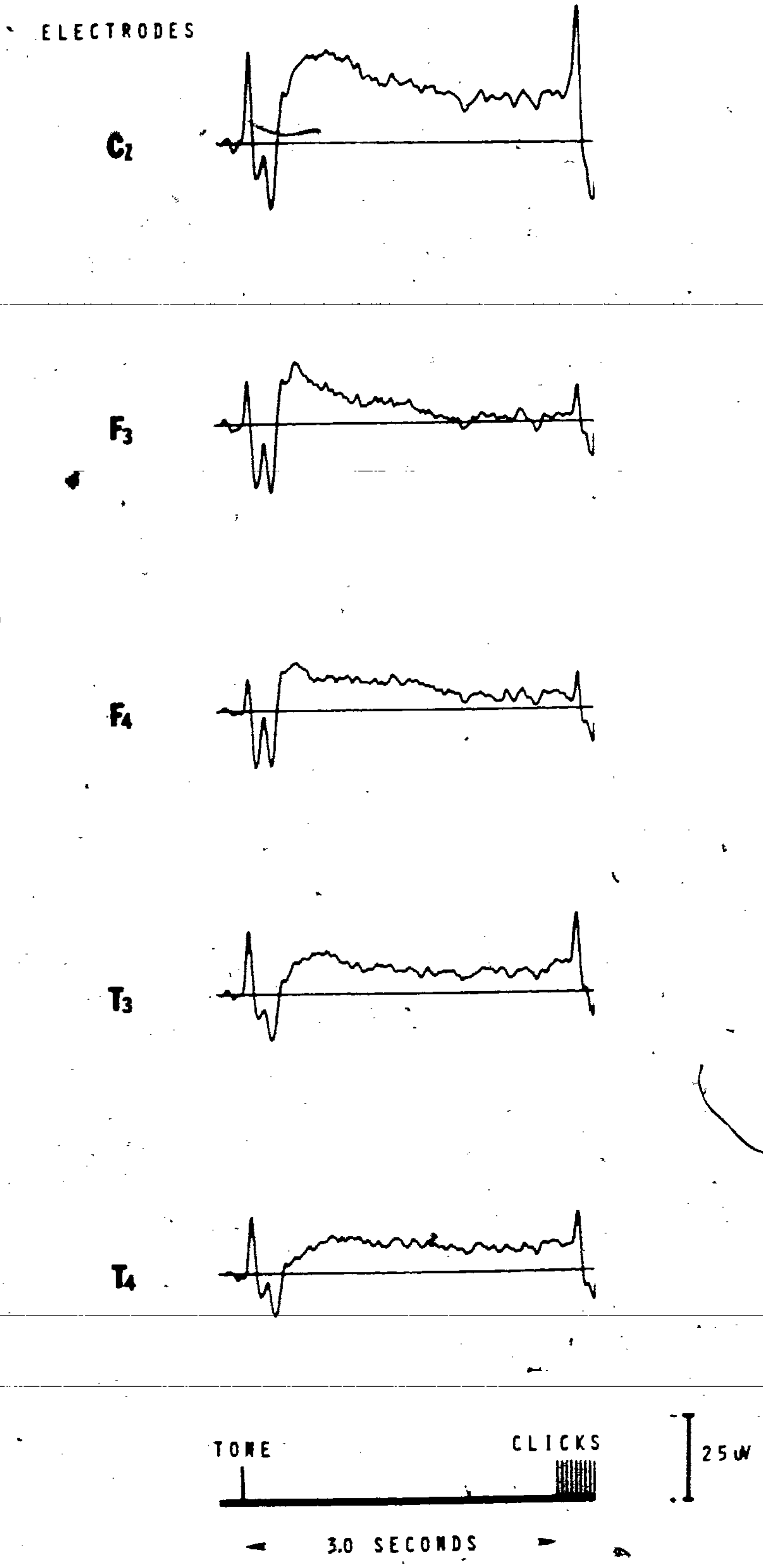
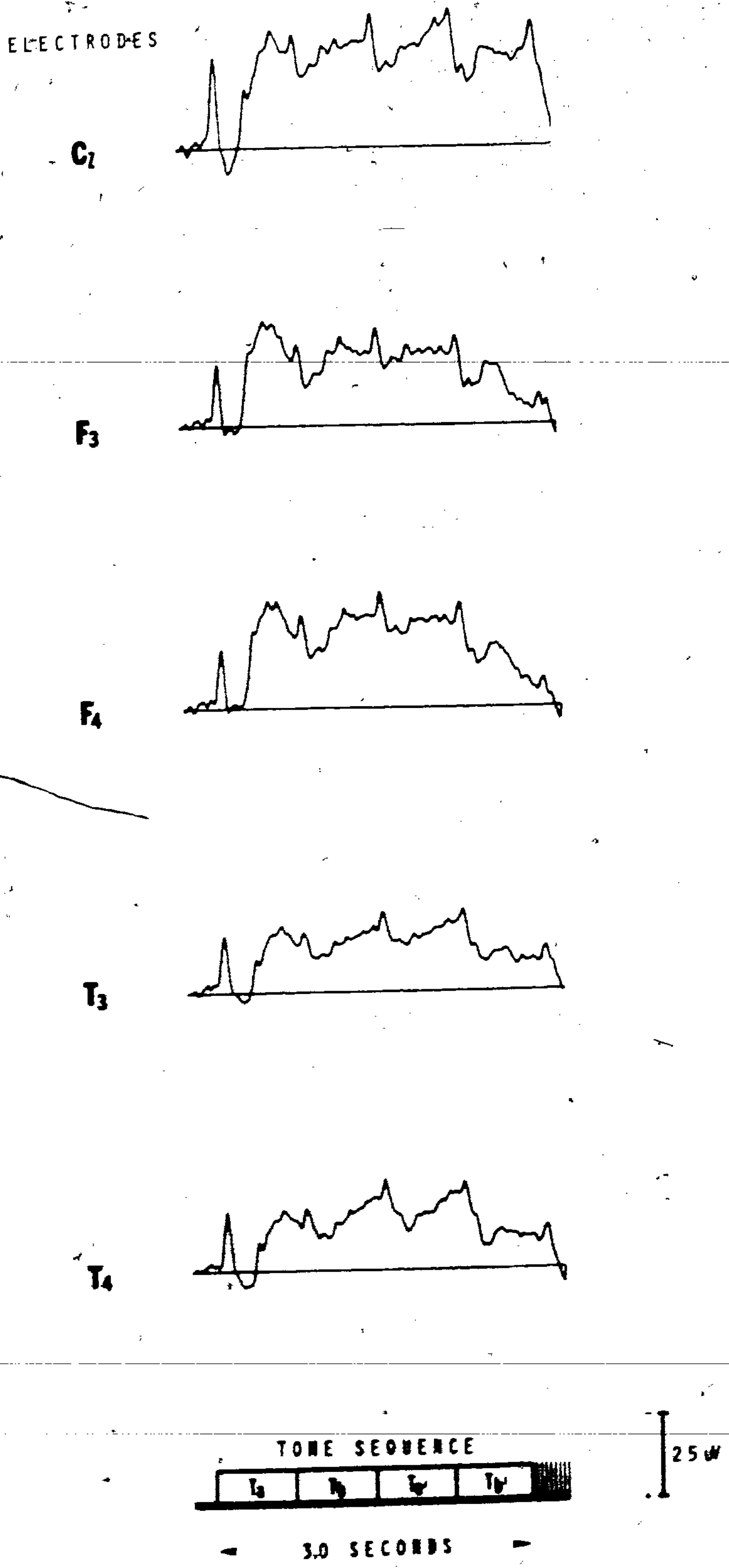

ELECTRODES
Cz
F3
F4
T3
T4
TONE
CLICKS
25 μV
3.0 SECONDS

Figure 16

Pooled CNV Averages for Each Active Electrode Site in the Tone Analysis Condition


ELECTRODES
Cz
F3
F4
T3
T4
TONE SEQUENCE
3.0 SECONDS
25 µV

period in the tone analysis condition are shown for subject J. M. in Figure 17.

Ratio Indices of Asymmetry

The ratio indices of asymmetry indicated that females displayed larger overall right hemisphere activity (.58) than males (.47), respectively ($F = 5.72$, $df = 1/8$, $p < .05$). The F ratios for conditions ($F < 1$, $df = 1/8$, $p > .20$) and electrodes ($F < 1$, $df = 1/8$, $p > .20$) did not reach significant levels. A summary of the analysis of variance for ratios is provided in Appendix C, Table C2.

The mean frontal ratios and the mean temporal ratios for both females and males in both SC and TA conditions are presented in Table 3. For the females, there was a tendency for the ratios to decrease in the TA condition; for the males, there was a tendency for the frontal ratio to increase slightly in TA, whereas the temporal ratio decreased slightly in TA. The conditions by electrodes (B × C) interaction approached a significant level ($F = 4.01$, $df = 1/8$, $p > .05$).

Cross-Correlations I

The cross-correlations of an electrode site in SC and the same site in TA yielded no significant differences between left and right frontal sites ($t = .96$, $df = 9$, $p > .10$) or between left and right temporal sites ($t = .59$, $df = 9$, $p > .50$). The mean cross-correlation values between left and right frontal sites were .40 and .37, respectively; the mean cross-correlation values between left and right temporal sites were .45 and .43, respectively.

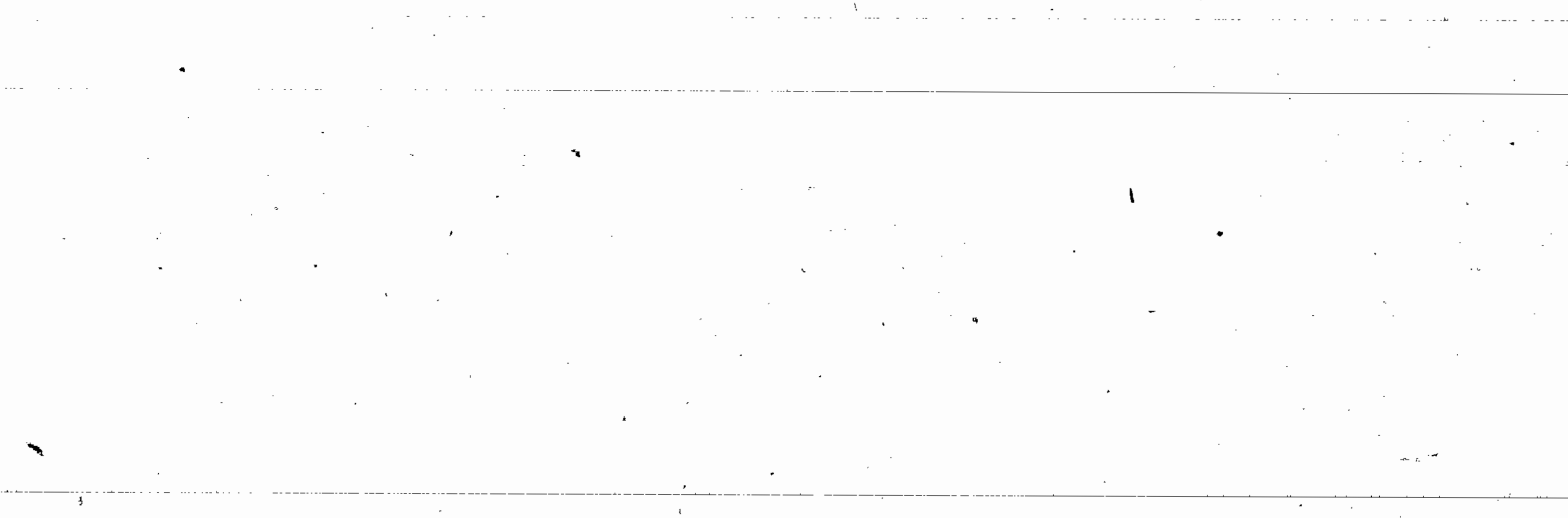
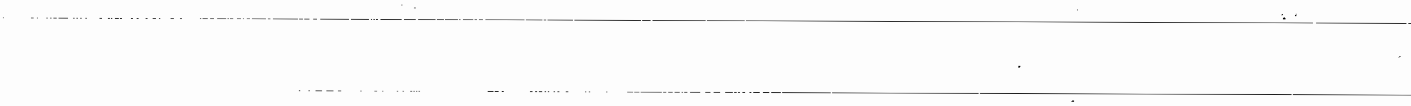


Figure 17

Raw Record Traces of CNV Activity for Subject J. M. in the Tone Analysis Condition



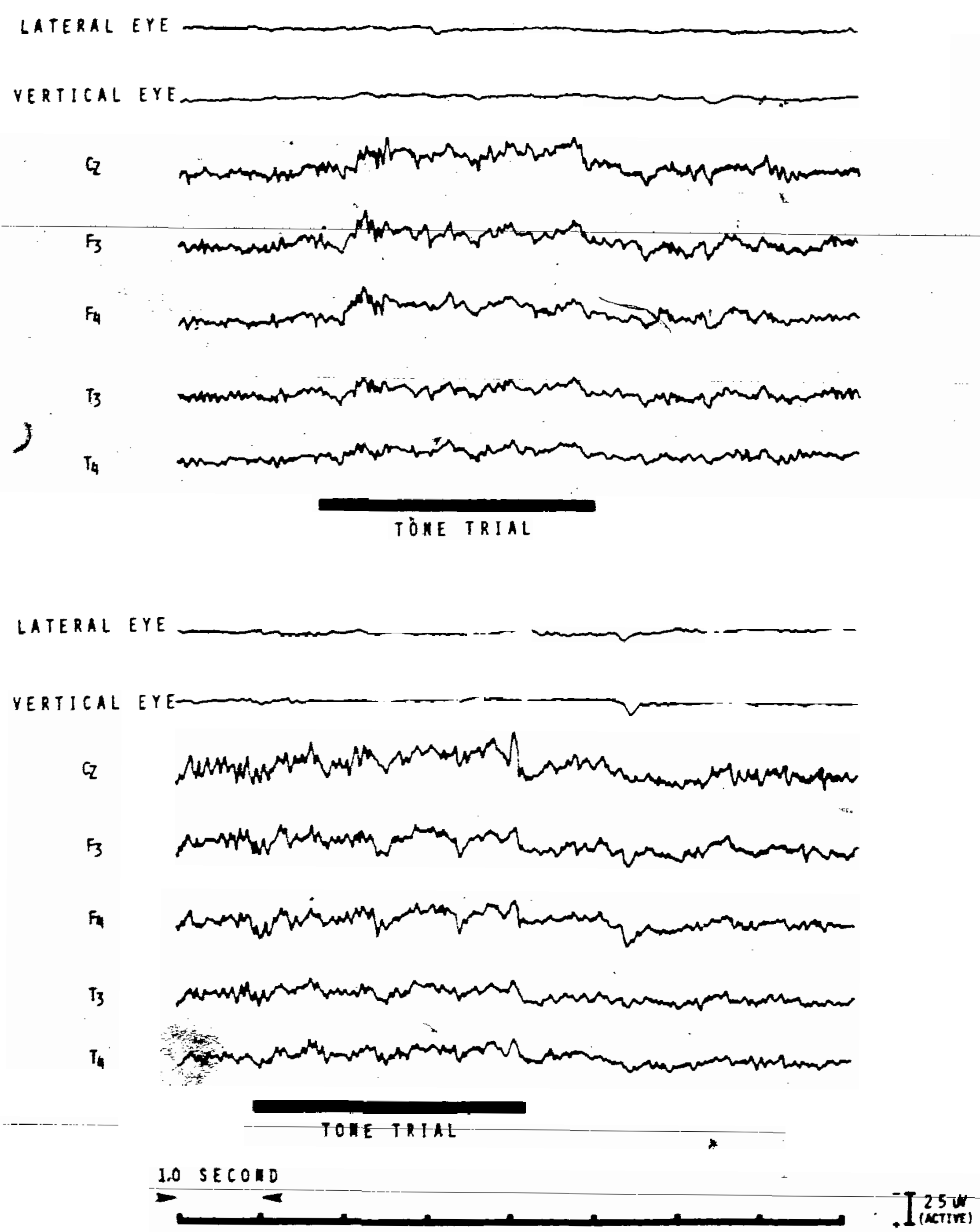

LATERAL EYE
VERTICAL EYE
Cz
F3
F4
T3
T4
TONE TRIAL
LATERAL EYE
VERTICAL EYE
Cz
F3
F4
T3
T4
TONE TRIAL
1.0 SECOND
25 µV
(ACTIVE)

Table 3

Mean Frontal Ratios and Mean Temporal Ratios for Females and Males in Both the Standard and Tone Analysis Conditions

Experimental Condition	Frontal Ratio ($F_4/[F_4 + F_3]$)		Temporal Ratio ($T_4/[T_4 + T_3]$)	
	Female	Male	Female	Male
Standard	.62	.42	.62	.48
Tone Analysis	.60	.49	.50	.48

Cross-Correlations II

Cross-correlations were computed between the vertex (C_z) of each experimental condition and each of the corresponding lateral electrode placements. The F ratios for sex ($F < 1$, $df = 1/8$, $p > .20$) and conditions ($F = 1.15$, $df = 1/8$, $p > .20$) did not reach significant levels. There was a significant effect for electrodes ($F = 7.93$, $df = 3/24$, $p < .001$). The summary of the analysis of variance for Cross-Correlations II is provided in Appendix C, Table C3. For both females and males, Cross-Correlation II means for frontal and temporal sites in both SC and TA conditions are shown in Table 4.

In further analyzing the electrodes effect, the right temporal (T_4) correlations were larger than left frontal (F_3) correlations ($p < .001$). Homologous frontal and homologous temporal sites did not differ from each other ($p > .001$). The Duncan range tests among the means of Factor C are shown in Appendix D, Table D22.

Cross-Correlations III

Cross-correlations were separately calculated for the homologous frontal and homologous temporal electrode sites for each of the experimental conditions. The F ratio for sex was not significant ($F < 1$, $df = 1/8$, $p > .20$). There was a significant conditions effect ($F = 10.44$, $df = 1/8$, $p < .025$) and electrodes effect ($F = 11.12$, $df = 1/8$, $p < .025$). A summary of the analysis of variance for Cross-Correlations III is provided in Appendix C, Table C4.

There was a tendency for higher cross-correlations in TA than in SC. For both SC and TA conditions, there was a tendency for

Table 4

Mean Cross-Correlation II Values for Frontal and Temporal Electrode Sites for Females and Males in Both the Standard and Tone Analysis Conditions

Experimental Condition	Electrode Site							
	F_3		F_4		T_3		T_4	
	F	M	F	M	F	M	F	M
Standard	.66	.82	.74	.77	.84	.85	.85	.83
Tone Analysis	.70	.73	.79	.71	.80	.79	.87	.79

Note. F = female, M = male.

higher correlations in the frontal than temporal locations. For both females and males, Cross-Correlation III means for frontal and temporal sites in both SC and TA conditions are shown in Table 5. The lack of a significant conditions by electrodes (B × C) interaction (_F_ < 1, _df_ = 1/8, _p_ $> .20$) provided evidence that no overall change in waveform between homologous sites occurred from SC to TA conditions.

Cross-Correlations IV

Separate cross-correlations were performed between left side intrahemispheric placements and right side intrahemispheric placements for both SC and TA conditions. No significant _F_ ratios were found for sex (_F_ = 2.01, _df_ = 1/8, _p_ $> .10$), conditions (_F_ = 1.12, _df_ = 1/8, _p_ $> .20$), or electrodes (_F_ < 1, _df_ = 1/8, _p_ $> .20$). A summary of the analysis of variance for Cross-Correlations IV is provided in Appendix C, Table C5. For both females and males, Cross-Correlation IV means for left side and right side locations in both SC and TA conditions are shown in Table 6.

Discussion

One of the outstanding features between the two experimental conditions was the overall increase in amplitudes produced by the tone analysis (TA) condition. This increase occurred at the vertex (C_z) as well as at frontal (F_3, F_4) and temporal (T_3, T_4) electrode locations. The amplitudes at the lateral placements were larger than those normally recorded for a standard (or SC) CNV paradigm (see J. Cohen, 1969; Low, 1969). From the results of distraction experiments, one

Table 5

Mean Cross-Correlation III Values for Frontal and Temporal Electrode Sites for Females and Males in Both the Standard and Tone Analysis Conditions

Experimental Condition	Frontal Electrodes (F_3 vs F_4)		Temporal Electrodes (T_3 vs T_4)	
	Female	Male	Female	Male
Standard	.86	.84	.83	.75
Tone Analysis	.88	.92	.85	.84

Table 6

Mean Cross-Correlation IV Values for Intrahemispheric Electrode Sites for Females and Males in Both the Standard and Tone Analysis Conditions

Experimental Condition	Left Side Electrodes (F_3 vs T_3)		Right Side Electrodes (F_4 vs T_4)	
	Female	Male	Female	Male
Standard	.75	.85	.75	.86
Tone Analysis	.75	.89	.80	.89

might have suspected that the tone condition would have reduced slow potential activity. Another distinct feature of the tone condition was the scalloping effect of the slow potential during the 4-tone presentation (see Figures 14, 16, & 17). The evoked potentials at the onset and offset of each tone partitioned the slow wave into separate sections. Low and McSherry (1968) observed a similar scalloping (as well as magnitude increase) in the CNV during a task that induced multiple anticipation by requiring an additional response from subjects already within an expectancy situation. McCallum (Note 30) has also reported an undulating effect in the CNV during a vigilance task.

Given the very strong conditions effect, differential CNV activity between homologous sites did not emerge. The small overall amplitude differences of lateral and oppositely placed electrodes did not reach significant levels. Separately analyzed by condition, amplitudes for homologous sites were not different from each other in either the standard or tone analysis conditions. The mandatory right hand button press in the standard condition did not appear to alter the slow wave balance between the hemispheres. This is in agreement with the findings of Weinberg and Papakostopoulos (Note 25).

No significant right or left intrahemispheric amplitude differences were found for the standard condition; in the tone analysis condition, the right frontal (F_4) site was larger than the right temporal (T_4) or left temporal (T_3) sites. Left hemisphere electrodes in TA were not different from each other at the significance levels tested.

The four separate amplitude measures made across the S_1-S_2

interval roughly reflected the general shape of the averaged slow potential. There was a decline in slow wave activity for succeeding time periods, especially Time 4. The reasons for the various interactions of the period measure (Factor D) with conditions (Factor B), electrodes (Factor C), and conditions by electrodes (B × C) can be seen summarized in Figure 12; similarly, the interaction effects can be visualized in the overlayed records (Figures 13 and 14) and the pooled averages (Figures 15 and 16) of both experimental conditions. For the most part, electrode sites in the standard condition displayed a decline in slow wave activity through the CNV interval; in the tone analysis condition, however, slow wave activity at some sites increased during the CNV interval.

The subject's task in the tone analysis condition was not difficult since most subjects were at least 90% correct in their judgments. From the design of the experiment, they probably made their decision about the tone pairs soon after the onset of the last tone. This corresponded with the decreased amplitudes recorded during the fourth period (Time 4). For each of the lateral electrode placements in TA, the first three periods were all at higher levels than the fourth period. From the various range tests that were computed, homologously placed sites in TA did not differentially resolve slow wave activity at Time 4. In the standard condition, differences in Factor D at the various electrode sites were either not there or were inconsistent.

The ratio indices of asymmetry indicated that larger overall activity occurred for females than for males. For females, the temporal ratios tended to show less right hemisphere asymmetry in TA than in SC.

Although the waveforms for an electrode location between experimental conditions were dissimilar, comparisons of homologous placements did not indicate differential activity from SC to TA. Cross-correlations that separately compared lateral placements to the vertex (C_Z) tended to show higher correlations for the temporal than for the frontal locations in both SC and TA. Cross-correlations for intrahemispheric electrode locations did not indicate any differential activity between the experimental conditions. To the extent that the tone condition represented a musical experience, the functional asymmetries ascribed to the right hemisphere by Milner (1962), Shankweiler (1966), and Kimura (1964, 1967) were not supported.

Even though no distinct lateralization effects were found in the statistical treatment of the data, the tone analysis condition did produce individual cases of marked hemispheric asymmetries. For example, the plotted averages for subject A. K. (male) are illustrated in Figure 18 for both SC and TA conditions. Compared to the distribution that existed in SC, visual inspection of the records during TA indicated that larger slow potentials were generated over the right than left hemisphere. On the other hand, the averages obtained for subject D. M. (male) are shown in Figure 19 for both SC and TA conditions. Compared to the standard condition, the frontal site on the left hemisphere produced larger CNV activity in TA than the frontal site on the right hemisphere. No doubt, due to the inconsistency of lateralization effects between individual subjects (males as well as

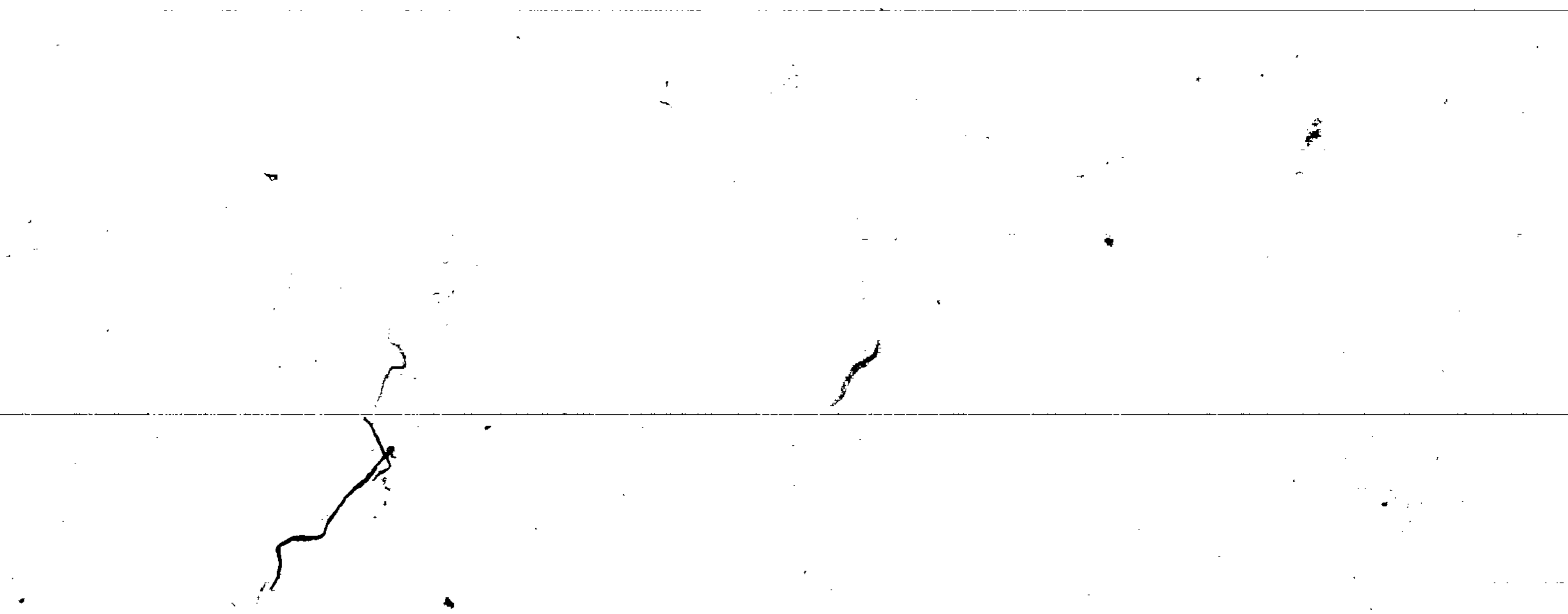


Figure 18

Symmetrical and Asymmetrical CNV Averages for Subject A. K. in the Standard and Tone Analysis Conditions

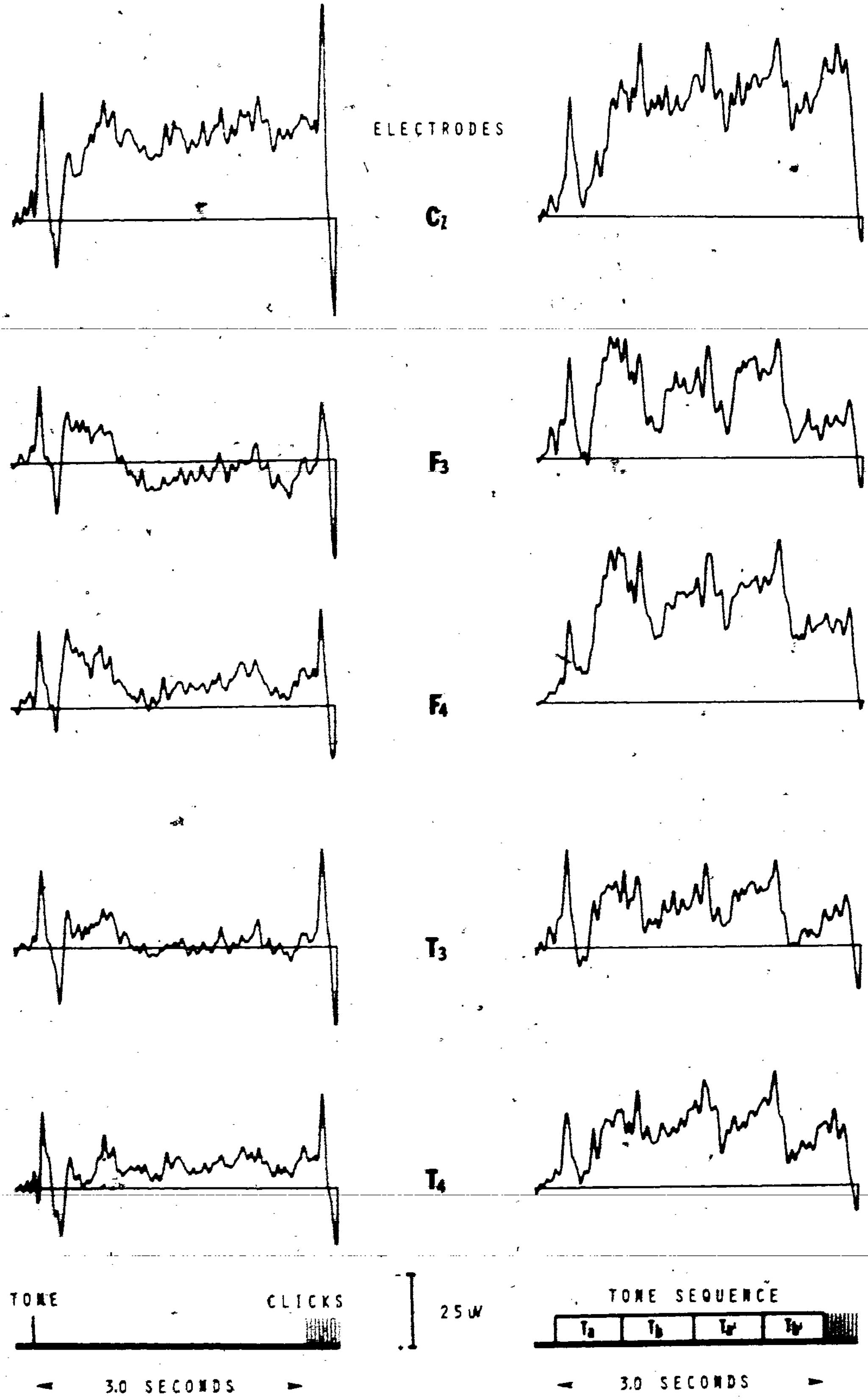
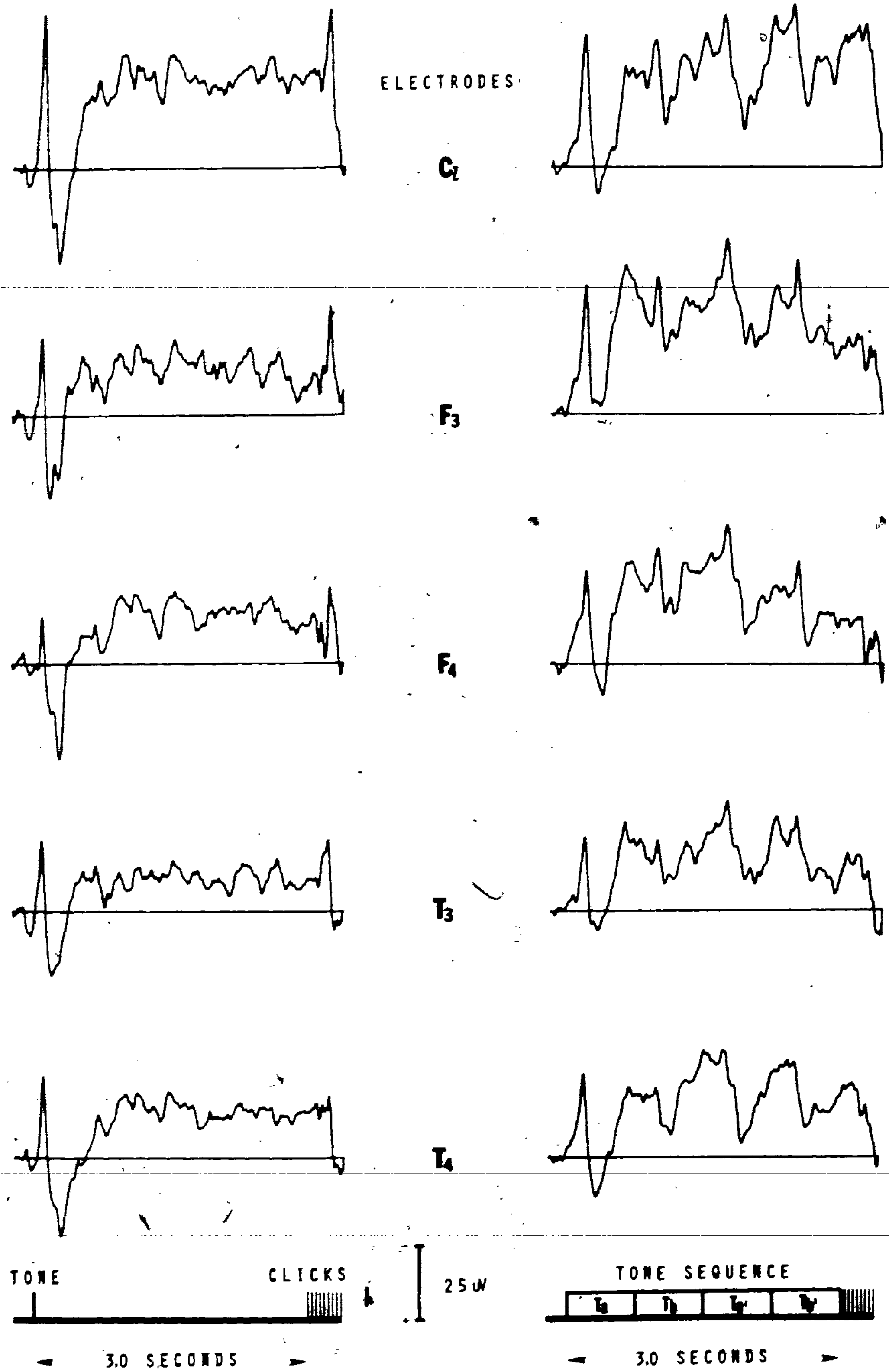

ELECTRODES
Cz
F3
F4
T3
T4
TONE
CLICKS
3.0 SECONDS
25 µV
TONE SEQUENCE
Ta
Tb
Ta'
Tb'
3.0 SECONDS

Figure 19

Symmetrical and Asymmetrical CNV Averages for
Subject D. M. in the Standard and Tone
Analysis Conditions


ELECTRODES
C_z
F_3
F_4
T_3
T_4
TONE
CLICKS
25 µV
3.0 SECONDS
TONE SEQUENCE
T_a
T_b
$T_{a'}$
$T_{b'}$
3.0 SECONDS

females), those instances of clear hemispheric differentiation were lost when subjected to variance analysis.

In summarizing the various analyses, the tone analysis condition was effective in increasing slow potential activity from the standard condition over all scalp sites. Certain amplitude aspects of slow wave activity were related to a simple decision process. Sex differences among the various analyses were minimal or nonexistent. Lateralization effects for slow wave activity were not present; but as the examples of individual records indicated, amplitude asymmetries were observed in TA for several subjects.

Flash Analysis

Based on the results of the tone analysis experiment, an additional brief study was performed. A situation analogous to TA was designed for presentation in the visual modality. The answers to two questions were sought: (a) Would an analysis of flash brightnesses produce a scalloped effect on the slow potential similar to that found for TA? and (b) Would the process of analyzing flash presentations increase overall CNV activity?

Apparatus and Recording Techniques

A special projector was designed and constructed in order to temporally present four flashes in discrete steps of intensity. A light-dimmer circuit was modified to operate an incandescent lamp at selected levels by a simple resistance change. The light from the lamp was projected onto a circular ground-glass screen. In order to minimize color change with intensity, the lamp was operated at the high end of its brightness range. Neutral density filters were added to reduce brightness to a baseline level. Switch selectable potentiometers were adjusted to produce three brightness levels above a continuous level of 25 ftL (85.656 cd/m^2): (1) 50 ftL (171.313 cd/m^2), (2) 75 ftL (256.969 cd/m^2), and (3) 100 ftL (342.626 cd/m^2). Fixation of the 2° screen was aided by a centrally placed, marked dot.

Flash sequences were preset before the start of each trial. The first flash-pair differed by at least one brightness step; randomly, the second pair of flashes was the *same* or *different* from the first flash-pair; if different, only one flash of the second flash-pair was divergent. For example, a *same* sequence might consist of steps 1-2-1-2; a *different* sequence might consist of steps 1-2-1-3. The duration of each flash was 750 milliseconds for a total flash period of 3.0 seconds. The timing and step switching were controlled by Grason-Stadler programming modules.

Scalp recordings were collected from three practiced, right-handed male subjects. Referenced to linked mastoids, active sites included the vertex (C$_z$), left frontal (F$_3$), right frontal (F$_4$), left occipital (O$_1$), and right occipital (O$_2$) locations. Vertical eye movements were monitored with electrodes placed above and below the right eye; an additional electrode was attached to the forehead in order to gound the subject. Amplifier sensitivity was adjusted to 50 µV/cm for active electrode sites; time constants were set at 5.0 seconds with upper cutoff frequencies set at 30 Hz. Data collection and recording followed the procedures described in the Methods section of this chapter.

Procedures and Results

Three experimental conditions were administered to each of the subjects: (a) a standard condition (SC), (b) a flash analysis condition (FA), and (c) a long flash condition (LF). In the standard condition, a brief flash (150 milliseconds at intensity 2) was followed 3.0 seconds later by clicks. The subject terminated the clicks as quickly as possible with a right hand button press. The flash analysis condition presented the subject with flash sets; the subject determined whether the second flash-pair was the same or different from the first flash-pair. The subject made his response by pressing with the right hand for a same judgment or with the left hand for a different judgment. The response also terminated clicks that sounded at the offset of the last flash. (Correct or incorrect responses were observed but were not recorded.) Finally, the long flash condition presented a continuous flash at one of the three intensity levels (randomly selected). At the end of the 3.0-second long flash, clicks sounded and were terminated by a right hand button press. The SC condition was administered first with the order of each of the other conditions randomly determined for each subject.

Individual trials for all conditions were separated by periods that ranged from 18 to 30 seconds in duration. The total sweep time was 3.5 seconds; for baseline purposes, data collection started 100 milliseconds prior to stimulus onset. Averages for each of the conditions consisted of 16 trials.

Averages for the three conditions were plotted for each subject. A visual inspection of the results indicated that during FA the slow wave was scalloped. This effect was present over the various active sites and is shown for subject H. M. in Figure 20. The overall averages that were gathered for subject H. M. are illustrated in Figure 21 for SC, FA, and LF conditions. The data from the other subjects showed a similar pattern of slow wave activity.

Further, single trials in LF were retrieved for each of the brightness steps and were separately averaged across electrode site for each subject. The slow wave averages that resulted were plotted across the three brightness steps. The results for subject H. M. are shown in Figure 22. The CNV magnitudes in LF were estimated by an area measurement. For each of the averages, a horizontal line was constructed from the positive most component of the evoked potential at flash onset to a point 50 milliseconds prior to the offset of the long flash; from there the line was moved perpendicularly to intersect the slow wave. The areas bounded by the slow wave and the constructed line segments were measured with a compensating planimeter. The resulting areas for each electrode site were scaled into μV-seconds and then normalized into μV. The amplitude densities for the three brightness steps are shown for subject H. M. in Figure 23. The amplitudes for the vertex (C_Z) site tended to decline with increased brightness; in contrast, lateral frontal placements tended to be lower at midrange than at either lower or higher levels; lateral occipital sites did not appear to shift across brightness steps.

A note about lateralization effects should be mentioned. In

Figure 20

CNV Averages for Subject H. M. at Each Active Electrode Site during the Flash Analysis Condition

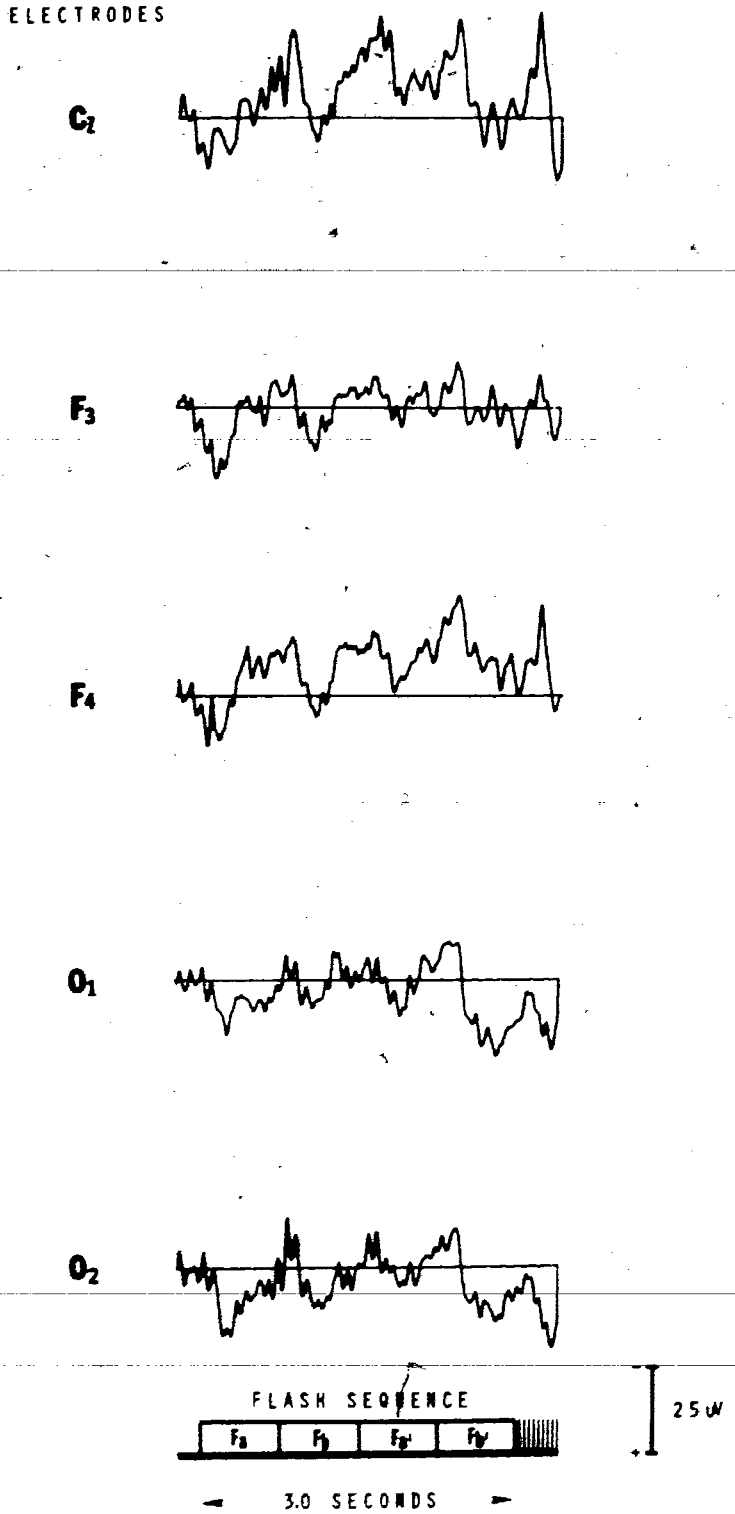

ELECTRODES
C_Z
F_3
F_4
O_1
O_2
FLASH SEQUENCE
F_a
F_b
$F_{a'}$
$F_{b'}$
25 µV
3.0 SECONDS

Figure 21

CNV Averages for Subject H. M. at Each Active Electrode
Site for the Standard, Flash Analysis, and
Long Flash Conditions

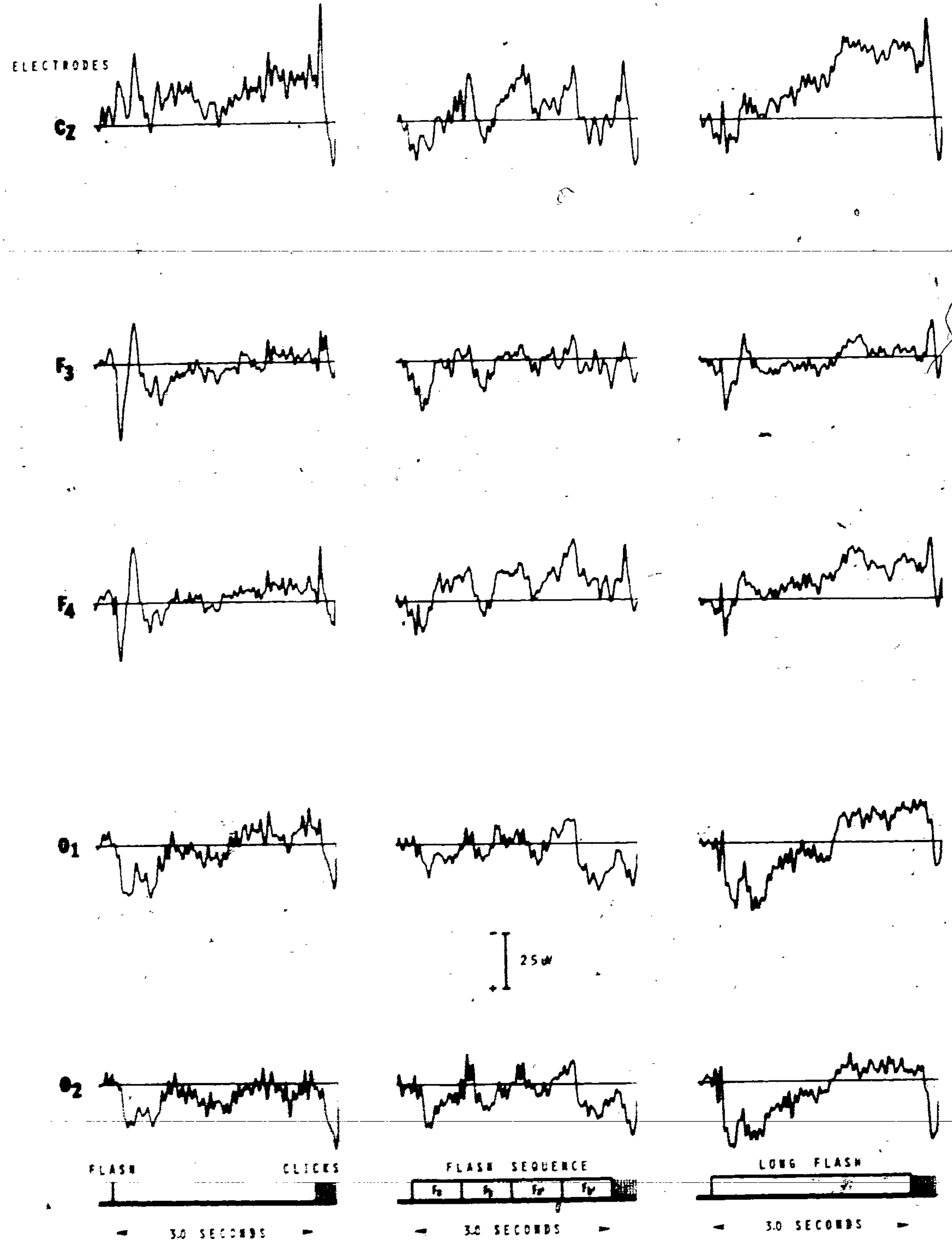
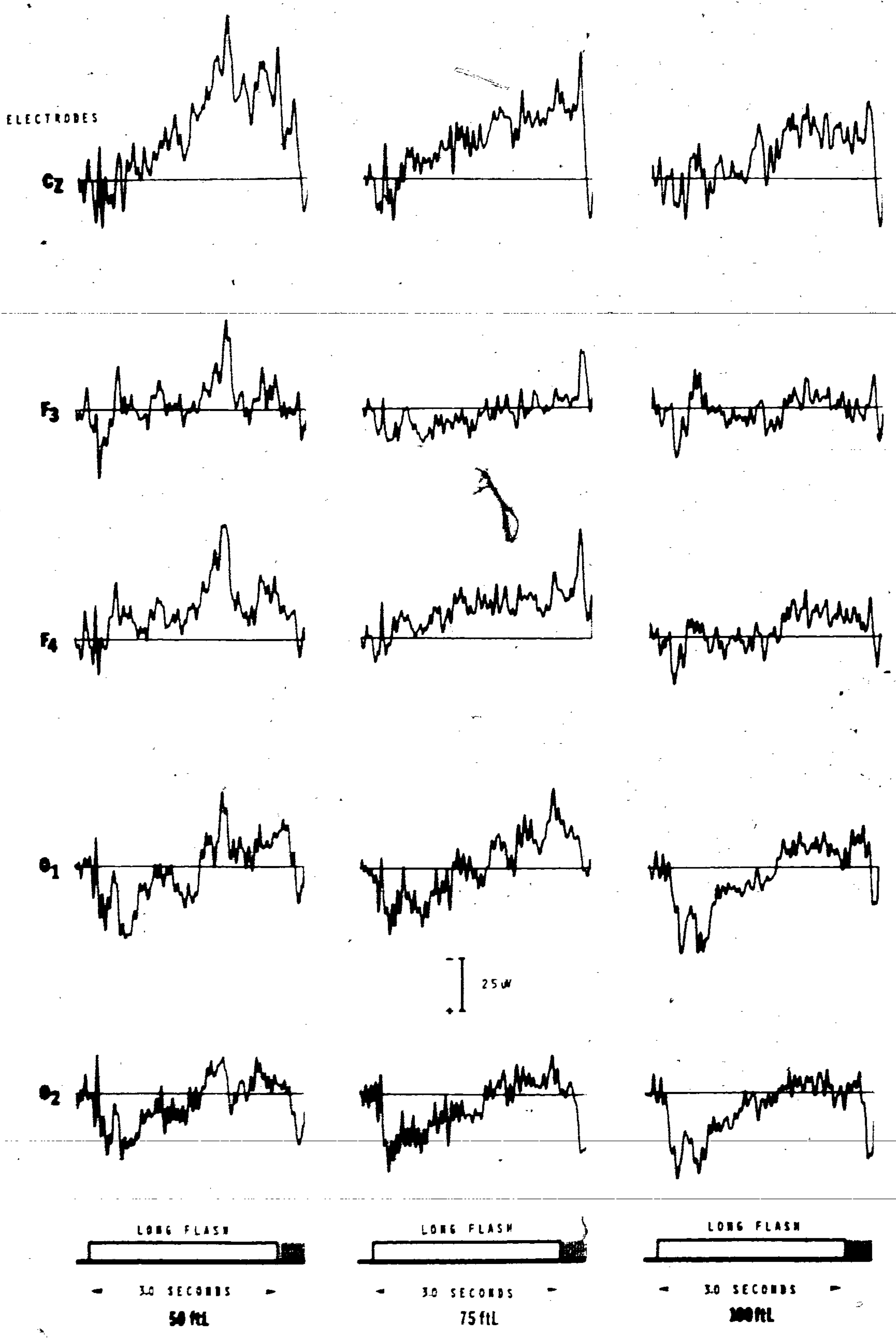

ELECTRODES
C_Z
F_3
F_4
O_1
O_2
25µv
FLASH
CLICKS
3.0 SECONDS
FLASH SEQUENCE
3.0 SECONDS
LONG FLASH
3.0 SECONDS

Figure 22

CNV Averages ($n \approx 5$) for Subject H. M. at Each Active Electrode Site for the Three Brightness Levels in the Long Flash Condition


ELECTRODES
Cz
F3
F4
O1
O2
25 µV
LONG FLASH
3.0 SECONDS
50 ftL
LONG FLASH
3.0 SECONDS
75 ftL
LONG FLASH
3.0 SECONDS
100 ftL

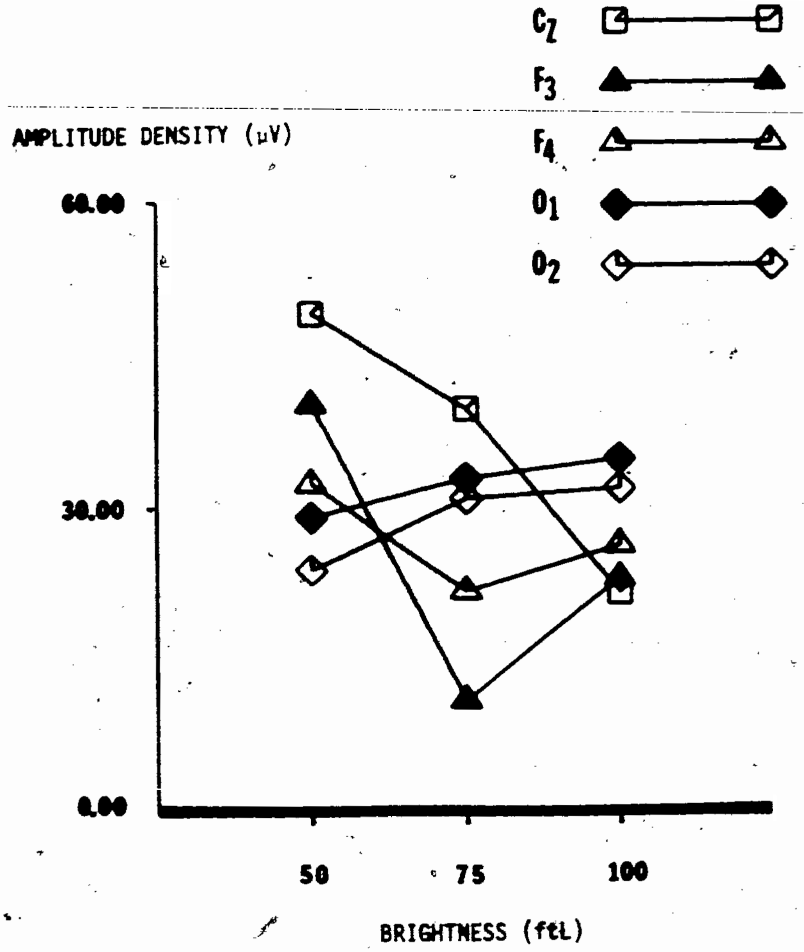


Figure 23

CNV Amplitude Densities for Subject H. M. at Each
Active Electrode Site for the Three
Brightness Levels

referring to Figure 21, the right side frontal site for both FA and LF conditions was considerably larger than in the SC condition. As pointed out earlier, individual instances of slow wave asymmetry were prominent among many subjects' records.

Although the scalloping effects appeared in the CNV, the second question regarding slow wave driving during FA could not adequately be answered by the experimental task employed. In the tone analysis presentations, intensities were maintained at a constant level; in FA, it was the intensities themselves that were manipulated and analyzed by the subject. The single trial analysis of brightness levels suggested that an inverse or at least inconsistent relation existed between level and slow wave amplitude. Intensity steps were probably confounded in some complicated way with slow potential activity.

Chapter 5

THE AREA OF WERNICKE AND THE LATERAL DEVELOPMENT OF THE CNV: EXPERIMENT 2

As indicated in Chapters 2 and 3, the most striking and convincing evidence for left hemisphere specialization comes from the presentation and evocation of verbal stimulus materials. Geschwind (1970) has outlined the principal cortical areas involved in language comprehension and language production. Destruction of an area of the left hemisphere known as the area of Wernicke was accompanied by the failure to understand written and spoken language. Another important verbal site was located in the inferior frontal region of the left hemisphere. This latter area, known as Broca's area, appeared primarily involved with the articulation of speech sounds.

In attempting to account for the well documented perceptual asymmetries between verbal and nonverbal stimulus materials, Kinsbourne (1970) has proposed an attentional model for explanation and experimentation. In his view, cerebral asymmetries are not generated unless an overall expectancy or set for a given type of stimulus can be established.

This chapter examines the lateral distribution of the CNV during conditions of instructed set. The posterior parietal area of Wernicke on the left hemisphere was compared to a homologous area on the right hemisphere. Additionally, CNV activity was recorded from central and frontal locations. The activity from lateral electrode placements over both cerebral hemispheres was used to assess CNV genesis during a standard condition and conditions which manipulated subject expectation for the reception and production of simple verbal stimuli.

Methods

Subjects

The subjects were five right-handed males and five right-handed females. The subjects were recruited from the university community as paid volunteers. Handedness was checked by requiring each subject to copy a short paragraph. The subjects reported no abnormal speech impediments. The subjects' ages ranged from 18 to 30 years and all had normal or corrected vision. None of the subjects had previously participated in electroencephalographic experimentation.

Recording Techniques

Monopolar scalp electrodes (Ag-AgCl) were cemented to the vertex (C_z), left frontal (F_3), and right frontal (F_4) locations according to the 10-20 System (Jasper, 1958). The area of Wernicke was estimated by locating the central point in the triangle formed by left side 10-20 positions T_3, T_5, and P_3; the central point was designated as W_1. A right side location was similarly determined by locating a central point in the triangle bounded by T_4, T_6, and P_4; this site was designated as W_2. (The method for locating the area of Wernicke was adopted from the article by Matsumiya, Tagliasco, Lombroso, & Goodglass, 1972.) All active electrode sites (C_Z, F_3, F_4, W_1, & W_2) were referenced to linked mastoids. A ground electrode was placed on the subject's forehead. In order to monitor ocular potentials, Beckman Biopotential electrodes were placed periorbitally above and below the right eye to record upward and downward movements, and electrodes were placed near the external canthus of each eye to record lateral eye movements. Skin sites were lightly cleaned with alcohol before electrode application. After the electrodes were injected with electrolyte (Beckman), electrode impedances were measured and were equated in the range from 3.0 to 3.5K ohms by tapped skin abrasion.

Scalp potentials were amplified and recorded on an 8-channel Elema-Schönander Mingograf recorder. Amplifier sensitivity was set to 50 μV/cm for active electrode sites; time constants were adjusted to 5.0 seconds with upper cutoff frequencies set at 70 Hz. Amplifier outputs were digitized on-line with a Hewlett-Packard 2116B computer. Data averages were stored on disc, whereas single trials were stored on magnetic tape. Continuous analog (FM) records were also collected. Channel 8 marked the various event sequences during stimulus presentations. (See Chapter 4 for details on data collection and data retrieval.) Before each day of testing, a calibration signal (50 μV) was placed in parallel across amplifier inputs to verify the equality of the final amplifier outputs throughout the data collection network.

Stimulus Construction

Common monosyllabic and polysyllabic English words, e.g., HOOK, WRIST, ELEPHANT, LIMESTONE, etc., were singly placed on cards for tachistoscopic presentation. See Appendix E for a complete list of stimulus words. Black press-on transfer letters (Letraset, style Futura Bold) were used in forming the words. A template was used to align and center individual words in the tachistoscope card hanger. A Sony portable video unit projected the scope (3-channel Scientific Prototype) presentations to the subject on a TV monitor inside the sound attenuating cubicle. Viewed on the screen monitor, stimuli were .3° high; longer words were approximately 4° across the screen.

Procedure

After electrode preparation, subjects reclined comfortably on a bed adjusted for viewing the screen of the TV monitor. Overall screen brightness was approximately .5 ftL (1.713 cd/m^2) and was essentially the only source of illumination in the cubicle.

A 15 - 20 minute period followed in which the electrodes were allowed to stabilize and a final equipment inspection was made.

Three experimental conditions were administered to each subject. In Condition A, the standard, a 30-millisecond tone (1000 Hz) pip (S_1) was followed 1.5 seconds later by clicks (S_2). The subject's task was to terminate the clicks as quickly as possible with a right hand button press. If the button was pressed before the clicks sounded, the clicks were automatically inhibited. The subjects were given several practice trials and were instructed to adopt a pattern of motor responding that was compatible with recording small electrical signals. During trial presentations, the subject continuously fixated a black dot projected on the TV monitor. Particular attention was given to instructing subjects on the methods of proper eye fixation.

The second condition, Condition B, consisted of a 30-millisecond tone pip (S_1) followed 1.5 seconds later by a stimulus word presented for 30 milliseconds. The subject was instructed to audibly vocalize the binocularly observed stimulus word as soon as it appeared. Several practice trials were given to acquaint the subject with the situation and also to select an individual response level that minimized the production of movement artifacts. The subject's word responses were verified via open intercom. During the experimental condition, the subject fixated a dot that momentarily disappeared during stimulus (S_2) presentation.

The third condition, Condition C, reversed the sequence of the S_1-S_2 presentation from Condition B. The 30-millisecond stimulus word was presented at S_1 followed 1.5 seconds later by a 30-millisecond tone pip (S_2). The tone signaled the subject to audibly vocalize the binocularly observed stimulus word seen at S_1. During practice trials, subjects were instructed to respond quickly at the S_2 signal but not in such a way that the EEG records were unduly disturbed. The subject's word responses were monitored via open intercom. Subjects fixated a dot that disappeared during word presentations.

The words that were used in Conditions B and C were presented in random order without repetition for each subject.

For all three experimental conditions, subjects listened to auditory stimuli from louspeakers under the bed. Sound levels measured at the subject's head ranged from 65 - 70 dB; in the standard condition, clicks were generated from a Grass S-4 stimulator at a rate of 15/second and were delivered at a level that ranged from 65 to 70 dB re 20 $\mu N/m^2$.

Condition A was administered first for all subjects; the order of Conditions B and C was randomly determined for each subject. Time periods between trials ranged from 18 to 30 seconds; periods between conditions ranged from 5 to 10 minutes.

An average of 16 trials was collected for each of the experimental conditions for each subject. Accepted trials were free from obvious eye movements or muscular activity during the critical S_1-S_2 interval. The start of data collection was issued manually after monitored records appeared satisfactorily stable. The total sweep period was 3.5 seconds; for baseline purposes, signal digitization started 500 milliseconds before the onset of S_1. Timing sequences, tachistoscopic presentations, and S_1 and S_2 stimuli were controlled by Grason-Stadler 1200 programming modules.

Data Treatment

The data averages collected for each subject were plotted for each experimental condition and for each of the electrode sites. Individual data averages were digitally filtered prior to plotting (see Appendix B) and were centered around a mean baseline voltage from the 500-millisecond prestimulation period.

Area measurements of CNV magnitude. The plotted records were used to derive area measurements of CNV magnitude. A horizontal line was constructed from the positive most component of the evoked potential at S_1 to a point 50 milliseconds before the onset of S_2; from there the line was perpendicularly directed until it intersected the slow wave. The areas bounded by the slow wave and the constructed line segments were measured with a compensating planimeter (K & E Model 4236). The area measures were scaled into μV-seconds and then were normalized into μV.

A three-factor (2 × 3 × 5) analysis of variance design with repeated measures on the last two factors was used to evaluate the magnitude measures. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C). The analysis of variance computations were carried out using BMD08V of the Health Sciences Computing Facility, UCLA.

Vertical measurements of CNV amplitude. A single estimate of slow wave activity was made for all subjects from the averaged records of each active electrode site for each of the corresponding experimental conditions. Direct (calipered) readings were collected from a baseline point 50 milliseconds prior to the onset of S_2 vertically to a point on the slow wave.

A three-factor (2 × 3 × 5) analysis of variance design with repeated measures on the last two factors was used to evaluate the vertical amplitude measures. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Ratio indices of asymmetry. In order to assess the relative proportion of left (L) hemisphere activity to right (R) hemisphere activity, ratios of the form $\underline{L}/(\underline{L} + \underline{R})$ were formed. Ratios were separately derived for homologous frontal sites, $F_3/(F_3 + F_4)$, and homologous posterior sites, $W_1/(W_1 + W_2)$, from the electrode averages (magnitude measures) for each of the experimental conditions. Ratios that exceeded .50 indicated larger left than right hemisphere activity; ratios below .50 indicated larger right than left hemisphere activity.

A three-factor (2 × 3 × 2) analysis of variance design with repeated measures on the last two factors was performed on the calculated proportions. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Evoked potential amplitudes at S_1. An estimate of evoked potential activity to S_1 was collected for each subject at each electrode site for each of the experimental conditions. Direct (calipered) measurements were taken from averaged records from the most positive component that occurred after S_1 (latencies ranged from 250 to 350 milliseconds) to the baseline.

A three-factor (2 × 3 × 5) analysis of variance design with repeated measures on the last two factors was used to evaluate the amplitude measures of evoked potential activity at S_1. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Additionally, the relationships of the area measurements, vertical measures, and evoked response (or EP) measures to each other were evaluated by Pearson Product-Moment correlations. The significance of each correlation was tested by $\underline{t} = \underline{r}[(\underline{n} - 2)/(1 - \underline{r}^2)]^{\frac{1}{2}}$ with $\underline{df} = \underline{n} - 2$.

Cross-Correlations I. Cross-correlations for each subject were separately performed between each active electrode site in the standard condition and itself in Condition B; similarly, cross-correlations were performed between an electrode site in the standard condition and itself in Condition C. The cross-correlations that were used here and in later analyses were modified to emphasize the slow wave build up and omit slow wave resolution. Consequently, the program that performed the cross-correlations used only the first 600 data points (of 1024) to calculate the correlation values. This corresponded to a period into the CNV interval of 2050 milliseconds from the start of data collection.

The Cross-Correlation I values that were obtained were entered into a three-factor (2 × 2 × 5) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations II. Separate cross-correlations were performed for each subject comparing the vertex (C_Z) of the standard condition to each of the lateral placements of Condition A; in Condition B, cross-correlations were performed between the vertex (C_Z) and the lateral placements of Condition B; likewise, correlations were similarly performed for Condition C.

The resulting correlation values were entered into a three-factor (2 × 3 × 4) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations III. Separate cross-correlations were performed for each subject between homologous frontal (F_3 vs F_4) and between homologous posterior (W_1 vs W_2) electrode sites for each of the experimental conditions.

The correlations that were obtained were entered into a three-factor [illegible] × 3 × 2) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations IV. Separate cross-correlations for each subject were performed between left side intrahemispheric placements (F_3 vs W_1) and between right side intrahemispheric placements (F_4 vs W_2) for each of the experimental conditions.

The correlation values were entered into a three-factor (2 × 3 × 2) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Results

The analysis of overall treatment effects relied on the general application of the analysis of variance. Individual tests of main effects were carried out using Duncan's Multiple-Range Test among the means for significant F ratios. Significant interactions were also analyzed using Duncan's Multiple-Range Test. In the calculation of the critical ranges, it was the level of the significant F ratio that normally determined the particular tables entered.

Area Measurements of CNV Magnitude

The overall effects for females and males were not significantly different ($\underline{F} < 1$, $\underline{df} = 1/8$, $\underline{p} > .20$). The conditions effect was also not significant ($\underline{F} = 2.38$, $\underline{df} = 2/16$, $\underline{p} > .10$). There was, however, a significant electrodes effect ($\underline{F} = 29.62$, $\underline{df} = 4/32$, $\underline{p} < .001$). Interactions that reached significant levels included sex by electrodes ($\underline{F} = 3.13$, $\underline{df} = 4/32$, $\underline{p} < .05$) and conditions by electrodes ($\underline{F} = 2.38$, $\underline{df} = 8/64$, $\underline{p} < .05$). A summary of the analysis of variance for the area measurements of CNV magnitude is provided in Appendix C, Table C6.

Further tests on electrodes (Factor C) indicated that the vertex (C_z) was larger than either F_3, F_4, W_1, or W_2 sites ($\underline{p} < .001$). The overall means for the normalized areas at each active electrode site are illustrated in Figure 24. None of the differences between laterally placed electrodes reached a significant level. The Duncan range tests among the means of Factor C are shown in Appendix D, Table D23.

The mean densities (normalized areas) involved in the sex by electrodes (A × C) interaction are illustrated in Figure 25. For the females, the vertex (C_z) was larger than either F_3, F_4, W_1, or W_2 scalp sites ($\underline{p} < .05$); frontal locations F_3 and F_4 were separately larger than either W_1 or W_2 ($\underline{p} < .05$). For the males, the vertex (C_z) was larger than either F_3, F_4, W_1, or W_2 scalp sites ($\underline{p} < .05$); also, lateral sites F_3, F_4, and W_1 were separately larger than W_2 ($\underline{p} < .05$). For the females and the males, no significant differences were found between homologous frontal or between homologous posterior sites. The Duncan range tests among the means for females across electrode sites

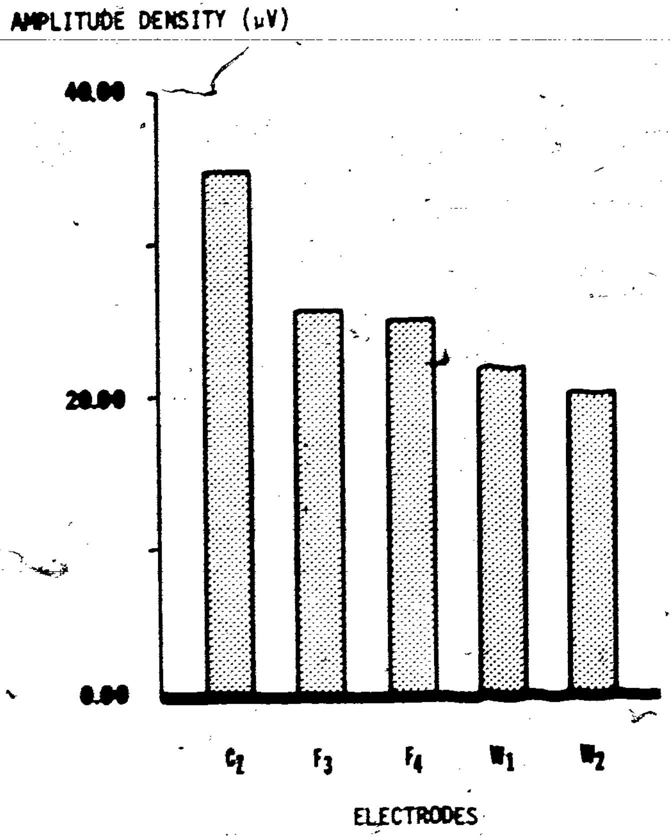


Figure 24

Overall Means for the Normalized Area Measurements of CNV Activity at Each Active Electrode Site

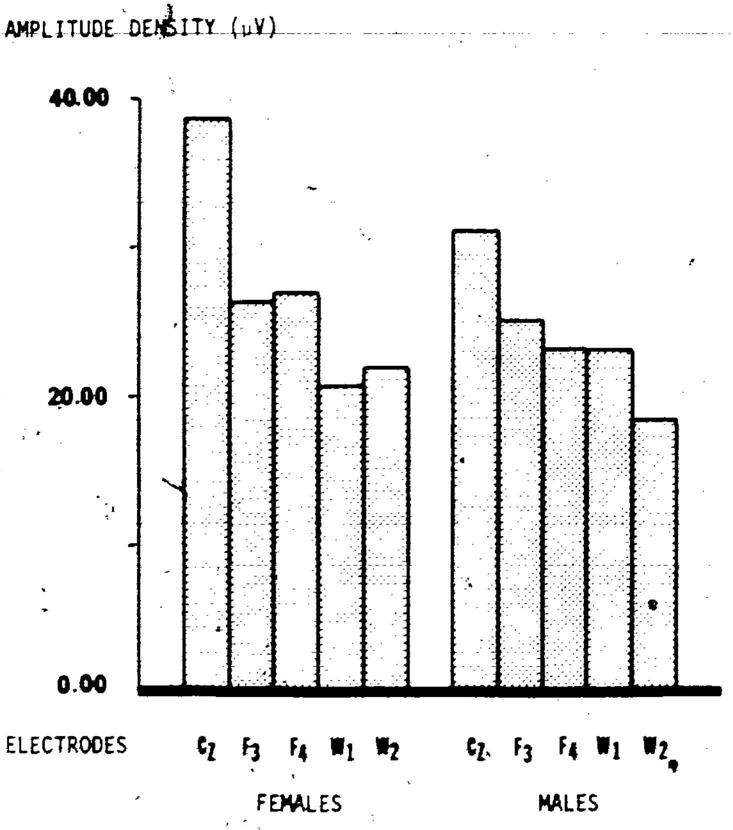


Figure 25

Means for the Normalized Area Measurements of CNV Activity for Females and Males at Each Active Electrode Site and for males across electrode sites are shown in Appendix D, Tables D24 and D25, respectively.

The mean densities involved in the conditions by electrodes (B × C) interaction are illustrated in Figure 26. In each of the experimental conditions, the vertex (C_Z) was separately larger than any of the corresponding lateral placements ($p < .05$). In Condition A, F_3 and F_4 sites were separately larger than either W_1 or W_2 locations ($p < .05$). In Condition B, F_3 and F_4 sites were separately larger than W_2 ($p < .05$). In Condition C, none of the contrasts between lateral placements reached significant levels. Separately considered by condition, no differences were found between homologous frontal or between homologous posterior sites. The Duncan range tests among the means of Conditions A, B, and C across electrodes are shown in Appendix D, Tables D26, D27, and D28, respectively.

Vertical Measurements of CNV Amplitude

The F ratio for sex was not significant ($F = 1.63$, $df = 1/8$, $p > .20$). There was a significant conditions effect ($F = 8.49$, $df = 2/16$, $p < .005$) and a significant electrodes effect ($F = 23.48$, $df = 4/32$, $p < .001$). There was also a significant conditions by electrodes (B × C) interaction ($F = 3.52$, $df = 8/64$, $p < .005$). The summary of the analysis of variance for the vertical measures of CNV amplitude is provided in Appendix C, Table C7.

The overall means for the separate experimental conditions are illustrated in Figure 27. Further tests revealed that Condition A was different from Condition C ($p < .005$); Conditions B and C did not

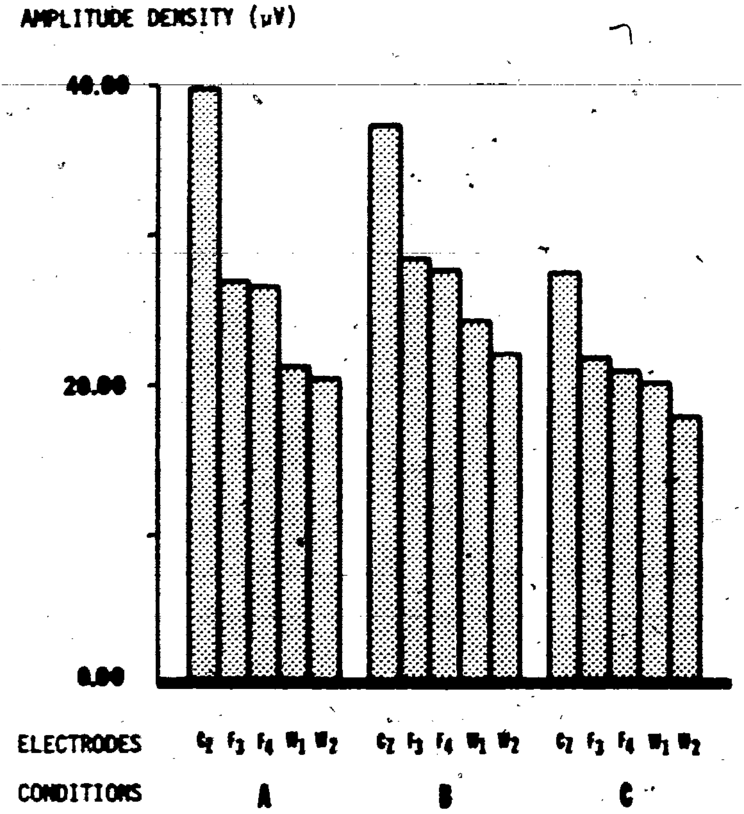


Figure 26

Means for the Normalized Area Measurements of CNV Activity at Each Active Electrode Site for Each of the Experimental Conditions

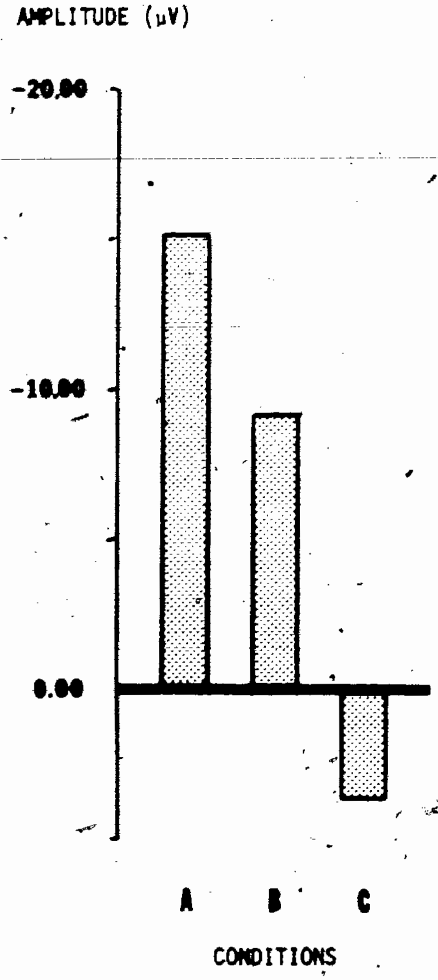


Figure 27

Overall Mean CNV Amplitudes for Each of the Experimental Conditions differ from each other. The Duncan range tests among the means for conditions (Factor B) are shown in Appendix D, Table D29.

The overall mean amplitudes for each of the electrode sites are illustrated in Figure 28. The vertex (C_z) was separately larger than either F_3, F_4, W_1, or W_2 sites ($p < .001$). No significant differences were found between homologous frontal or between homologous posterior sites. The Duncan range tests among the means for electrodes (Factor C) are shown in Appendix D, Table D30.

The mean amplitudes involved in the conditions by electrodes ($B \times C$) interaction are illustrated in Figure 29. In Condition A, the vertex (C_z) was separately larger than either F_3, F_4, W_1, or W_2 sites ($p < .005$); also, F_4 was larger than W_1. In Condition B, none of the contrasts between active electrode sites reached a significant level ($p > .005$). In Condition C, the vertex (C_z) was larger than W_1 ($p < .005$); none of the other contrasts between lateral sites reached significant levels ($p > .005$). Separately considered by condition, no differences were found between homologous frontal or between homologous posterior sites. The Duncan range tests among the means for Conditions A, B, and C across electrodes are shown in Appendix D, Tables D31, D32, and D33, respectively.

Ratio Indices of Asymmetry

The F ratios for sex ($F = 2.08$, $df = 1/8$, $p > .10$), conditions ($F < 1$, $df = 2/16$, $p > .20$), and electrodes ($F = 1.36$, $df = 1/8$, $p > .20$) did not reach significant levels. The interaction of sex by electrodes did reach a significant level ($F = 7.43$, $df = 1/8$, $p < .05$).

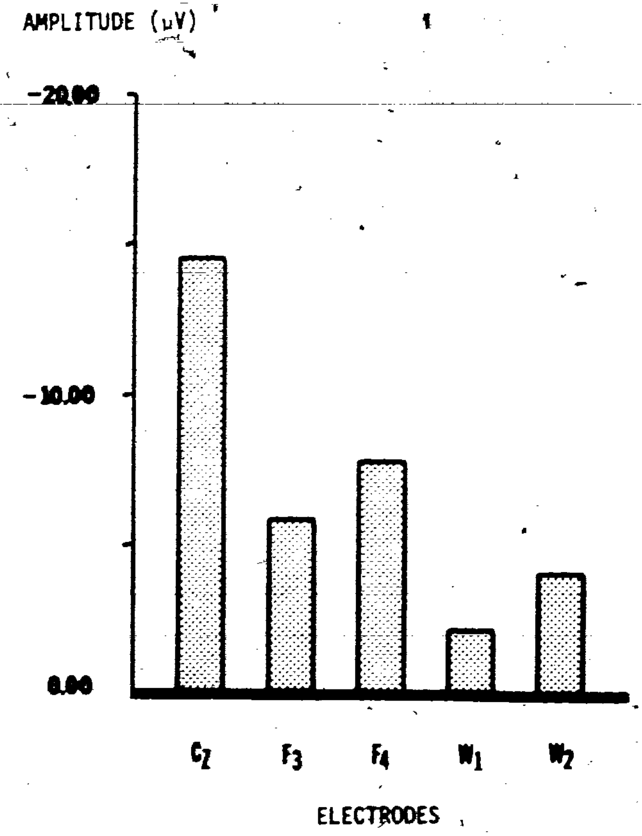


Figure 28

Overall Mean CNV Amplitudes at Each of the Active Electrode Sites

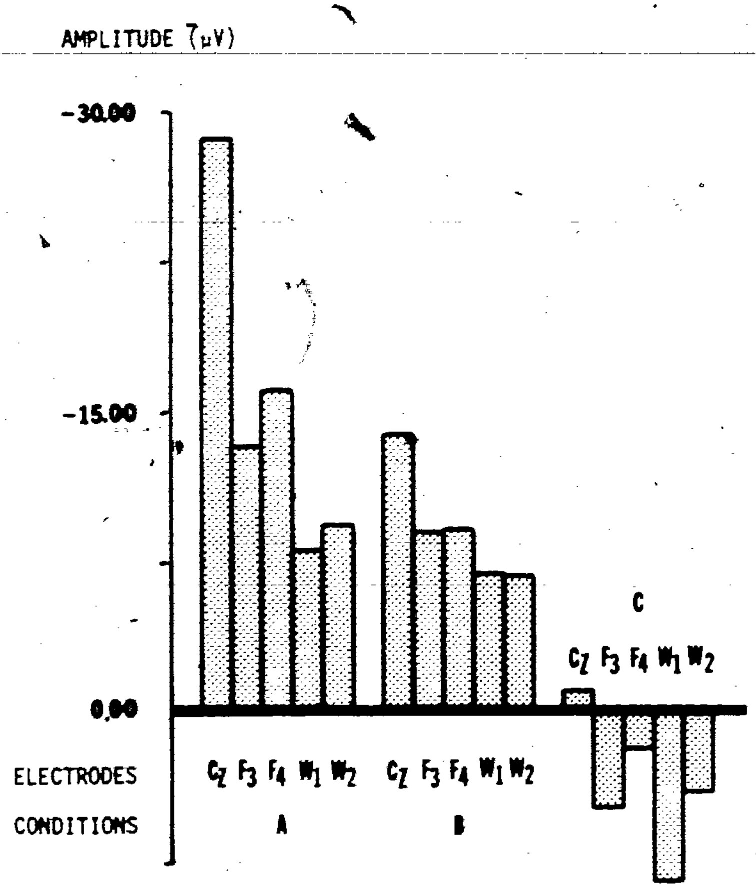


Figure 29

Mean CNV Amplitudes at Each Active Electrode Site for Each of the Experimental Conditions

The summary of the analysis of variance for ratios is provided in Appendix C, Table C8.

The mean ratios involved in the sex by electrodes (A × C) interaction are illustrated in Figure 30. For the females, the ratios between frontal (.48) and posterior (.46) locations were not significantly different (Duncan's Multiple-Range Test: $\underline{k} = 2$, $\underline{df} = 8$, $\underline{n} = 15$, $\underline{p} > .05$). For the males, the ratios between frontal (.49) and posterior (.55) sites were significantly different (Duncan's Multiple-Range Test: $\underline{k} = 2$, $\underline{df} = 8$, $\underline{n} = 15$, $\underline{p} < .05$).

The mean frontal ratios and the mean posterior ratios for both females and males in each of the experimental conditions are shown in Table 7. These means corresponded to the nonsignificant sex by conditions by electrodes (A × B × C) interaction. The females tended to have larger frontal ratios than posterior ratios across all the experimental conditions, whereas males tended to have larger posterior than frontal ratios across the experimental conditions. Although not statistically justifiable, Duncan range tests among the mean frontal ratios for females across conditions and mean posterior ratios for females across conditions are shown in Appendix D, Tables D34 and D35, respectively; likewise, the Duncan range tests among the mean frontal ratios for males across conditions and mean posterior ratios for males across conditions are shown in Appendix D, Tables D36 and D37, respectively.

Evoked Potential Amplitudes at S_1

The $\underline{F}$ ratios for sex ($\underline{F} < 1$, $\underline{df} = 1/8$, $\underline{p} > .20$) and conditions

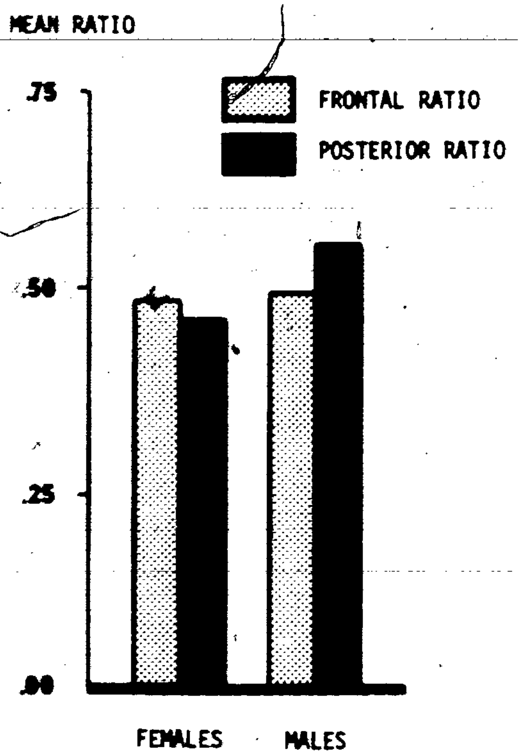


Figure 30

Mean Ratio Indices of Asymmetry for Frontal and Posterior Locations for Females and Males

Table 7

Mean Frontal Ratios and Mean Posterior Ratios for Females and Males for Each of the Experimental Conditions

Experimental Condition	Frontal Ratio ($F_3/[F_3 + F_4]$)		Posterior Ratio ($W_1/[W_1 + W_2]$)	
	Female	Male	Female	Male
A (Tone → Clicks)	.48	.50	.44	.57
B (Tone → Word)	.47	.51	.45	.55
C (Word → Tone)	.50	.47	.48	.54

(F = 1.66, df = 2/16, $p > .20$) did not reach significant levels. There was a significant electrodes effect (F = 14.53, df = 4/32, $p < .001$). The interaction of conditions by electrodes (B × C) also reached a significant level (F = 2.38, df = 8/64, $p < .05$). A summary of the analysis of variance for evoked potential amplitudes at S_1 is provided in Appendix C, Table C9.

The overall means for evoked potential amplitudes at S_1 across electrodes are illustrated in Figure 31. Tests indicated that the vertex (C_z) site was separately larger than either F_4, W_1, or W_2 placements ($p < .001$). None of the contrasts between lateral electrode locations reached significant levels ($p > .001$). The Duncan range tests among the means for electrodes (Factor C) are shown in Appendix D, Table D38.

The mean amplitudes involved in the conditions by electrodes (B × C) interaction are illustrated in Figure 32. In Condition A, the vertex (C_z) was separately larger than either F_3, W_1, or W_2 sites ($p < .05$). In Condition B, the vertex (C_z) was larger than F_3, F_4, W_1, or W_2 locations ($p < .05$); F_3 and F_4 sites were separately larger than W_2 ($p < .05$); also, F_3 was larger than W_1 ($p < .05$). In Condition C, the vertex (C_z) was separately larger than either F_3, F_4, W_1, or W_2 locations ($p < .05$); F_3 and F_4 sites were separately larger than W_2 ($p < .05$); also, F_3 was larger than W_1 ($p < .05$). Separately considered by condition, no differences were found between homologous frontal or between homologous posterior sites. The Duncan range tests among the means for Conditions A, B, and C across electrodes are shown in Appendix D, Tables D39, D40, and D41, respectively.

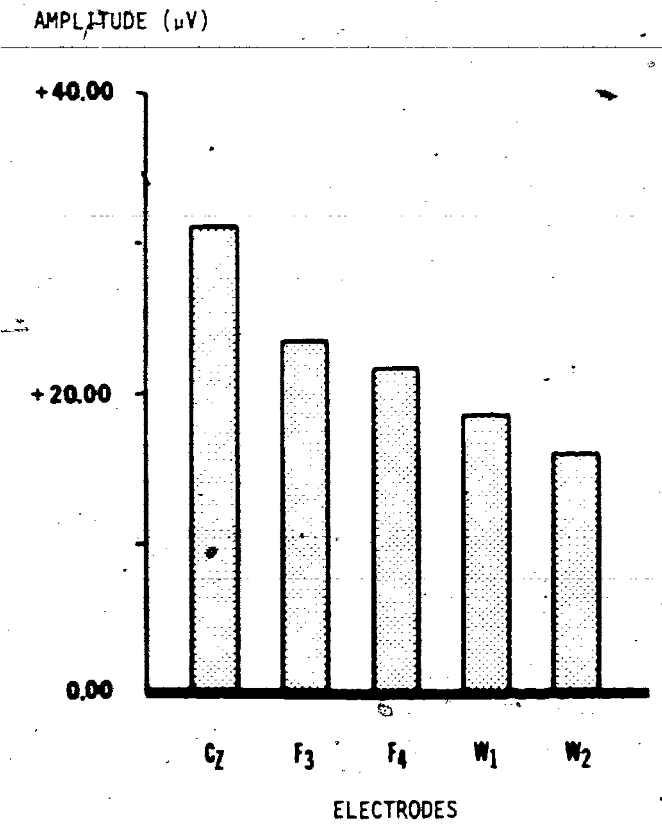


Figure 31

Overall Means for Evoked Potential Amplitudes at S_1 for Each of the Active Electrode Sites

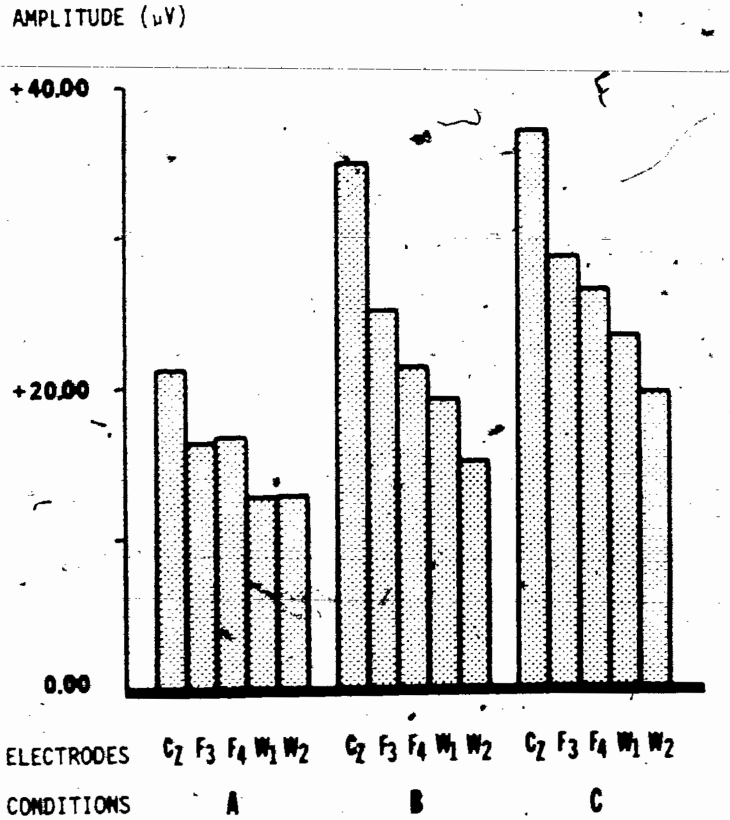


Figure 32

Mean Evoked Potential Amplitudes at S_1 for each of the Active Electrode Sites in each of the Experimental Conditions

In order to examine the relationships between the two estimates of CNV activity and their separate relationships to the evoked responses (or EPs) that were collected, product-moment correlations were performed between the various measures. Using the normalized area measurements of CNV activity and the vertical measures of CNV activity, correlations were performed between each active electrode site and itself for each of the experimental conditions. The correlation values that resulted are shown in Table 8. Low correlations were found between the normalized area measurements and the vertical measures of CNV amplitude. Using the normalized area measurements of CNV activity and the evoked response amplitudes at S_1, correlations were performed between each active electrode site and itself for each of the experimental conditions. The correlation values that resulted are shown in Table 9. The correlations between the normalized area measurements and evoked response measurements were generally higher in Conditions A and B than in Condition C. Lastly, correlations were performed between each active electrode site and itself for the vertical measures of CNV amplitude and the evoked response measures of amplitude in each of the experimental conditions. The correlation values that resulted are shown in Table 10. There was a tendency for higher correlations in Conditions A and C than in Condition B.

Cross-Correlations I

Cross-correlations between each active electrode site and itself were performed which separately compared the standard condition to each of the other experimental conditions. The _F_ ratios revealed

Table 8

Correlations between Normalized Area Measurements of CNV Activity and Vertical Measurements of CNV Activity at Each Active Electrode Site for Each of the Experimental Conditions

Correlation and Test	Electrode Site C_z	F_3	F_4	W_1	W_2
Condition A (Tone → Clicks)					
r = ...	-.28	-.28	.01	-.20	-.12
t = ...	-.83	-.83	.05	-.59	-.35
Condition B (Tone → Word)					
r = ...	-.49	-.35	-.64	-.44	-.54
t = ...	-1.60	-1.08	-2.38[a]	-1.40	-1.85
Condition C (Word → Tone)					
r = ...	-.48	-.26	-.26	.02	-.12
t = ...	-1.55	-.77	-.78	.06	-.36

Note. For each *t*-test, *n* = 10, *df* = 8. Polarities of the vertical measurement above (negative) or below (positive) baseline were observed.

[a] $p < .05$.

Table 9

Correlations between Normalized Area Measurements of CNV Activity and Evoked Potential Amplitudes at S_1 at Each Active Electrode Site for Each of the Experimental Conditions

Correlation and Test	Electrode Site				
	C_z	F_3	F_4	W_1	W_2
	Condition A (Tone → Clicks)				
r = ...	.70	.73	.63	.80	.60
t = ...	2.83^a	3.09^a	2.31^a	3.80^a	2.14
	Condition B (Tone → Word)				
r = ...	.60	.86	.74	.86	.74
t = ...	2.16	4.88^b	3.14^a	4.86^b	3.14^a
	Condition C (Word → Tone)				
r = ...	.35	.61	.70	.48	.63
t = ...	1.06	2.20	2.79^a	1.57	2.30^a

Note. For each *t*-test, *n* = 10, *df* = 8. Polarities of the evoked potential measurements above (negative) and below (positive) baseline were observed.

$^a p < .05$.

$^b p < .01$.

Table 10

Correlations between the Vertical Measurements of CNV Activity and Evoked Potential Amplitudes at S_1 at Each Active Electrode Site for Each of the Experimental Conditions

Correlation and Test	Electrode Site				
	C_z	F_3	F_4	W_1	W_2
	Condition A (Tone → Clicks)				
_r_ = ...	.35	.26	.72	.10	.28
_t_ = ...	1.08	.78	2.93[a]	.30	.83
	Condition B (Tone → Word)				
_r_ = ...	.11	-.01	-.21	-.08	-.04
_t_ = ...	.31	-.03	-.63	-.23	-.11
	Condition C (Word → Tone)				
_r_ = ...	.46	.40	.26	.20	.14
_t_ = ...	1.48	1.26	.76	.58	.40

Note. For each _t_-test, _n_ = 10, _df_ = 8. Polarities of vertical measurements and the evoked potential measurements above (negative) or below (positive) baseline were observed.

[a] $p < .05$.

that no significant effects were found for sex ($F < 1$, $df = 1/8$, $p > .20$), conditions ($F = 2.95$, $df = 1/8$, $p > .10$), or electrodes ($F < 1$, $df = 4/32$, $p > .20$). A summary of the analysis of variance for Cross-Correlations I is provided in Appendix C, Table C10.

The mean Cross-Correlation I values for the nonsignificant conditions by electrodes (B × C) interaction are shown in Table 11. It can be seen that the means were generally higher in Condition B than in Condition C. Although not statistically justifiable, the Duncan range tests among the Cross-Correlation I means for Conditions B and C across electrodes are shown in Appendix D, Tables D42 and D43, respectively.

Cross-Correlations II

Cross-correlations were computed between the vertex (C_z) of each experimental condition and each of the corresponding lateral electrode placements. The F ratios for sex ($F = 1.11$, $df = 1/8$, $p > .20$) and conditions ($F < 1$, $df = 2/16$, $p > .20$) did not reach significant levels. There was a significant effect for electrodes ($F = 19.59$, $df = 3/24$, $p < .001$). A summary of the analysis of variance for Cross-Correlations II is provided in Appendix C, Table C11.

The overall correlation means involved in the electrodes effect (Factor C) are illustrated in Figure 33. The frontal sites, F_3 and F_4, separately displayed larger correlations than either W_1 or W_2 locations ($p < .001$). There were no differences between homologous frontal or between homologous posterior sites. The Duncan range tests among the

Table 11

Mean Cross-Correlation I Values for the Nonsignificant Conditions by Electrodes Interaction

Experimental Condition	Electrode Site				
	C_z	F_3	F_4	W_1	W_2
B (Tone → Word)	.59	.57	.58	.51	.47
C (Word → Tone)	.22	.19	.21	.15	.21

Figure 33

Overall Mean Cross-Correlation II Values at Each Active Electrode Site means for electrodes (Factor C) are shown in Appendix D, Table D44.

The mean Cross-Correlation II values for the nonsignificant conditions by electrodes (B × C) interaction are shown in Table 12. Even though the frontal and posterior differences are clearly evident, there was no consistent tendency for either homologous frontal or homologous posterior locations to change with experimental conditions. Although not statistically justifiable, the Duncan range tests among the Cross-Correlation II means for Conditions A, B, and C across electrodes are shown in Appendix D, Tables D45, D46, and D47, respectively.

Cross-Correlations III

Cross-correlations were separately calculated between the homologous frontal and between the homologous posterior electrode sites for each of the experimental conditions. The F ratios for sex ($F < 1$, $df = 1/8$, $p > .20$), conditions ($F < 1$, $df = 2/16$, $p > .20$), and electrodes ($F = 2.69$, $df = 1/8$, $p > .10$) did not reach significant levels. The summary of the analysis of variance for Cross-Correlations III is provided in Appendix C, Table C12.

The mean Cross-Correlation III values for the nonsignificant conditions by electrodes (B × C) interaction are shown in Table 13. Across experimental conditions, homologous frontal sites tended to have larger correlations than homologous posterior sites.

Cross-Correlations IV

Separate cross-correlations were performed between left side intrahemispheric placements and right side intrahemispheric placements

Table 12

Mean Cross-Correlation II Values for the Nonsignificant Conditions by Electrodes Interaction

Experimental Condition	Electrode Site			
	F_3	F_4	W_1	W_2
A (Tone → Clicks)	.91	.92	.77	.72
B (Tone → Word)	.88	.87	.69	.67
C (Word → Tone)	.89	.84	.70	.66

Table 13

Mean Cross-Correlation III Values for the Nonsignificant Conditions by Electrodes Interaction

Experimental Condition	Frontal Electrodes (F_3 vs F_4)	Posterior Electrodes (W_1 vs W_2)
A (Tone → Clicks)	.92	.85
B (Tone → Word)	.91	.54
C (Word → Tone)	.89	.88

for each of the experimental conditions. The F ratios for sex ($F < 1$, $df = 1/8$, $p > .20$), conditions ($F < 1$, $df = 2/16$, $p > .20$), and electrodes ($F < 1$, $df = 1/8$, $p > .20$) did not reach significant levels. A summary of the analysis of variance for Cross-Correlations IV is provided in Appendix C, Table C13.

The mean Cross-Correlation IV values involved in the non-significant conditions by electrodes (B × C) interaction are shown in Table 14. Across conditions, left side intrahemispheric correlations were slightly higher than right side correlations.

Discussion

The normalized area measurements of CNV activity revealed that the vertex (C_Z) was consistently larger than any of the lateral electrode placements. Considered by condition, frontal sites were generally larger than posterior sites. The anticipation of seeing and vocalizing a word (Condition B) had no effect on the differences between homologous frontal or between homologous posterior (area of Wernicke over the left hemisphere) sites. The anticipation of vocalizing a particular stimulus word (Condition C) also had no effect on the differences between homologous frontal or between homologous posterior sites. To the extent that the CNV situations created expectancy, Kinsbourne's (1970) hypothesis concerning the production of hemispheric asymmetries, at least in terms of slow potentials, was not supported. The mandatory right hand button press in Condition A had no effect between the hemispheres for the separately considered homologous frontal and homologous posterior sites.

Table 14

Mean Cross-Correlation IV Values for the Nonsignificant Conditions by Electrodes Interaction

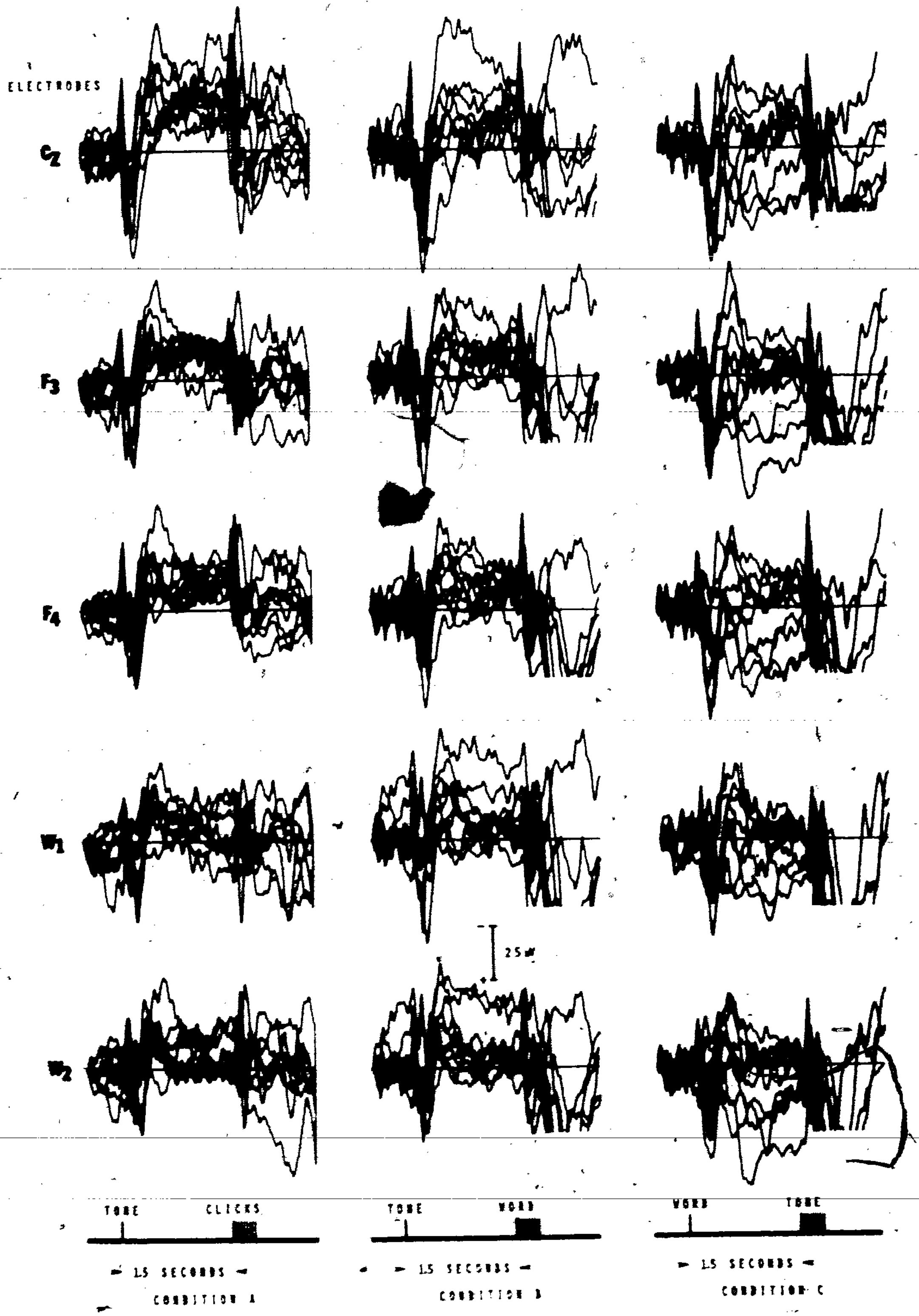
Experimental Condition	Left Side Electrodes (F_3 vs W_1)	Right Side Electrodes (F_4 vs W_2)
A (Tone → Clicks)	.93	.88
B (Tone → Word)	.90	.87
C (Word → Tone)	.90	.88

The vertical analysis of CNV activity distinguished between Condition A and Condition B but did not distinguish Condition B from Condition C. Most of the active electrodes in Condition C were at baseline levels or below. Separately considered by condition, differences between homologous frontal and differences between homologous posterior sites were not observed. The amplitude results presented here are in disagreement with those of Marsh and Thompson (1973) and Marsh, Poon, and Thompson (Note 31). Sex had little effect upon either the normalized area measurements or vertical measurements of CNV activity.

In order to provide an overall picture of slow potential activity, the overlayed averages for each subject at each active electrode site for each of the experimental conditions are illustrated in Figure 34. The small amount of negative activity in Condition C was probably due to the order of stimulus presentation. Since the stimulus word appeared at S_1, the subject's expectancy or anticipation was probably heightened between trials instead of during the S_1-S_2 interval. Given an increased negativity before S_1, a kind of cortical asymptote may have been reached that did not permit any further increases in negative activity. This notion coincides with results from experiments in which the position of the discriminative stimulus (either S_1 or S_2) had effects on the subsequent CNV waveform (Weinberg, Michalewski, & Koopman, Note 36). Low (1969) has pointed out cases where CNV amplitudes decreased with increased negativity at prestimulation levels. Similarly, other authors have noted the effects of pretrial shifts on subsequent CNV generation (Delse, Marsh, & Thompson,

Figure 34

Overlayed CNV Averages for Each Subject at Each Active Electrode Site for Each of the Experimental Conditions


ELECTRODES
C_Z
F_3
F_4
W_1
W_2
25 µV
TONE
CLICKS
1.5 SECONDS
CONDITION A
TONE
WORD
1.5 SECONDS
CONDITION B
WORD
TONE
1.5 SECONDS
CONDITION C

1972; Otto & Leifer, 1973; Billinger, Peters, & Knott, Note 37).

A considerable disturbance occurred in the EEG records at the time the subject vocalized the stimulus word. Some subjects were unable to avoid blinking when particular words were articulated quickly, e.g., BUCKET. The measures of CNV activity avoided the period just before and after S_2.

As indicated by the ratio indices of asymmetry, changes in the proportion of left hemisphere activity did not occur in Conditions B or C. Although frontal and posterior ratios were not different for females, the differences between frontal and posterior ratios were significant for males. Considered separately by condition, neither females nor males exhibited any differential slow wave changes in either frontal or posterior locations.

Aside from the vertex (C_z), evoked responses at frontal locations were generally larger than at posterior locations. It is interesting to note that the tone (S_1) in Condition B tended to evoke larger responses than the same tone (S_1) in Condition A. Considered by condition, there were no differences between homologous frontal or between homologous posterior sites. Since the word stimuli were not directed to a particular visual field, it might be argued that the optimal conditions for the production of lateralized effects were not met. However, Buchsbaum and Fedio (1969) provided evidence that lateral field stimulation was not necessary in order to produce asymmetrical cortical activity.

The correlations between the normalized area measurements of CNV activity and the vertical measures of CNV activity were either low or slightly inverse. This is probably due to the unconventional method used in the calculation of the CNV areas. Normally, substantial (e.g., +.80) correlations exist between these types of measurements (McCallum & Papakostopoulos, 1973). Since lateralization effects might have originated at the evoked response, it appeared appropriate to have a measure that included CNV activity from the very onset of the slow wave. The low correlations between normalized areas and vertical estimates of CNV activity suggested that there was little overlap among the measures. Based upon the method used in calculating the area measurements, the high correlations between normalized areas and evoked potential activity at S_1 were not unexpected. Congruently, there was little relation between vertical amplitude measurements of CNV activity and EP amplitudes.

Compared to the standard or Condition A, cross-correlations indicated that the overall waveforms in Conditions B and C were not dissimilar. Although correlations were generally lower in Condition C than in Condition B, differences between homologous frontal or between homologous posterior sites did not reach a significant level for either of the experimental conditions. Correlations between the vertex (C_z) and each of the lateral placements indicated higher overall correlations for frontal locations than for posterior locations. Separately considered by condition, differences between homologous frontal or between homologous posterior sites did not reach significant levels. Cross-correlations between homologous frontal and between homologous posterior sites were not differentiated between experimental conditions. Intrahemispheric cross-correlations indicated that no left or right side differences occurred for the separate experimental conditions. In all the cross-correlational analyses, sex effects were minimal or nonexistent.

There were several instances in which sizeable lateralization effects were observed. For example, the average records for subject B. G. (male) at each active electrode site for each of the experimental conditions are illustrated in Figure 35. A visual inspection showed that both lateral placements on the left hemisphere produced larger CNV activity in Condition C than in either Condition A or B. As a contrast, the average records for subject B. B. (male) are illustrated in Figure 36. Compared to the bilaterally symmetrical distribution of CNV activity that existed in Conditions A and B, right side placements in Condition C were considerably larger than left side placements. Many times the asymmetrical effects only involved the posterior sites or only the frontal sites. This same sort of inconsistency between subjects was noted in Experiment 1. In the following chapter, additional indices of hemispheric differentiation are considered in relation to lateral slow wave development.

Figure 35

Symmetrical and Asymmetrical CNV Averages
for Subject B. G. in Each of the
Experimental Conditions

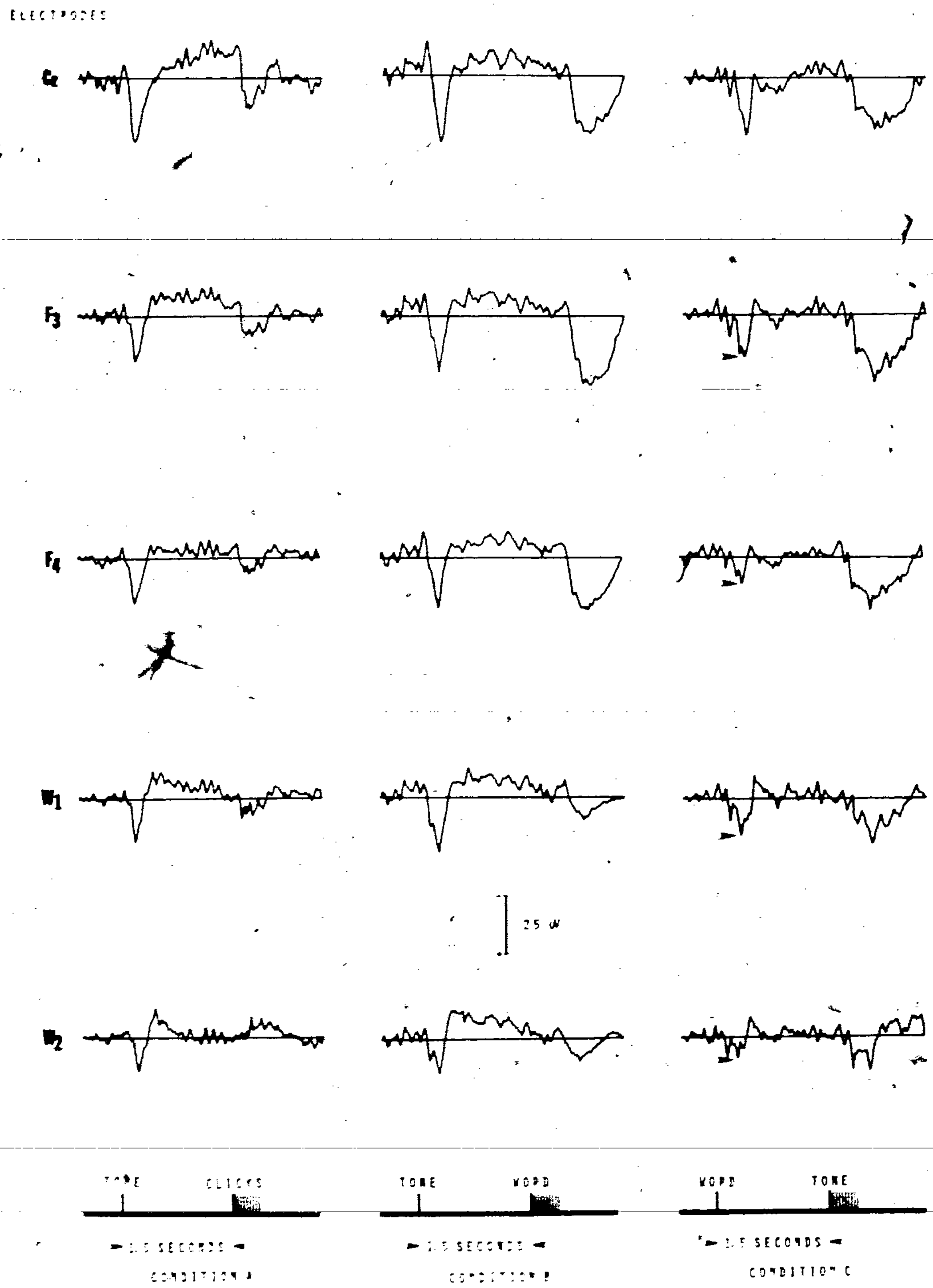
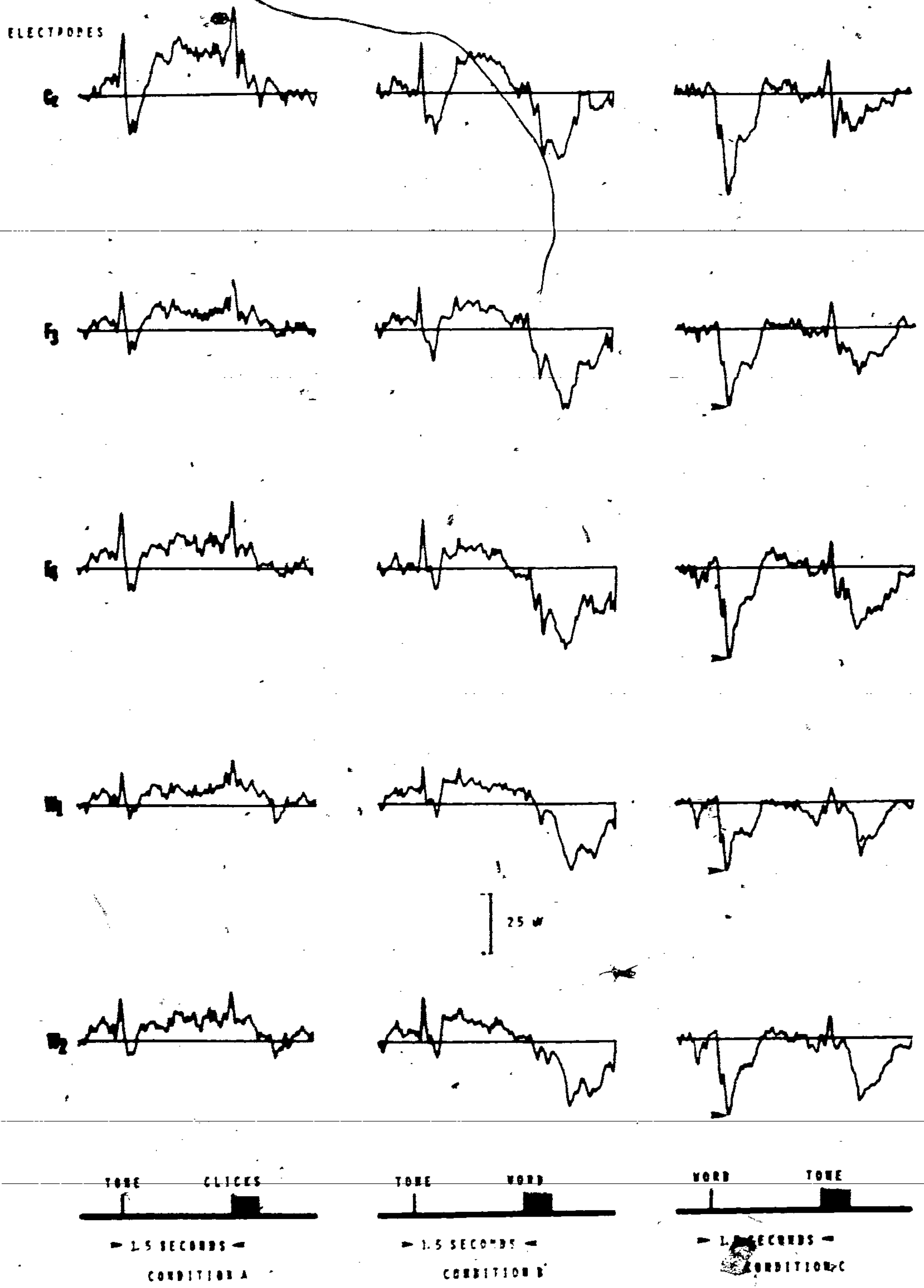

ELECTRODES
Cz
F3
F4
W1
W2
25 µV
TONE
CLICKS
1.5 SECONDS
CONDITION A
TONE
WORD
1.5 SECONDS
CONDITION B
WORD
TONE
1.5 SECONDS
CONDITION C

Figure 36

Symmetrical and Asymmetrical CNV Averages for Subject B. B. in Each of the Experimental Conditions


ELECTRODES
Cz
F3
F4
W1
25 µV
W2
TONE
CLICKS
TONE
WORD
WORD
TONE
1.5 SECONDS
1.5 SECONDS
1.5 SECONDS
CONDITION A
CONDITION B
CONDITION C

Chapter 6

BROCA'S AREA AND THE LATERAL DEVELOPMENT OF THE CNV: EXPERIMENT 3

For a long time now, Broca's area of the left hemisphere has been associated with various language functions. The integrity of the area appears especially critical, however, for articulated language production (Geschwind, 1970). Although located in the inferior region of the frontal lobe in the left hemisphere, Broca's area is accessible in the normal topography of the CNV.

An interesting eye movement phenomenon related to attention was reported by Day (1964). This investigator was able to demonstrate that directional eye-gaze shifts were elicited from individuals when they were asked so-called reflective questions. Given the proper situation, consistent eye movements were made to either the left or right while the individual contemplated the answer or response to the question. Day (1967) implicated the frontal eye field of the cortex in the mediation of the movements. Duke (1968) confirmed the occurrence of the eye movements and, in addition, found that males were more consistent in their eye movements than were females; ocular dominance did not appear related to the directional movements. Bakan

(1969) has discussed lateral eye movements in terms of a functional asymmetry of the brain. This investigator has found that left-movers (eye movements made consistently to the left) were more hypnotically susceptible, more image-oriented, and were less mathematically inclined than right-movers (eye movements made consistently to the right). Bakan and Svorad (1969) found that ongoing alpha production was more prominent among left-movers than right-movers. Kinsbourne (1974) found that during verbal processing subjects looked more often to the right, whereas during spatial processing subjects looked up and to the left. Although Kinsbourne (1970) thought that subject set was necessary in order to elicit hemispheric differences, Dee and Hannay (1973) found that asymmetries were observed in experiments where expectancy was prevented from developing. In exploring lateral eye movement phenomena, Ehrlickman, Weiner, and Baker (1974) questioned the effects of verbal material provoking right eye movements and spatial material provoking left eye movements. They were not able to replicate the gaze shifts reported by other workers.

This chapter investigates the frontal distribution of the lateral CNV in situations designed to promote expectancy for the production of simple word stimuli. In addition to the standard condition, subjects were required to vocalize a specified stimulus word at S_2 which appeared separately in S_1 or S_2 positions; further, an experimental condition was included that required vocalization of a word at S_2 that was associated to an S_1 stimulus. In addition to frontal and central sites, recordings were collected from a site estimating the area of Broca on the left hemisphere and a homologous comparison site on the right hemisphere. The activity from lateral placements was used to analyze the lateral distribution of the CNV during the various experimental conditions. Also, subjects were classified according to eye movement predisposition and ocular dominance. In Chapters 4 and 5, many instances of lateralized slow potentials were observed. The dominance indices were used to sort subjects into different categories in order to examine the effectiveness of predicting lateralized slow wave effects.

Methods

Subjects

The subjects were nine right-handed males and nine right-handed females. The subjects were recruited from the university community as paid volunteers. Handedness was checked by requiring each subject to copy a short paragraph. The subjects reported no abnormal speech or reading problems. The subjects' ages ranged from 17 to 33 years and all had normal or corrected to normal vision. Three of the subjects had previously participated in electroencephalographic experiments but did not take part in the studies presented in Chapters 4 or 5.

Pretesting

Visual determinations of lateral eye movements were made for each subject. Individuals were seated oppositely the questioner. After visual attention was gained, first eye movement responses were recorded to several reflective questions. The actual questions that were used are listed in Appendix F and were adopted from the published articles of several authors (Bakan, 1969; Duke, 1968; Morgan, McDonald, & Macdonald, 1971). For example, the following types of questions were asked: (a) How many letters are there in the word MONTREAL? (b) What is 123 times 6? and (c) Tell me an English word that starts with L and ends with C. Eye movement direction was recorded after each response. Successive questions were not asked of the subject until the questioner was satisfied that the subject's attention was regained. Ten movement responses were elicited from each subject; when eye movements with vertical components were encountered, the response was scored only on the direction of the lateral displacement.

Next, the ocular dominance of each subject was determined. The first task only required the subject to sight with one eye down the edge of a ruler to an object directly in front of him. The eye that was used to sight the object was recorded. The second task consisted of a modified version of the Dolman peephole test (see Davson, 1972). In this other dominance test, subjects were handed a 7 × 12 cm card with a centered 2 cm hole. The subject was then asked to grasp the card with both hands at arms' length and to sight a target object 6 m away through the hole. The eye that was used by the subject to sight the target was recorded.

Before testing, subjects were assured that all their questions about the pretesting and the purpose of the EEG testing would be answered after the recording session.

Recording Techniques

Monopolar scalp electrodes (Ag-AgCl) were cemented to the vertex (C_z), left frontal (F_3), and right frontal (F_4) locations according to the 10-20 System (Jasper, 1958). Additionally, two inferior frontal sites were homologously situated. Broca's area on the left hemisphere was approximated by moving downward from the vertex (C_z) 11 cm and then moving anteriorly 4 cm from the interaural line; this site was designated as B_1. Similarly, an area opposite to B_1 was located on the right hemisphere by moving downward 11 cm from the vertex (C_z) and then moving anteriorly 4 cm; this site was designated as B_2. (The method for locating the area of Broca was adopted from the article by McAdam & Whitaker, 1971a.) Active electrode sites were referenced to linked mastoids. A ground electrode was placed on the subject's forehead. In order to monitor ocular potentials, Beckman Biopotential electrodes were periorbitally placed above and below the right eye to record upward and downward movements, and electrodes were placed near the external canthus of each eye to record lateral eye movements. Skin sites were cleaned with alcohol; active electrode locations were marked with tincture of merthiolate. After the electrodes were attached and injected with electrolyte (Beckman), electrode impedances were measured and were equated in the range from 3.0 to 3.5K ohms by tapped skin abrasion.

Scalp activity was amplified and recorded on an 8-channel Elema-Schönander Mingograf recorder. Amplifier sensitivity was set to 50 μV/cm for active electrode sites; time constants were adjusted to 5.0 seconds with upper cutoff frequencies set at 70 Hz. Final amplifier outputs were digitized on-line with a Hewlett-Packard 2116B computer. Displayed trials that were accepted for entering an average were stored cumulatively on disc and consecutively on magnetic tape. Continuous analog (FM) records were also collected. Channel 8 marked the various event sequences defining an experimental trial. (See Chapter 4 for details on data collection and retrieval.) Before each day of testing, a 50 μV calibration signal was placed in parallel across amplifier inputs to verify the equality of the final amplifier outputs throughout the data collection network.

Stimulus Construction

For tachistoscopic presentation, common monosyllabic and polysyllabic English words, e.g., PAPERS, FAUCET, GORILLA, SNOW, etc., were singly placed on cards constructed from press-on transfer letters. The words that were used here were the same stimuli that were used in Chapter 5; see Appendix E for a complete list of the stimulus words. A closed-circuit TV system (Sony) projected the scope (3-channel Scientific Prototype) presentations into the shielded cubicle for subject viewing. Viewed on the screen monitor, stimuli were .3° high; longer words were approximately 4° across the screen.

Procedure

After pretesting and electrode preparation, subjects reclined comfortably on a bed adjusted for viewing the screen of the TV monitor. The face of the monitor was aligned to the straight ahead gaze of the subject. Overall screen brightness was approximately .5 ftL (1.713 cd/m^2) and was essentially the only source of illumination in the cubicle.

After connecting the subject to the amplifiers, a 15 - 20 minute period followed in which the electrodes were allowed to stabilize and a final equipment inspection was made.

When satisfactory resting records were achieved, four experimental conditions were administered to each subject. In Condition 1, the standard, a 30-millisecond tone (1000 Hz) pip (S_1) was followed 1.5 seconds later by clicks (S_2). With a button switch placed in his right hand, the task of the subject was to terminate the clicks by button press as soon as they were sounded. The click presentation was automatically inhibited if the subject pressed the button before their occurrence. The subject fixated a point projected on the TV monitor during the standard condition. Several practice trials were given to each subject in order to assure proper eye fixation, a proper response pattern, and to attain an acceptably stable signal record.

In Condition 2, a 30-millisecond tone pip (S_1) was followed 1.5 seconds later by a stimulus word (S_2) presented for 30 milliseconds. The subject's task was to audibly vocalize the binocularly observed S_2 word as soon as it appeared. In practice trials, individual levels of response were established that allowed word verification over open intercom and did not unreasonably disturb the EEG tracings. The subject fixated a dot that momentarily disappeared during word presentation.

In Condition 3, the sequence of the S_1 and S_2 presentations was reversed from that of Condition 2. A word (S_1) was presented for 30 milliseconds followed 1.5 seconds later by a tone pip (S_2) of 30 milliseconds duration. The S_2 tone signaled the subject to audibly vocalize the binocularly observed stimulus word seen at S_1. When subjects were given practice trials, word pronunciation was observed; the subject was cautioned not to say the word until the S_2 signal and then to do so with a minimum of articulatory movement. The subject's verbal responses were verified over open intercom. Subjects fixated a dot that disappeared during word presentations.

Lastly, in Condition 4, a stimulus word (S_1) appeared for 30 milliseconds duration followed 1.5 seconds later by a tone pip (S_2) also of 30 milliseconds duration. The sounding of S_2 in this case signaled the subject to audibly vocalize a one word association made to the binocularly observed word seen at S_1. During practice trials, subjects were reinstructed on word articulation. The word responses were monitored over open intercom. The subject continuously fixated a dot that momentarily disappeared during the word presentations.

The words that were used in Conditions 2, 3, and 4 were presented in random order without repetition for each subject. The standard condition was administered first for all subjects; the order for Conditions 2, 3, and 4 was randomly determined for each subject. Time periods between trials ranged from 18 to 30 seconds; periods between conditions ranged from 5 to 10 minutes.

For all four experimental conditions, subjects listened to auditory stimuli from loudspeakers under the bed. Sound levels measured at the subject's head ranged from 65 to 70 dB; in the standard condition, clicks were generated from a Grass S-4 stimulator at a rate of 15/second and were delivered at a level that ranged from 65 to 70 dB re 20 $\mu N/m^2$.

An average of 16 trials was collected for each of the experimental conditions for each subject. The trials that were used for an average were reasonably free from eye movements and were free from obvious muscular activity in the critical S_1-S_2 interval. The start of data collection was issued manually after ongoing EEG traces were determined to be satisfactorily stable. A total sweep period of 3.5 seconds was used; signal digitization for baseline purposes started 500 milliseconds prior to the onset of S_1. Timing sequences, tachistoscopic presentations, and S_1 and S_2 stimuli were controlled by Grason-Stadler 1200 programming modules.

Data Treatment

The data averages collected for each subject were plotted for each experimental condition and for each of the electrode sites. Individual data averages were digitally filtered prior to plotting (see Appendix B) and were centered around a mean baseline voltage from the 500-millisecond prestimulation period.

Area measurements of CNV magnitude. The individually recorded averages were used to derive area measurements of CNV magnitude. From the most positive point in the evoked potential to S_1, a horizontal line was directed to a point 50 milliseconds prior to the onset of S_2; from there the line was directed perpendicularly to intersect the slow wave. The enclosed area bounded by the slow wave and the constructed line segments was measured with a compensating planimeter (K & E Model 4236). The area measures were scaled into μV-seconds and then were normalized in μV.

A three-factor (2 × 4 × 5) analysis of variance design with repeated measures on the last two factors was used to evaluate the magnitude measures. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C). The analysis of variance computations were carried out using program BMDO8V of the Health Sciences Computing Facility, UCLA.

Vertical measurements of CNV amplitude. A single estimate of slow wave activity was made for all subjects from the averaged records of each active electrode site for each of the corresponding experimental conditions. Direct (calipered) readings were collected from a baseline level 50 milliseconds prior to the onset of S_2 vertically to a point on the slow wave.

A three-factor (2 × 4 × 5) analysis of variance design with repeated measures on the last two factors was used to evaluate the vertical amplitude measures. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Ratio indices of asymmetry. In order to assess the relative proportion of left (L) hemisphere activity to right (R) hemisphere activity, ratios of the form $L/(L + R)$ were formed. Ratios were separately derived for homologous frontal sites, $F_3/(F_3 + F_4)$, and homologous inferior frontal sites, $B_1/(B_1 + B_2)$, from the electrode averages for each of the experimental conditions. The CNV activity at an electrode site was estimated by the magnitude (area) measure previously made for that location. The proportions that exceeded .50 indicated larger left than right hemisphere activity; proportions below .50 indicated larger right than left hemisphere activity.

A three-factor (2 × 4 × 2) analysis of variance design with repeated measures on the last two factors was used to evaluate the ratios. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Evoked potential amplitudes at S_1. A general estimate of evoked potential activity was taken in response to S_1 for each of the subjects at each of the active electrode sites for each of the corresponding experimental conditions. Direct (calipered) measurements were taken from averaged records from the most prominent component that occurred after S_1 (latencies ranged from 250 - 350 milliseconds) to the baseline level determined around the 500-millisecond prestimulation period.

A three-factor (2 × 4 × 5) analysis of variance design with repeated measures on the last two factors was used to evaluate the evoked potential amplitudes. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Additionally, the relationships of the area measurements, vertical measures, and evoked response (or EP) measures to each other were evaluated by Pearson Product-Moment correlations. The significance of each correlation was tested by $t = r[(n - 2)/(1 - r^2)]^{\frac{1}{2}}$ with $df = n - 2$.

Cross-Correlations I. Cross-correlations for each subject were separately performed between each active electrode site in the standard condition and itself in Condition 2; likewise, cross-correlations were separately performed between an electrode site in the standard condition and itself in Condition 3, and between an electrode site in the standard and itself in Condition 4. The computer program that calculated the cross-correlations was designed to emphasize slow wave build up and omit slow wave resolution. Only 600 data points of the 1024 points available were used in the computations. With a total sweep period of 3.5 seconds, the 600 data points corresponded to a period into the CNV interval of 2050 milliseconds from the start of data collection.

The resulting Cross-Correlation I values that were obtained were entered into a three-factor (2 × 3 × 5) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations II. In order to examine the activity of the central site (C_z) with each of the lateral placements, separate cross-correlations were performed for each subject comparing the vertex (C_z) of the standard condition to each of the lateral placements of Condition 1; in Condition 2, cross-correlations were performed between the vertex (C_z) and each of the lateral placements of Condition 2; likewise, correlations were similarly performed for Condition 3 and Condition 4.

The resulting correlation values were entered into a three-factor (2 × 4 × 4) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations III. Separate cross-correlations were performed for each subject between homologous frontal (F_3 vs F_4) and between homologous inferior frontal (B_1 vs B_2) electrode sites for each of the experimental conditions.

The correlations that were obtained were entered into a three-factor (2 × 4 × 2) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Cross-Correlations IV. Separate cross-correlations for each subject were performed between left side intrahemispheric placements (F_3 vs B_1) and between right side intrahemispheric placements (F_4 vs B_2) for each of the experimental conditions.

The correlation values were entered into a three-factor (2 × 4 × 2) analysis of variance design with repeated measures on the last two factors. Factors and factor labels were as follows: sex (A) by conditions (B) by electrodes (C).

Lateral eye movements and ocular dominance. Disregarding sex, Factor A of the previously described analyses was now used to classify lateral eye movement predisposition. Subjects that moved consistently to the left 7 out of 10 times were classified as left-movers and were assigned A = 1; similarly, subjects that moved to the right 7 out of 10 times were classified as right-movers and were assigned A = 2; the remaining subjects were pooled into a general category of inconsistent-movers and were assigned A = 3. The other factor classifications, i.e., conditions (Factor B) and electrodes (Factor C) remained the same as before. Differences in the levels of Factor A resulted in the following design changes (n = 18): (a) Area measurements of CNV magnitude (3 × 4 × 5); (b) Vertical measurements of CNV amplitude (3 × 4 × 5); (c) Ratio indices of asymmetry (3 × 4 × 2); (d) Evoked potential amplitudes at S_1 (3 × 4 × 5); (e) Cross-Correlations I (3 × 3 × 5); (f) Cross-Correlations II (3 × 4 × 4); (g) Cross-Correlations III (3 × 4 × 2); and (h) Cross-Correlations IV (3 × 4 × 2).

Disregarding sex and eye movement classifications, scores of ocular dominance were analyzed under Factor A for each of the analyses previously considered. Subjects that sighted with their left eye in both tasks were accordingly considered left eye dominant and were assigned level A = 1; similarly, subjects that sighted with their right eye in both tasks were considered right eye dominant and were assigned level A = 2. The other factor classifications, i.e., conditions (Factor B) and electrodes (Factor C) remained the same as before. Differences in the levels of Factor A resulted in the following design changes ($\underline{n} = 6$): (a) Area measurements of CNV magnitude (2 × 4 × 5); (b) Vertical measurements of CNV amplitude (2 × 4 × 5); (c) Ratio indices of asymmetry (2 × 4 × 2); (d) Evoked potential amplitudes at S_1 (2 × 4 × 5); (e) Cross-Correlations I (2 × 3 × 5); (f) Cross-Correlations II (2 × 4 × 4); (g) Cross-Correlations III (2 × 4 × 2); and (h) Cross-Correlations IV (2 × 4 × 2).

Results

The analysis of overall treatment effects relied upon the general application of the analysis of variance. Individual tests of main effects were carried out using Duncan's Multiple-Range Test among the means for significant $\underline{F}$ ratios. Generally, significant interactions were also analyzed using Duncan's Multiple-Range Test. In the calculation of the critical ranges, it was the level of the significant F ratio that normally determined the particular tables entered.

Area Measurements of CNV Magnitude

The overall effects between females and males were not significantly different ($F < 1$, $df = 1/16$, $p > .20$). The effects for conditions ($F = 2.88$, $df = 3/48$, $p < .05$) and electrodes ($F = 63.78$, $df = 4/64$, $p < .001$) reached significant levels. Interactions that reached significance included sex by electrodes ($F = 4.82$, $df = 4/64$, $p < .005$) and conditions by electrodes ($F = 9.64$, $df = 12/192$, $p < .001$). A summary of the analysis of variance for the area measurements of CNV magnitude is provided in Appendix C, Table C14.

The overall means for the normalized areas for each of the experimental conditions are illustrated in Figure 37. Further tests indicated that Condition 1 was different from Condition 3 ($p < .05$), whereas contrasts between other conditions did not reach a significant level. The Duncan range tests among the means of Factor B are shown in Appendix D, Table D48.

In the overall electrodes effect, the vertex (C_z) was larger than any of the laterally placed electrodes ($p < .001$). The overall left frontal (F_3) site was larger than either B_1 or B_2 locations ($p < .001$). The overall differences between homologous frontal and between homologous inferior frontal sites did not reach a significant level. The overall means for normalized areas at each active electrode site are illustrated in Figure 38. The Duncan range tests among the means of Factor C are shown in Appendix D, Table D49.

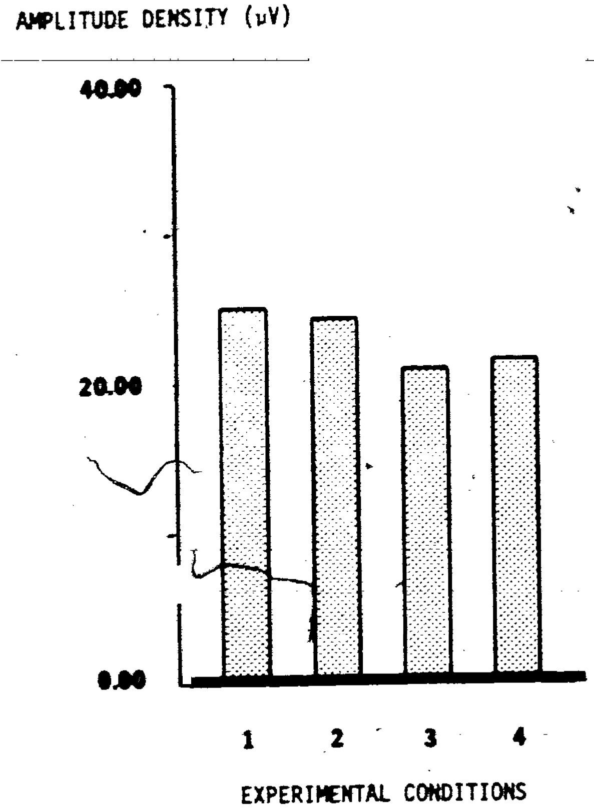


Figure 37

Overall Means for the Normalized Area Measurements of CNV Activity for Each of the Experimental Conditions

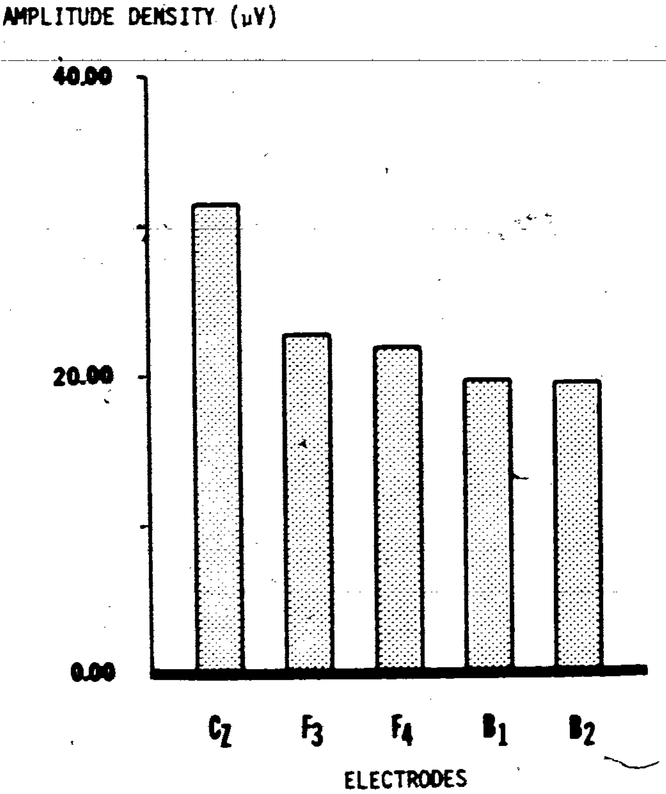


Figure 38

Overall Means for the Normalized Area Measurements of CNV Activity at Each Active Electrode Site

The mean densities (normalized areas) involved in the sex by electrodes (A × C) interaction are illustrated in Figure 39. For the females, the vertex (C_z) site was larger than any of the lateral placements; F_3 and F_4 sites were separately larger than either B_1 or B_2 sites ($p < .005$). For the males, the vertex (C_z) site was separately larger than any of the lateral placements ($p < .005$); however, none of the differences between lateral placements reached a significant level. For both females and males, differences between homologous frontal or between homologous inferior frontal sites did not reach a significant level. The Duncan range tests among the means for females across electrode sites and for males across electrode sites are shown in Appendix D, Tables D50 and D51, respectively.

The mean densities involved in the conditions by electrodes (B × C) interaction are illustrated in Figure 40. Further tests indicated that the vertex (C_z) of each experimental condition was larger than any of the corresponding lateral placements ($p < .001$). In Condition 1, frontal sites F_3 and F_4 were separately larger than either B_1 or B_2 locations ($p < .001$). In Condition 2, the left frontal (F_3) site was separately larger than either B_1 or B_2 sites ($p < .001$). In Condition 3, none of the differences between lateral placements reached a significant level; similarly, none of the differences between lateral placements reached a significant level in Condition 4. Separately considered by experimental condition, differences between homologous frontal or between homologus inferior frontal sites did not reach a significant level. The Duncan range tests among the means of Conditions 1, 2, 3, and 4 across electrodes

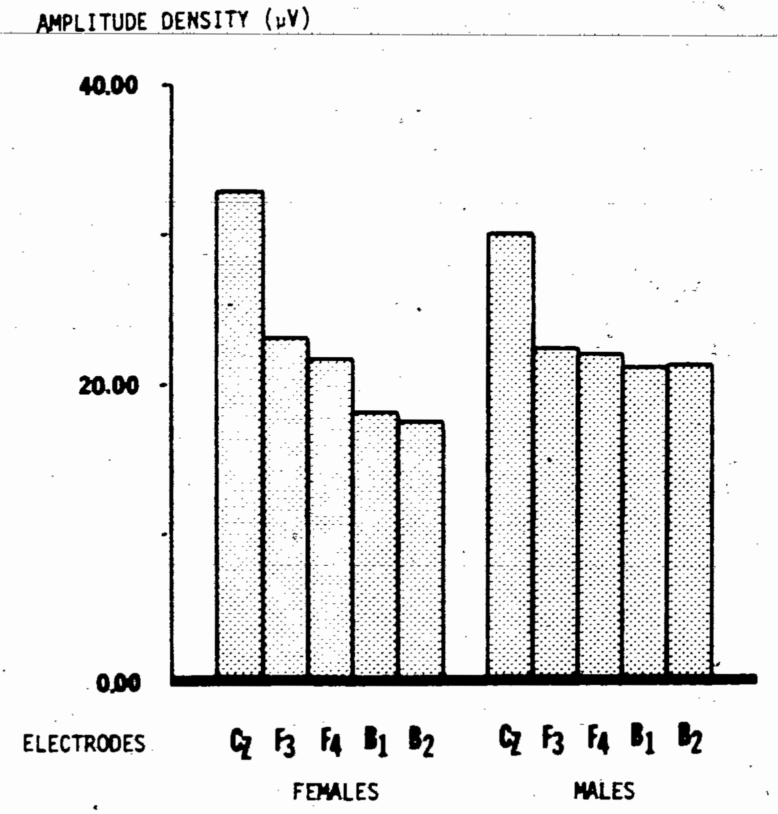


Figure 39

Means for the Normalized Area Measurements of CNV Activity for Females and Males at Each Active Electrode Site

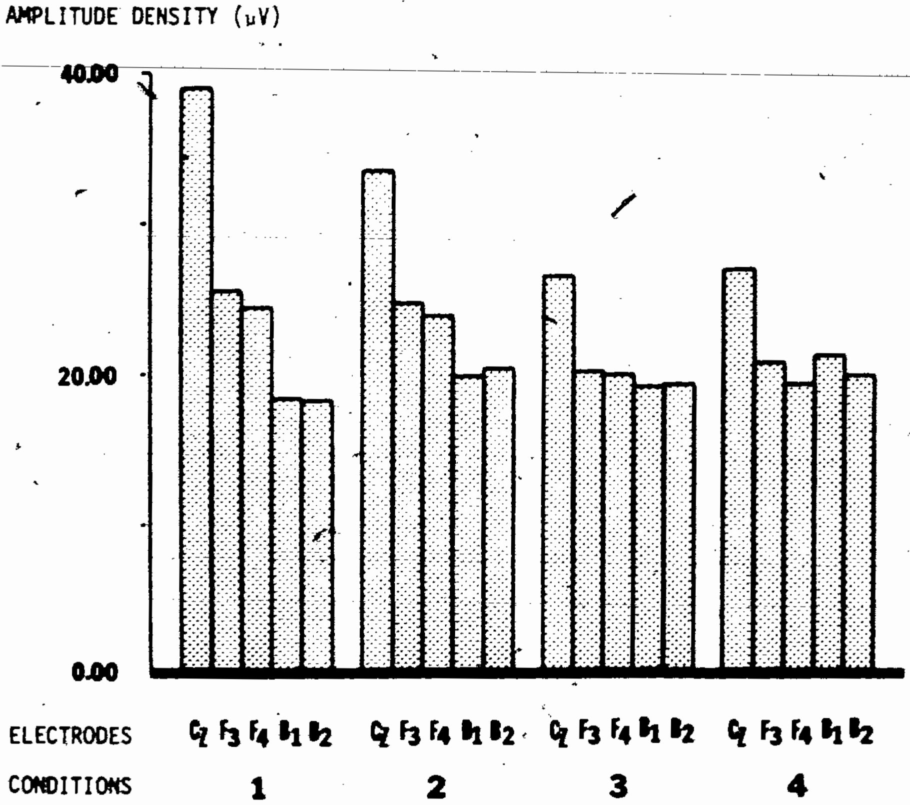


Figure 40

Means for the Normalized Area Measurements of CNV Activity at Each Active Electrode Site for Each of the Experimental Conditions are shown in Appendix D, Tables D52, D53, D54, and D55, respectively.

Vertical Measures of CNV Amplitude

The F ratio for sex was not significant ($F < 1$, df = 1/16, $p > .20$). However, the F ratios for conditions ($F = 18.48$, df = 3/48, $p < .001$) and electrodes ($F = 33.28$, df = 4/64, $p < .001$) did reach significant levels. There was also a significant conditions by electrodes interaction ($F = 4.16$, df = 12/192, $p < .001$). The summary of the analysis of variance for the vertical measures of CNV amplitude is provided in Appendix C, Table C15.

The overall mean amplitudes for the separate experimental conditions are illustrated in Figure 41. Further tests indicated that Condition 1 was separately different from Conditions 3 and 4 ($p < .001$). The Duncan range tests among the means of Factor B are shown in Appendix D, Table D56.

The overall mean amplitudes at each of the electrode sites are illustrated in Figure 42. The vertex (C_z) was larger than either F_3, F_4, B_1, or B_2 sites ($p < .001$). None of the differences between lateral sites reached a significant level. The Duncan range tests among the means of Factor C are shown in Appendix D, Table D57.

The mean amplitudes involved in the conditions by electrodes (B × C) interaction are illustrated in Figure 43. In Condition 1, the vertex (C_z) was separately larger than any of the lateral placements ($p < .001$); the right frontal (F_4) site was also larger than the left inferior frontal site (B_1) at the $p < .001$ level. In Condition 2, the vertex (C_z) was larger than any of the lateral placements ($p < .001$);

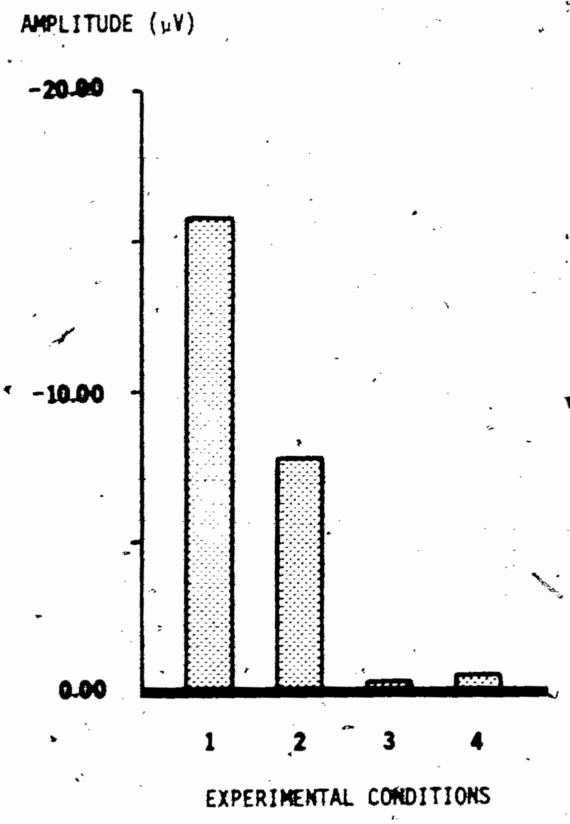


Figure 41

Overall Mean CNV Amplitudes for Each
of the Experimental Conditions

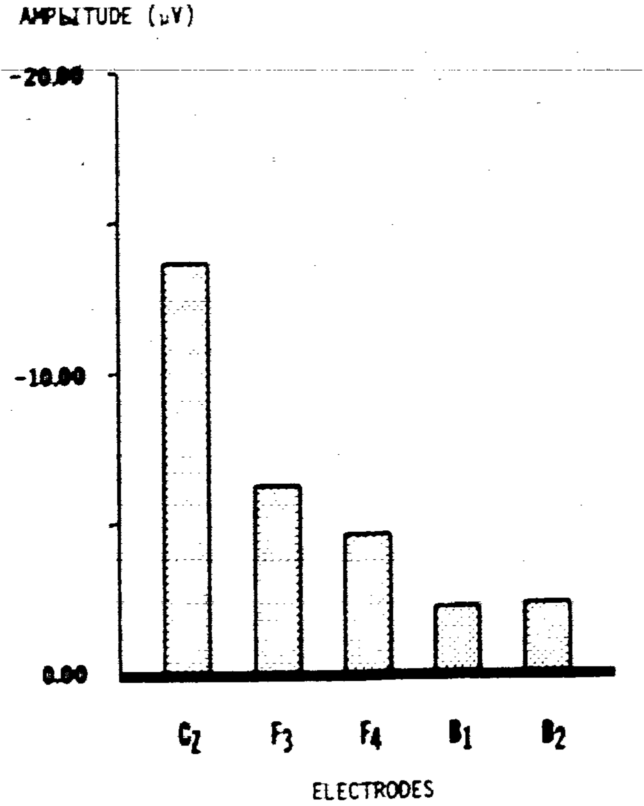


Figure 42

Overall Mean CNV Amplitudes at Each Active Electrode Site

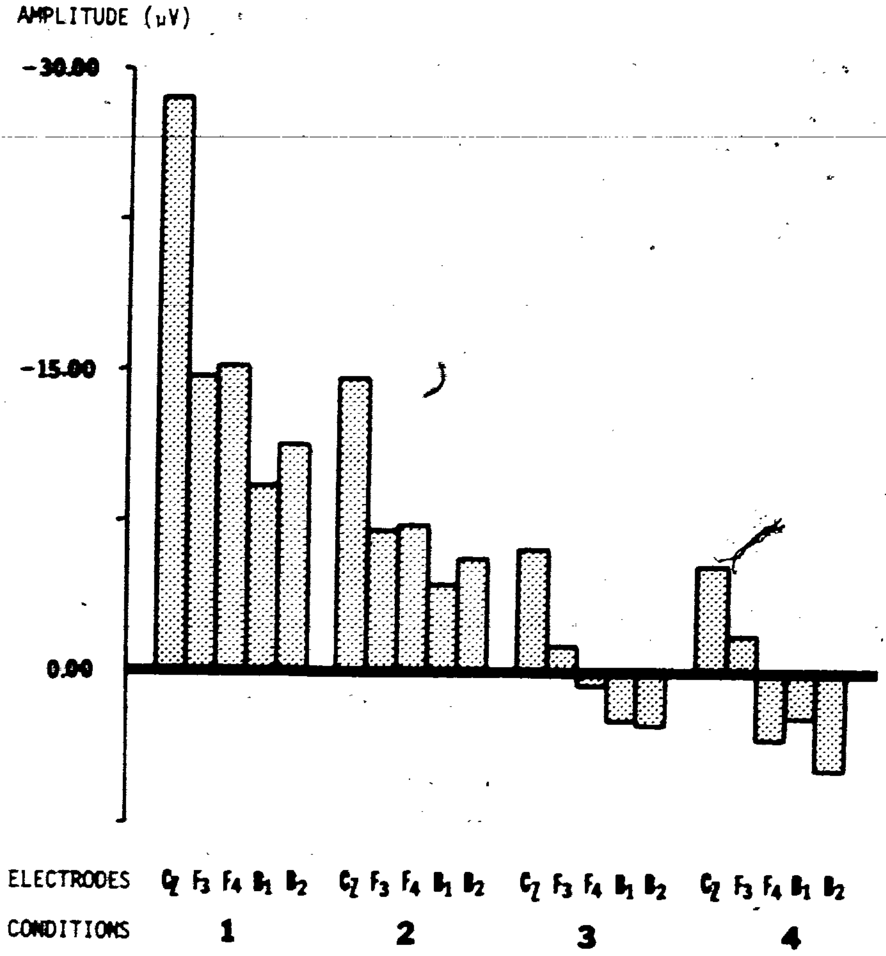


Figure 43

Mean CNV Amplitudes at Each Active Electrode Site
For Each of the Experimental Conditions

none of the differences between lateral placements reached a significant level. In Condition 3, the vertex (C_z) was separately larger than either F_4, B_1, or B_2 locations ($p < .001$); none of the differences between lateral placements reached a significant level. In Condition 4, the vertex (C_z) was separately larger than F_4, B_1, or B_2 ($p < .001$); also, F_3 was larger than B_2 ($p < .001$). Separately considered by condition, differences between homologous frontal and between homologous inferior frontal sites did not reach a significant level. The Duncan range tests among the means of Conditions 1, 2, 3, and 4 across electrodes are shown in Appendix D, Tables D58, D59, D60, and D61, respectively.

Ratio Indices of Asymmetry

The F ratios for sex ($F < 1$, $df = 1/16$, $p > .20$), conditions ($F < 1$, $df = 3/48$, $p > .20$), and electrodes ($F = 1.14$, $df = 1/16$, $p > .20$) did not reach significant levels. The summary of the analysis of variance for ratios is provided in Appendix C, Table C16.

The mean ratios involved in the nonsignificant conditions by electrodes (B × C) interaction are shown in Table 15. The frontal ratios and the inferior frontal ratios were similar among conditions with the ratios generally exceeding .50 by only a slight amount. Although not statistically justifiable, Duncan range tests among the frontal ratios across conditions and inferior frontal ratios across conditions are shown in Appendix D, Tables D62 and D63, respectively.

Evoked Potential Amplitudes at S_1

The overall F ratio for sex ($F < 1$, $df = 1/16$, $p > .20$) did

Table 15

Mean Frontal Ratios and Mean Inferior Frontal Ratios for Each of the Experimental Conditions

Experimental Condition	Frontal Ratio ($F_3/[F_3 + F_4]$)	Inferior Frontal Ratio ($B_1/[B_1 + B_2]$)
1 (Tone → Clicks)	.51	.50
2 (Tone → Word)	.50	.49
3 (Word → Tone)	.51	.50
4 (Word → Assoc.)	.52	.52

not reach a significant level. There were significant effects for conditions ($\underline{F} = 5.51$, $\underline{df} = 3/48$, $\underline{p} < .005$) and electrodes ($\underline{F} = 17.46$, $\underline{df} = 4/64$, $\underline{p} < .001$). Interactions that reached significant levels included sex by electrodes ($\underline{F} = 4.53$, $\underline{df} = 4/64$, $\underline{p} < .005$) and conditions by electrodes ($\underline{F} = 2.13$, $\underline{df} = 12/192$, $\underline{p} < .025$). A summary of the analysis of variance for evoked potential amplitudes at S_1 is provided in Appendix C, Table C17.

The overall means for evoked potential amplitudes at S_1 across conditions are illustrated in Figure 44. The evoked potentials in Condition 3 were larger than in Condition 1 ($\underline{p} < .005$). The Duncan range tests among the means of Factor B are shown in Appendix D, Table D64.

The overall means for evoked potential amplitudes across electrodes are illustrated in Figure 45. Tests indicated that the vertex (C_z) was larger than any of the lateral electrode sites ($\underline{p} < .001$); none of the differences between lateral sites reached a significant level. The Duncan range tests among the means of Factor C are shown in Appendix D, Table D65.

The mean EP amplitudes involved in the sex by electrodes (A × C) interaction are illustrated in Figure 46. For the females, the vertex (C_z) was larger than any of the lateral sites ($\underline{p} < .005$); also, F_3 and F_4 sites were separately larger than B_2 ($\underline{p} < .005$). For the males, none of the differences between electrodes reached a significant level ($\underline{p} > .005$). For both females and males, differences between homologous frontal and between homologous inferior frontal sites did not reach a significant level. The Duncan range tests among

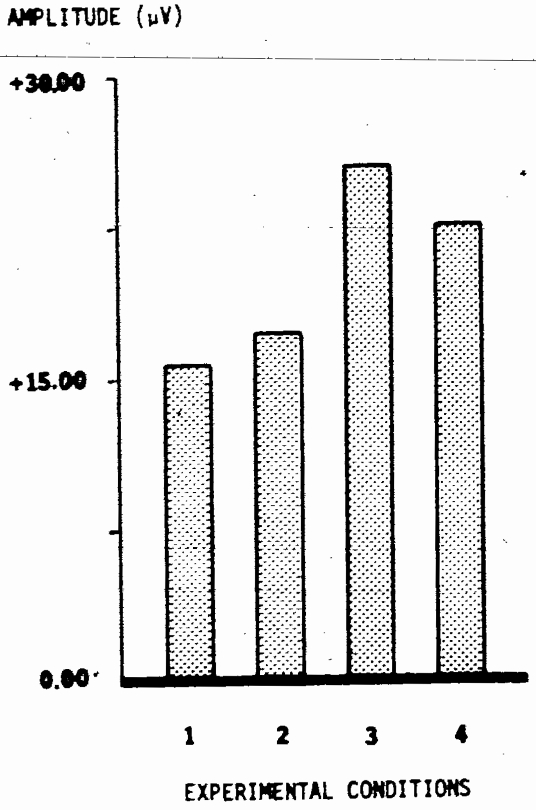


Figure 44

Overall Means for Evoked Potential Amplitudes at S_1
for Each of the Experimental Conditions

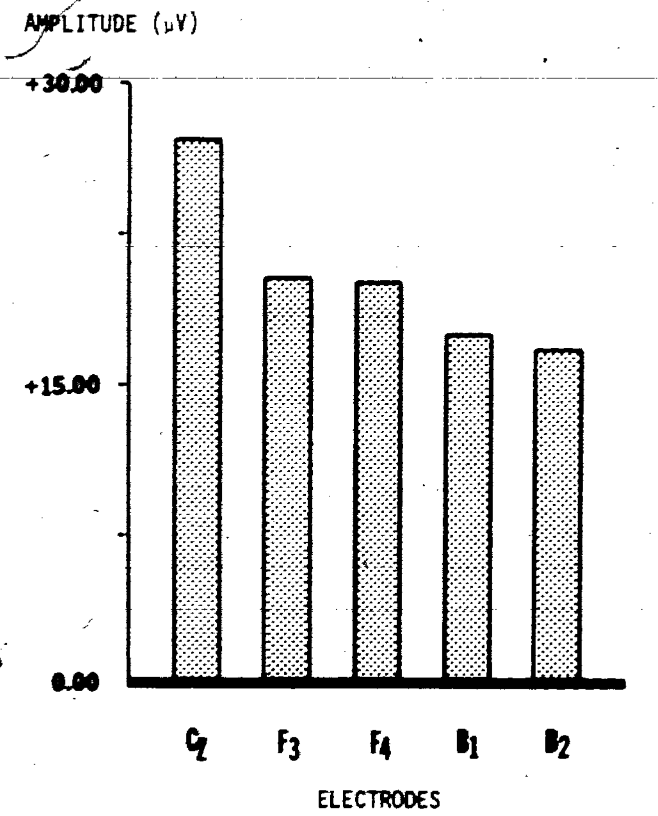


Figure 45

Overall Means for Evoked Potential Amplitudes at S_1 for Each Active Electrode Site

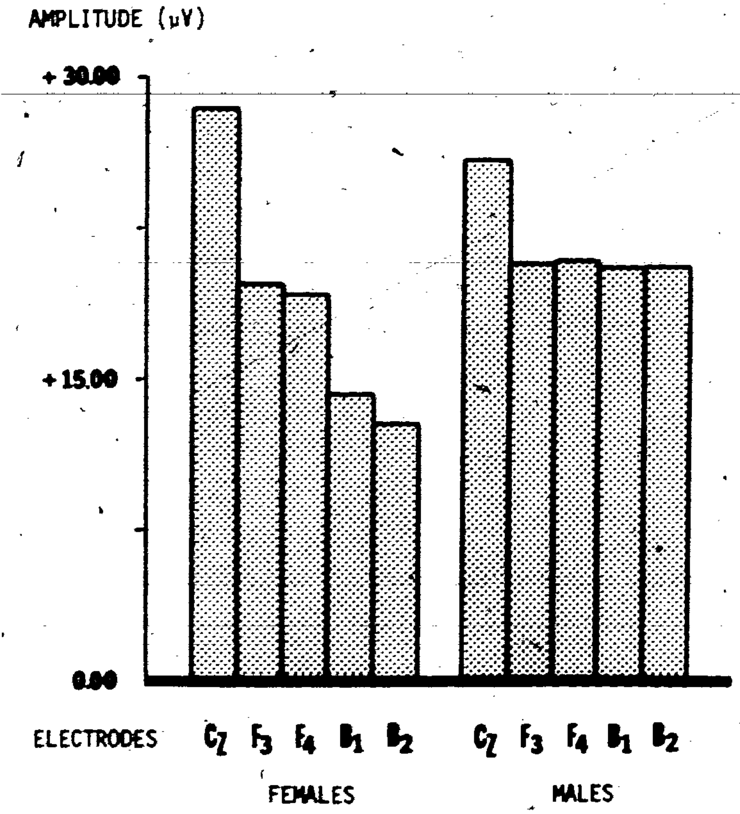


Figure 46

Means for Evoked Potential Amplitudes at S_1 for Females and Males at Each Active Electrode Site the means for females across electrodes and males across electrodes are shown in Appendix D, Tables D66 and D67, respectively.

The mean EP amplitudes involved in the conditions by electrodes (B × C) interaction are illustrated in Figure 47. For each condition, the vertex (C_Z) was larger than any of the corresponding lateral placements ($p < .05$). In Conditions 1 and 2, frontal sites F_3 and F_4 were separately larger than B_1 or B_2 ($p < .05$). In Conditions 3 and 4, however, none of the differences between lateral placements reached a significant level ($p > .05$). Separately considered by condition, differences between homologous frontal and between homologous inferior frontal sites did not reach a significant level. The Duncan range tests among the means for Conditions 1, 2, 3, and 4 across electrodes are shown in Appendix D, Tables D68, D69, D70, and D71, respectively.

In order to examine the relationships between the two estimates of CNV activity and their separate relationships to the evoked responses (or EPs) that were collected, product-moment correlations were performed between the various measures. From the normalized area measurements of CNV activity ~~and vertical~~ measurements of CNV activity, correlations were performed between each active electrode site and itself for each of the experimental conditions. The correlation values that resulted are shown in Table 16. The overall correlations were very low or inverse over all conditions. From the normalized area measurements of CNV activity and the evoked response amplitudes at S_1, correlations were performed between each active electrode site and itself for each of the experimental conditions. The correlations that resulted are shown in Table 17. The overall correlations were high in

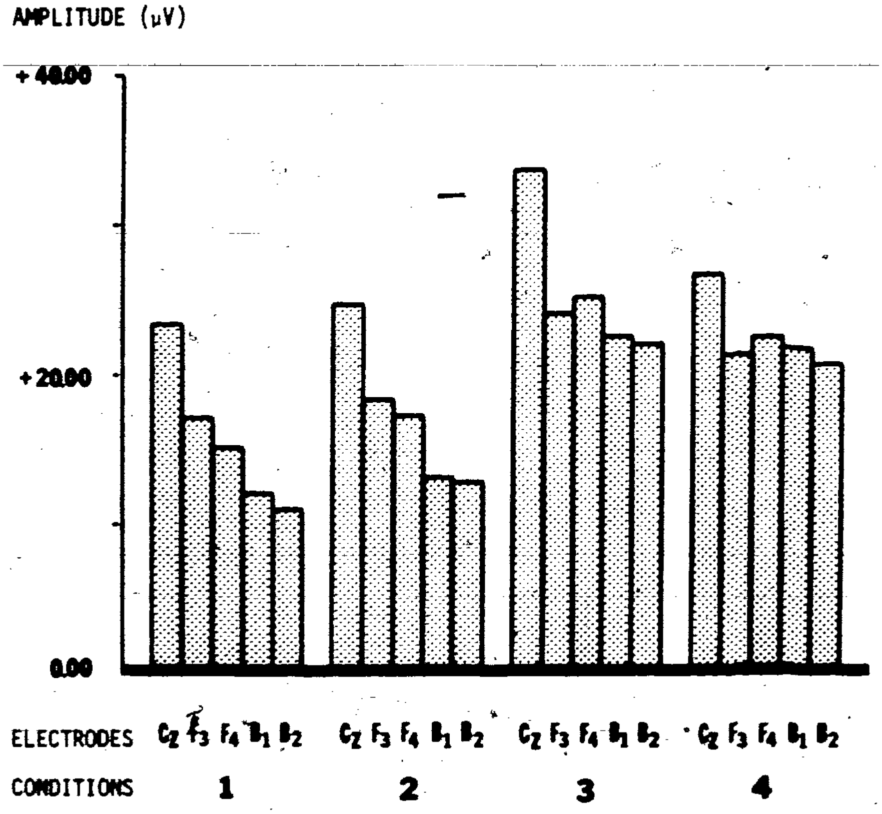


Figure 47

Mean Evoked Potential Amplitudes at S_1 for Each of the Active Electrode Sites in Each of the Experimental Conditions

Table 16

Correlations between Normalized Area Measurements of CNV Activity and Vertical Measurements of CNV Activity at Each Active Electrode Site for Each of the Experimental Conditions

Correlation and Test	Electrode Site				
	C_z	F_3	F_4	B_1	B_2
		Condition 1 (Tone → Clicks)			
r = ...	-.33	-.42	-.54	-.09	-.28
t = ...	-1.43	-1.88	-2.56[a]	-.38	-1.17
		Condition 2 (Tone → Word)			
r = ...	-.40	-.47	-.59	-.13	-.35
t = ...	-1.77	-2.14	-2.93[b]	-.53	-1.53
		Condition 3 (Word → Tone)			
r = ...	-.12	-.24	-.49	-.23	-.36
t = ...	-.50	-1.01	-2.29[a]	-.96	-1.54
		Condition 4 (Word → Assoc.)			
r = ...	-.37	-.56	-.39	.07	-.23
t = ...	-1.61	-2.71[a]	-1.70	.28	-.95

Note. For each *t*-test, *n* = 18, *df* = 16. Polarities of the vertical measurement above (negative) or below (positive) baseline were observed.

[a] $p < .05$.

[b] $p < .01$.

Table 17

Correlations between Normalized Area Measurements of CNV Activity and Evoked Potential Amplitudes at S_1 at Each Active Electrode Site for Each of the Experimental Conditions

Correlation and Test	Electrode Site				
	C_z	F_3	F_4	B_1	B_2
	Condition 1 (Tone → Clicks)				
r = ...	.69	.54	.54	.77	.72
t = ...	3.85^b	2.62^a	2.57^a	4.83^c	4.21^c
	Condition 2 (Tone → Word)				
r = ...	.76	.68	.68	.73	.81
t = ...	4.69^c	3.80^b	3.71^b	4.37^c	5.66^c
	Condition 3 (Word → Tone)				
r = ...	.84	.75	.93	.76	.88
t = ...	6.23^c	4.67^c	10.45^c	4.75^c	7.74^c
	Condition 4 (Word → Assoc.)				
r = ...	.83	.73	.88	.87	.82
t = ...	6.03^c	4.30^c	7.43^c	7.04^c	5.82^c

Note. For each *t*-test, *n* = 18, *df* = 16. Polarities of the evoked potential measurements above (negative) and below (positive) baseline were observed.

$^a p < .05$. $^c p < .001$.

$^b p < .01$.

Conditions 1 and 2 but tended to be slightly higher in Conditions 3 and 4. Finally, correlations were performed between each active site and itself for the vertical measures of CNV amplitude and the evoked response measures of amplitude for each of the experimental conditions. The correlations that resulted are shown in Table 18. The overall correlations were low or slightly inverse over the experimental conditions.

Cross-Correlations I

Cross-correlations between each active electrode site and itself were performed which separately compared the standard condition to each of the other experimental conditions. The overall effects for sex were not significant ($\underline{F} = 1.44$, $\underline{df} = 1/16$, $\underline{p} > .20$). There were significant effects for conditions ($\underline{F} = 40.06$, $\underline{df} = 2/32$, $\underline{p} < .001$) and electrodes ($\underline{F} = 7.79$, $\underline{df} = 4/64$, $\underline{p} < .001$). There was also a significant conditions by electrodes interaction ($\underline{F} = 2.94$, $\underline{df} = 4/64$, $\underline{p} < .05$). A summary of the analysis of variance for Cross-Correlations I is provided in Appendix C, Table C18.

The overall mean Cross-Correlation I values across conditions are illustrated in Figure 48. Further tests indicated that the correlations in Condition 2 were separately higher than in either Condition 3 or Condition 4 ($\underline{p} < .001$). The Duncan range tests among the means of Factor B are shown in Appendix D, Table D72.

The overall correlation means for electrodes (Factor C) are illustrated in Figure 49. Tests indicated that the vertex (C_z) correlations were separately higher than the correlations for any of the

Table 18

Correlations between the Vertical Measurements of CNV Activity and Evoked Potential Amplitudes at S_1 at Each Active Electrode Site for Each of the Experimental Conditions

Correlation and Test	Electrode Site				
	C_z	F_3	F_4	B_1	B_2
Condition 1 (Tone → Clicks)					
r = ...	.31	.31	.24	.41	.26
t = ...	1.33	1.32	1.00	1.82	1.11
Condition 2 (Tone → Word)					
r = ...	.16	-.09	-.07	.26	-.03
t = ...	.64	-.39	-.28	1.09	-.15
Condition 3 (Word → Tone)					
r = ...	.31	.23	-.32	.09	-.42
t = ...	1.34	.97	-1.38	.38	-1.88
Condition 4 (Word → Assoc.)					
r = ...	.05	.05	-.02	.28	.12
t = ...	.20	.21	-.10	1.20	.50

Note. For each *t*-test, *n* = 18, *df* = 16. Polarities of vertical measurements and evoked potential measurements above (negative) or below (positive) baseline were observed.

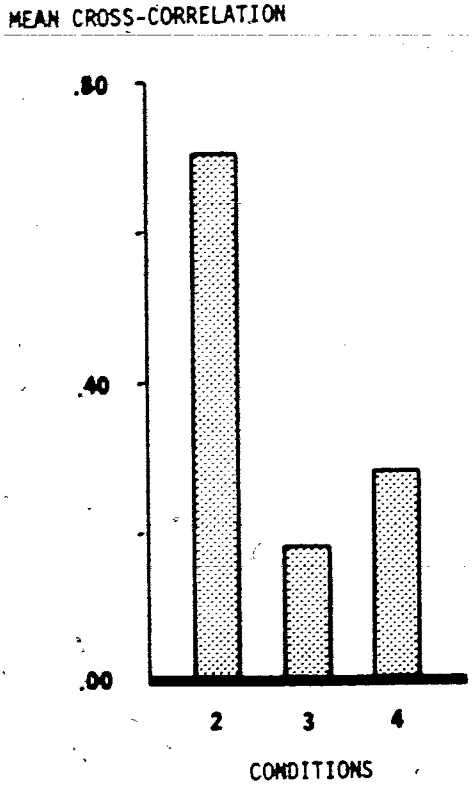


Figure 48

Overall Mean Cross-Correlation I Values for Each of the Experimental Conditions

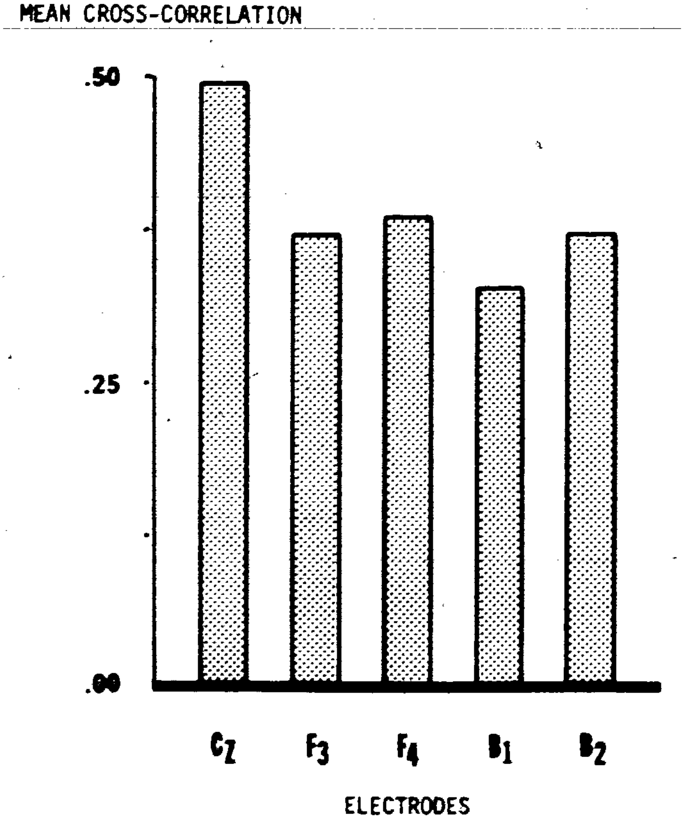


Figure 49

Overall Mean Cross-Correlation I Values
at Each Active Electrode Site

lateral placements ($p < .001$); none of the correlation differences between lateral sites reached a significant level. The Duncan range tests among the Cross-Correlation I means for Factor C are shown in Appendix D, Table D73.

The mean Cross-Correlation I values for the sex by electrodes (A × C) interaction are illustrated in Figure 50. For the females, the vertex (C_z) correlations were separately higher than for any of the other lateral placements ($p < .05$); the right frontal (F_4) correlations were also higher than for the left inferior frontal (B_1) site ($p < .05$). For the males, none of the correlation differences between electrodes reached a significant level ($p > .05$). The overall correlations tended to be higher for males than for females. For both females and males, differences between homologous frontal and between homologous inferior frontal sites did not reach a significant level. The Duncan range tests among the Cross-Correlation I means for females across electrodes and for males across electrodes are shown in Appendix D, Tables D74 and D75, respectively.

The mean Cross-Correlation I values involved in the nonsignificant conditions by electrodes (B × C) interaction are shown in Table 19. Generally, the means tended to be lower in Conditions 3 and 4 than in Condition 2. Although not statistically justifiable, Duncan range tests among the Cross-Correlation I means for Conditions 2, 3, and 4 across electrodes are shown in Appendix D, Tables D76, D77, and D78, respectively.

Cross-Correlations II

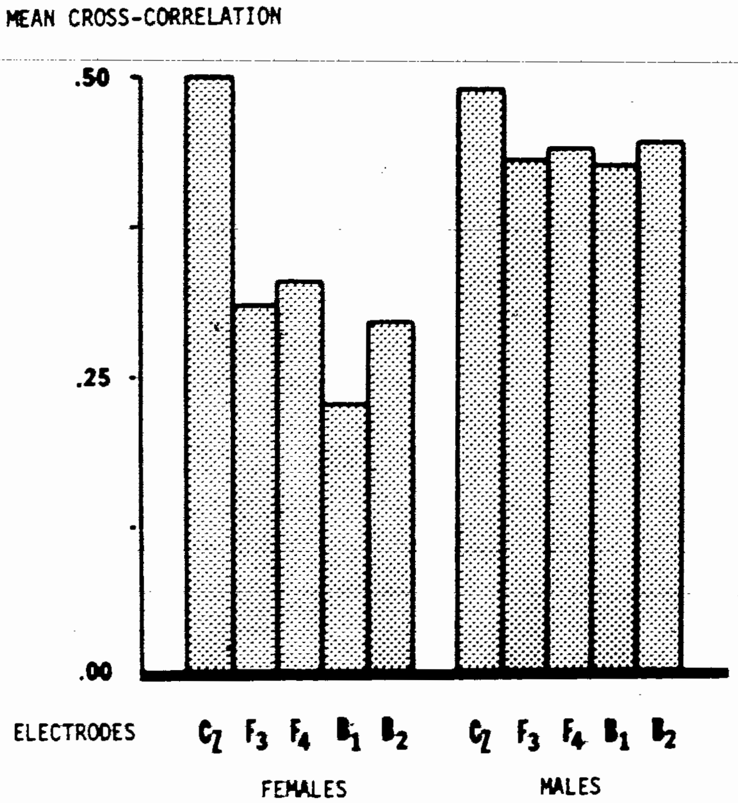


Figure 50

Mean Cross-Correlation I Values for Females and Males at Each Active Electrode Site

Table 19

Mean Cross-Correlation I Values for the Nonsignificant Conditions by Electrodes (B × C) Interaction

Experimental Condition	Electrode Site				
	C_z	F_3	F_4	B_1	B_2
2 (Tone → Word)	.78	.73	.71	.62	.64
3 (Word → Tone)	.27	.14	.18	.12	.18
4 (Word → Assoc.)	.41	.23	.24	.23	.27

Cross-correlations were computed between the vertex (C_z) of each experimental condition and each of the corresponding lateral electrode placements. The F ratio for sex did not reach a significant value ($F = 2.28$, $df = 1/16$, $p > .10$). There were significant effects for conditions ($F = 10.79$, $df = 3/48$, $p < .001$) and electrodes ($F = 47.99$, $df = 3/48$, $p < .001$). There was also a significant sex by electrodes (A × C) interaction ($F = 3.15$, $df = 3/48$, $p < .05$). A summary of the analysis of variance for Cross-Correlations II is provided in Appendix C, Table C19.

The overall correlation means for the conditions effect (Factor B) are illustrated in Figure 51. Further tests indicated that higher correlations were found for Condition 2 than for either Condition 3 or Condition 4 ($p < .001$); the correlations for Condition 1 were also higher than for Condition 3 ($p < .001$). The Duncan range tests among the Cross-Correlation II means for Factor B are shown in Appendix D, Table D79.

The overall correlation means for the electrodes effect (Factor C) are illustrated in Figure 52. The correlations for frontal sites F_3 and F_4 were separately higher than for inferior frontal sites B_1 and B_2 ($p < .001$). The Duncan range tests among the Cross-Correlation II means for Factor C are shown in Appendix D, Table D80.

The Cross-Correlation II means involved in the sex by electrodes (A × C) interaction are illustrated in Figure 53. For both females and males, the correlation means for frontal sites F_3 and F_4 were higher than for inferior frontal sites B_1 and B_2 ($p < .05$). Differences between homologous frontal and between homologous inferior

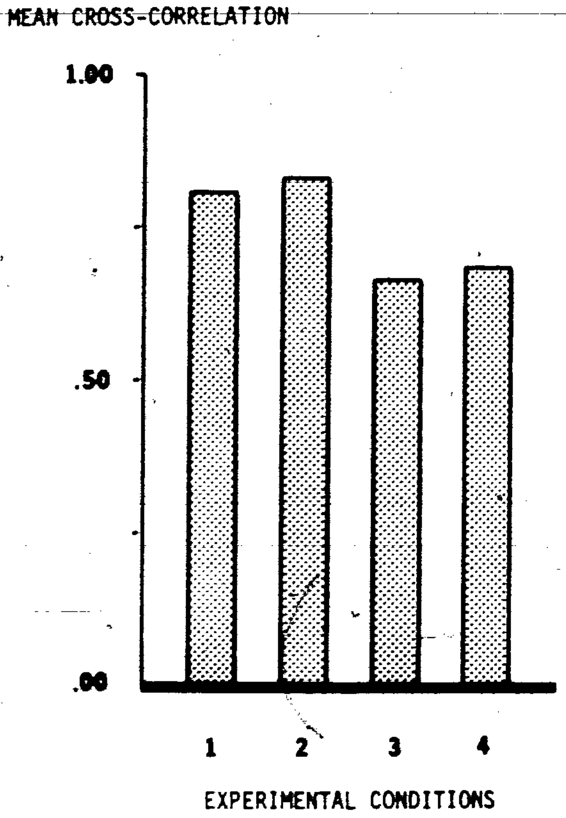


Figure 51

Overall Mean Cross-Correlation II Values for Each of the Experimental Conditions

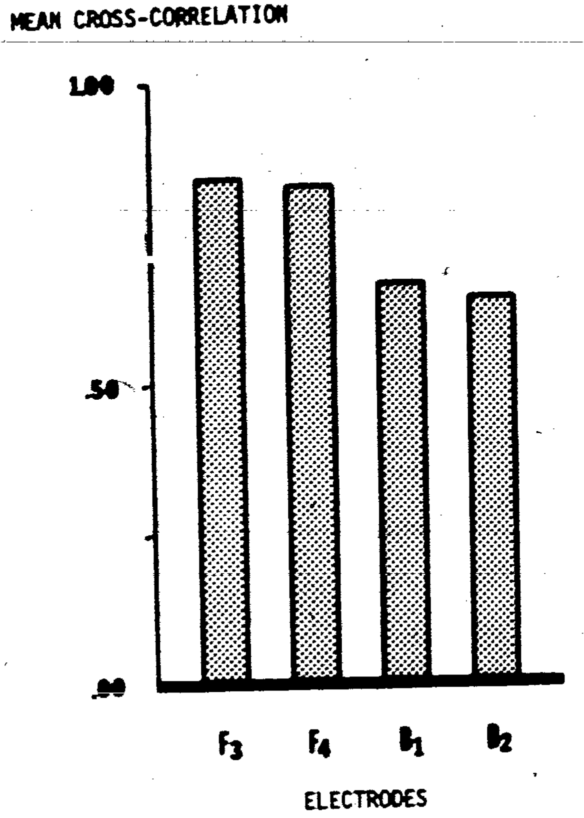


Figure 52

Overall Mean Cross-Correlation II Values
at Each Active Electrode Site

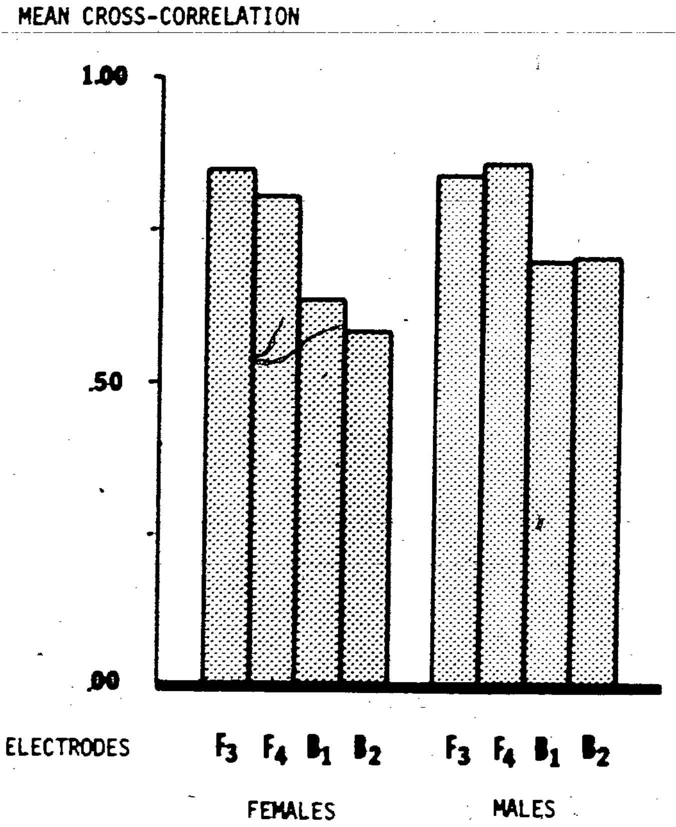


Figure 53

Mean Cross-Correlation II Values for Females and Males at Each Active Electrode Site frontal sites did not reach a significant level. The Duncan range tests among the Cross-Correlation II means for females across electrodes and males across electrodes are shown in Appendix D, Tables D81 and D82, respectively.

The mean Cross-Correlation II values involved in the nonsignificant conditions by electrodes (B × C) interaction are shown in Table 20. Generally, the F_3 and F_4 sites exhibited higher correlations than B_1 and B_2 sites over experimental conditions. Although not statistically justifiable, the Duncan range tests among the Cross-Correlation II means for Conditions 1, 2, 3, and 4 across electrodes are shown in Appendix D, Tables D83, D84, D85, and D86, respectively.

Cross-Correlations III

Cross-correlations were separately calculated between homologous frontal and between homologous inferior frontal electrode sites for each of the experimental conditions. The F ratio for sex was not significant ($F = 1.89$, $df = 1/16$, $p > .10$). There was a significant conditions effect ($F = 7.26$, $df = 3/48$, $p < .001$). The F ratio for electrodes did not reach a significant level ($F = 3.38$, $df = 1/16$, $p > .10$). The interaction of conditions by electrodes (B × C) reached the $p < .001$ level ($F = 9.00$, $df = 3/48$). A summary of the analysis of variance for Cross-Correlations III is provided in Appendix C, Table C20.

The overall correlation means for the conditions effect (Factor B) are illustrated in Figure 54. Further tests revealed that the correlations of Condition 1 were higher than those of Condition 3

Table 20

Mean Cross-Correlation II Values for the Nonsignificant Conditions by Electrodes (B × C) Interaction

Experimental Condition	Electrode Site			
	F_3	F_4	B_1	B_2
1 (Tone → Clicks)	.90	.90	.71	.71
2 (Tone → Word)	.90	.89	.77	.76
3 (Word → Tone)	.78	.78	.55	.53
4 (Word → Assoc.)	.78	.75	.63	.57

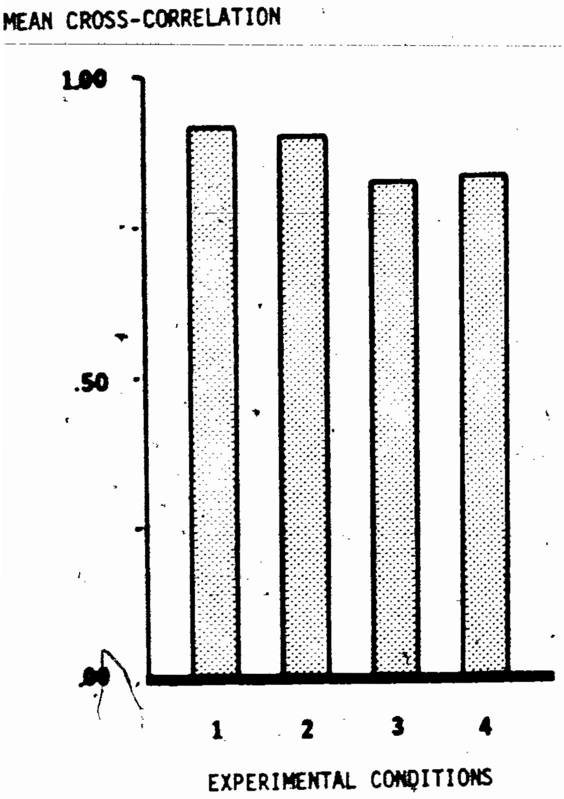


Figure 54

Overall Means for Cross-Correlation III Values for Each of the Experimental Conditions

($p < .001$). The Duncan range tests among the Cross-Correlation III means for conditions (Factor B) are shown in Appendix D, Table D87.

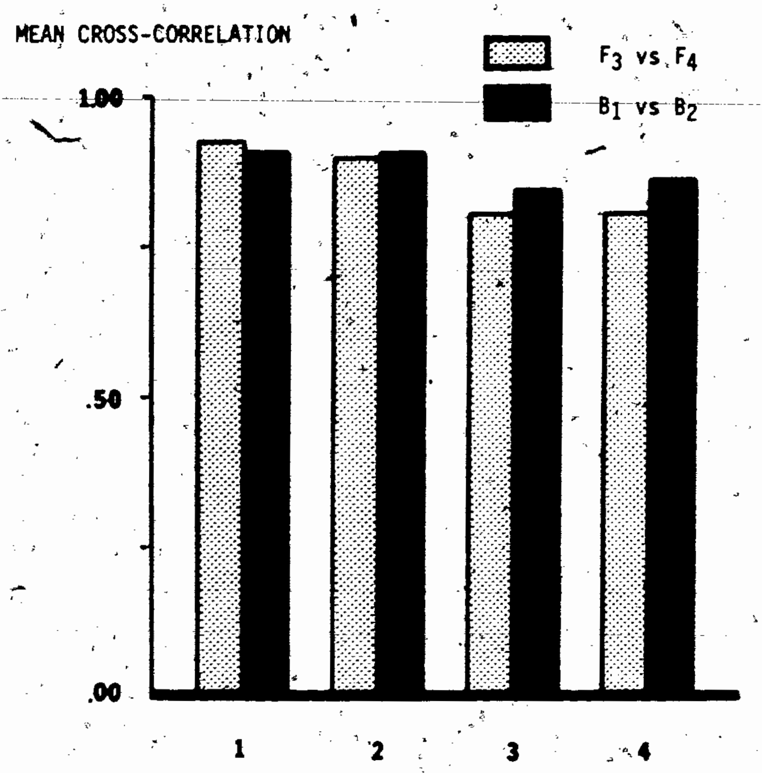
The correlation means involved in the conditions by electrodes (B × C) interaction are illustrated in Figure 55. In Conditions 1 and 2, differences between frontal and inferior frontal sites were not significant ($p > .001$); however, in Conditions 3 and 4, the differences between frontal and inferior frontal sites were significant at the $p < .001$ level. (Duncan's Multiple-Range Test: $k = 2$, $df = 48$, $n = 18$.)

Cross-Correlations IV

Separate cross-correlations were performed between left side intrahemispheric placements and right side intrahemispheric placements for each of the experimental conditions. The F ratios for sex ($F = 4.60$, $df = 1/16$, $p < .05$) and conditions ($F = 3.34$, $df = 3/48$, $p < .05$) reached significant levels. The F ratio for electrodes was not significant ($F = 2.57$, $df = 1/16$, $p > .10$). A summary of the analysis of variance for Cross-Correlations IV is provided in Appendix C, Table C21.

The overall means indicated that females had lower correlations than males, .86 and .90, respectively.

The overall correlation means for conditions (Factor B) are illustrated in Figure 56. Further tests indicated that the correlations for Conditions 1, 2, and 4 were separately higher than for Condition 3 ($p < .05$). The Duncan range tests among Cross-Correlation IV means for Factor B are shown in Appendix D, Table D88.



EXPERIMENTAL CONDITIONS

Figure 55

Mean Cross-Correlation III Values for Each of the Active Electrode Sites in Each of the Experimental Conditions

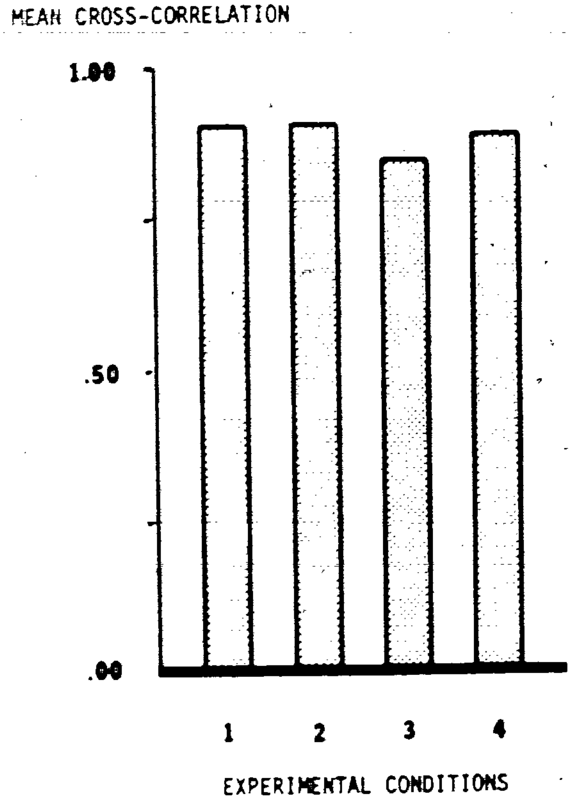


Figure 56

Overall Mean Cross-Correlation IV Values for Each of the Experimental Conditions

The correlation means involved in the nonsignificant sex by conditions by electrodes (A × B × C) interaction are shown in Table 21. High correlations existed for both hemispheres over the experimental conditions.

Dominance Indices

The results of eye movement predisposition that were analyzed as levels of Factor A are summarily presented for the separate analyses in Tables 22 and 23. For comparison purposes, the principal analysis of variance ratios are also included. The *F* ratios that involved eye movement did not reach significant levels. However, effects for conditions (Factor B) and electrodes (Factor C) generally paralled the earlier *F* ratios.

The results for ocular dominance that were analyzed as levels of Factor A are also shown in Tables 22 and 23. The *F* ratios that involved ocular dominance did not reach significant levels. The effects of conditions (Factor B) and electrodes (Factor C) were reduced; this was probably due to the smaller *n* that was used in the analyses.

Discussion

The magnitude measures of CNV activity indicated that Condition 1, the standard, was different from Condition 3 (Word → Tone). The vertical measures of CNV amplitude indicated this same difference except that the standard condition was also found to be different from Condition 4 (Word → Association). The CNV averages for Conditions

Table 21

Mean Cross-Correlation IV Values for the Nonsignificant Sex by Conditions by Electrodes (A × B × C) Interaction

Experimental Condition	Left Side Electrodes (F_3 vs B_1)		Right Side Electrodes (F_4 vs B_2)	
	Female	Male	Female	Male
1 (Tone → Clicks)	.90	.90	.90	.90
2 (Tone → Word)	.87	.92	.90	.93
3 (Word → Tone)	.80	.87	.84	.87
4 (Word → Assoc.)	.83	.90	.88	.94

Table 22

Summary F Ratios for Factor A Classifications for CNV Magnitudes, CNV Amplitudes, Ratio Indices, and EP Amplitudes

Design	Measurement Analysis							
	CNV Mag.		CNV Amp.		Ratio		EP Amp.	
	F =	p =	F =	p =	F =	p =	F =	p =
				Factor A as Sex				
A	.04	ns	.67	ns	.48	ns	.46	ns
B	2.88	<.05	18.48	<.001	.93	ns	5.51	<.005
C	63.78	<.001	33.28	<.001	1.14	ns	17.46	<.001
AB	.83	ns	.63	ns	.81	ns	.64	ns
AC	4.82	<.005	.35	ns	.00	ns	4.53	<.005
BC	9.64	<.001	4.16	<.001	.33	ns	2.13	<.025
ABC	.81	ns	.80	ns	.53	ns	.24	ns
				Factor A as Eye Movement Predisposition				
A	.02	ns	2.77	ns	.89	ns	.27	ns
B	3.03	<.05	18.52	<.001	.93	ns	6.14	<.005
C	58.04	<.001	31.72	<.001	1.15	ns	14.42	<.001
AB	1.36	ns	.83	ns	.95	ns	1.77	ns
AC	1.97	ns	.29	ns	.58	ns	.98	ns
BC	9.54	<.001	4.23	<.001	.35	ns	2.26	<.025
ABC	.81	ns	1.04	ns	1.16	ns	1.11	ns
				Factor A as Ocular Domiance				
A	2.95	ns	1.04	ns	.61	ns	2.62	ns
B	1.12	ns	8.23	<.005	.57	ns	5.46	<.025
C	2.33	<.001	13.00	<.001	1.50	ns	1.98	ns
AB	1.44	ns	.59	ns	.81	ns	.05	ns
AC	.30	ns	.42	ns	.03	ns	.91	ns
BC	1.89	ns	2.62	<.025	1.25	ns	.82	ns
ABC	.54	ns	.56	ns	2.08	ns	.39	ns

Table 23

Summary F Ratios for Factor A Classifications for Cross-Correlations I, Cross-Correlations II, Cross-Correlations III, and Cross-Correlations IV

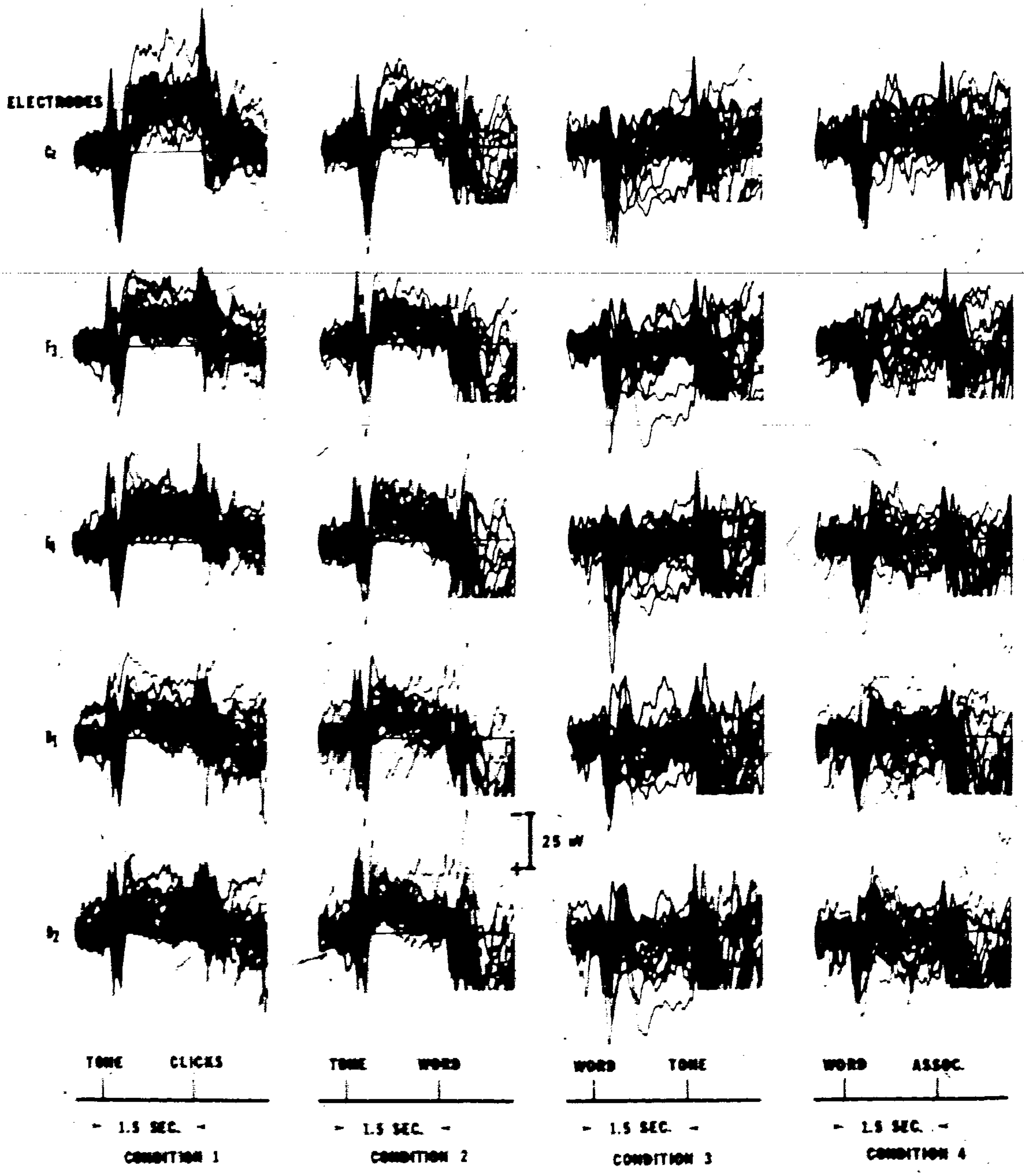
Design	Measurement Analysis							
	Cross I		Cross II		Cross III		Cross IV	
	F =	p =	F =	p =	F =	p =	F =	p =
	Factor A as Sex							
A	1.44	ns	2.28	ns	1.89	ns	4.60	ns
B	40.06	<.001	10.79	<.001	7.26	<.001	3.34	<.05
C	7.79	<.001	47.99	<.001	3.38	ns	2.57	ns
AB	.82	ns	1.58	ns	.87	ns	.88	ns
AC	2.94	<.05	3.15	<.05	1.36	ns	.38	ns
BC	1.98	ns	1.85	ns	9.00	<.001	.85	ns
ABC	1.41	ns	1.33	ns	.20	ns	.23	ns
	Factor A as Eye Movement Predisposition							
A	1.16	ns	.92	ns	.16	ns	.11	ns
B	40.13	<.001	9.88	<.001	6.69	<.001	3.05	<.05
C	6.50	<.001	39.66	<.001	3.32	ns	2.95	ns
AB	.92	ns	.55	ns	.27	ns	.21	ns
AC	.39	ns	.41	ns	1.03	ns	1.89	ns
BC	1.90	ns	1.87	ns	8.98	<.001	.94	ns
ABC	.85	ns	1.28	ns	.58	ns	1.49	ns
	Factor A as Ocular Dominance							
A	4.69	ns	.00	ns	.52	ns	1.24	ns
B	14.23	<.005	2.87	ns	7.76	<.005	3.29	ns
C	.78	ns	24.66	<.001	1.73	ns	.76	ns
AB	.86	ns	.62	ns	.46	ns	2.11	ns
AC	.25	ns	.40	ns	.63	ns	.47	ns
BC	2.02	ns	2.25	ns	1.48	ns	1.39	ns
ABC	.40	ns	1.14	ns	.43	ns	1.11	ns

1 and 2 were typical in appearance. In Conditions 3 and 4, however, there was little activity in the S_1-S_2 interval above baseline levels. These differences between experimental conditions can be seen in the overlayed averages for each subject. The plots at each active electrode site for each of the experimental conditions for all subjects are illustrated in Figure 57. As discussed in Chapter 5, the low amount of CNV activity observed for Conditions 3 and 4 was probably due to pretrial shifts that limited further increases in negativity. The EEG tracings were disturbed when subjects vocalized the stimulus words. The CNV measures that were taken from the averaged records avoided the period just before S_2. Not unexpectedly, the vertex (C_z) was generally larger than any of the lateral placements; also, frontal sites F_3 and F_4 were usually larger than inferior frontal sites B_1 and B_2. The subject set for word production had little effect in changing the lateral distribution of the slow potentials. Subjects reported that Condition 3 (Word → Tone) was an easy task which required little cognitive activity; in Condition 4 (Word → Association), subjects reported that they were able to think of 2 or 3 associations in the S_1-S_2 interval and usually vocalized the word closest in time to the tone. The effectiveness of set in producing lateralized slow wave changes was probably greatly reduced by the pretrial shifts which occurred in Conditions 3 and 4. The right hand button press in Condition 1 did not affect the slow wave balance between homologous frontal or between homologous inferior frontal sites. Sex effects for magnitude and amplitude estimates of CNV activity were minimal.

The ratio indices of asymmetry indicated that there was no

Figure 57

Overlayed CNV Averages for Each Subject at Each Active Electrode Site for Each of the Experimental Conditions


ELECTRODES
Cz
F3
F4
P3
Pz
25 µV
TONE
CLICKS
1.5 SEC.
CONDITION 1
TONE
WORD
1.5 SEC.
CONDITION 2
WORD
TONE
1.5 SEC.
CONDITION 3
WORD
ASSOC.
1.5 SEC.
CONDITION 4

increase in left hemisphere activity during Conditions 2, 3, or 4 from Condition 1. However, there was a tendency for ratios over Broca's area to be larger in Condition 4 than in the other experimental conditions.

Evoked potential amplitudes at S_1 indicated that the vertex (C_z) consistently produced larger responses than any of the laterally place electrodes. Frontal sites F_3 and F_4 were larger than inferior frontal sites B_1 and B_2 in Conditions 1 and 2; this relationship between frontal and inferior frontal sites was diminished in Conditions 3 and 4. There was a tendency for slightly larger tone responses in Condition 2 than in Condition 1. The word stimuli in Conditions 3 and 4 had no effect on the distribution of the EPs for either homologous frontal or homologous inferior frontal sites.

There was little relationship between the measures of CNV magnitude and the measures of CNV amplitude. As expected, the measures of CNV magnitude and EP amplitude were highly correlated. The relationships between CNV amplitudes and EP responses were small. These general findings between cortical activity were similar to those described in Chapter 5. (See Peters, Knott, & Hamilton, Note 38 for a discussion of the different measures that have been used to assess CNV activity.)

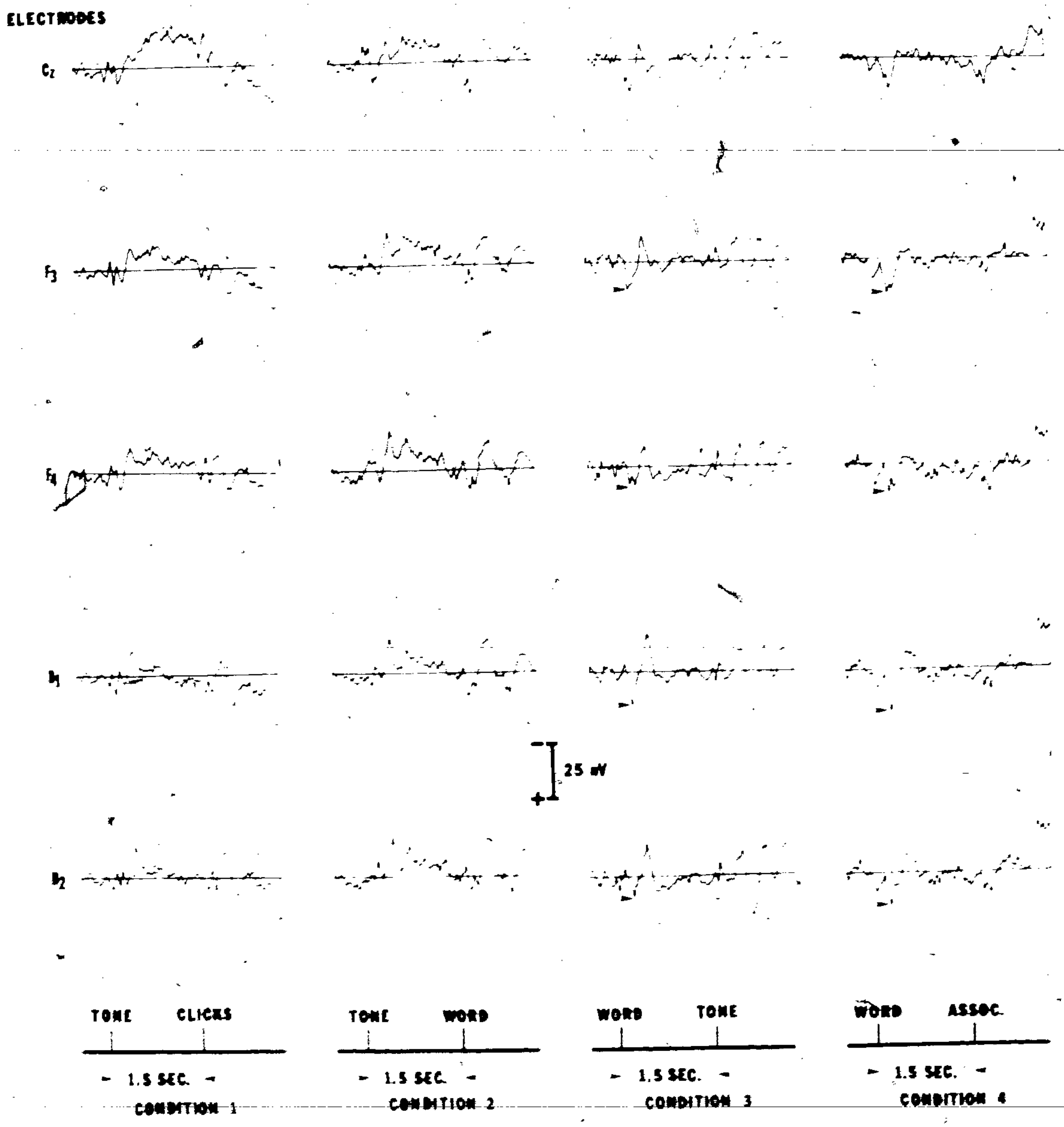
Compared to Condition 1, the cross-correlations indicated that the waveforms for separately considered homologous pairs were not different even in the presence of significant effects for conditions and electrodes. Cross-correlations between the vertex (C_z) and each of the lateral placements indicated significant conditions and electrodes effects. Although frontal correlations tended to be higher than inferior frontal correlations, comparisons between homologous pairs did not reveal any lateralized effects. When correlations between homologous pairs were considered, differences between frontal and inferior frontal sites were not significant in Conditions 1 and 2; however, in Conditions 3 and 4, the correlations were slightly higher for inferior frontal than for frontal locations. Intrahemispheric cross-correlations indicated that no left or right side differences occurred for the separate experimental conditions. Some sex effects were observed in a few of the cross-correlation analyses; however, the effects were not related to the production of asymmetrical waveforms between separately considered homologous pairs. Although not directly comparable, the overall CNV results presented here are in conflict with those of Low, Wada, and Fox (Note 32, Note 33), Zimmermann and Knott (Note 34), and Grözinger, Kriebel, and Kornhuber (Note 35).

Classifying subjects on eye movement predisposition or ocular dominance was not effective in separating or changing the results for the lateral distribution of the CNV in any of the analyses. However, the eye movement phenomena were clearly evident and easily elicited. Davson (1972) has pointed out that ocular dominance probably has little effect under conditions of binocular viewing.

The individual averages of several subjects indicated that there were instances when marked asymmetries in the distribution of the slow wave occurred. For example, the averaged records for subject K. A. (male) are shown in Figure 58. Compared to either Conditions 1 or 2, Conditions 3 and 4 produced a noticeable increase in CNV

Figure 58

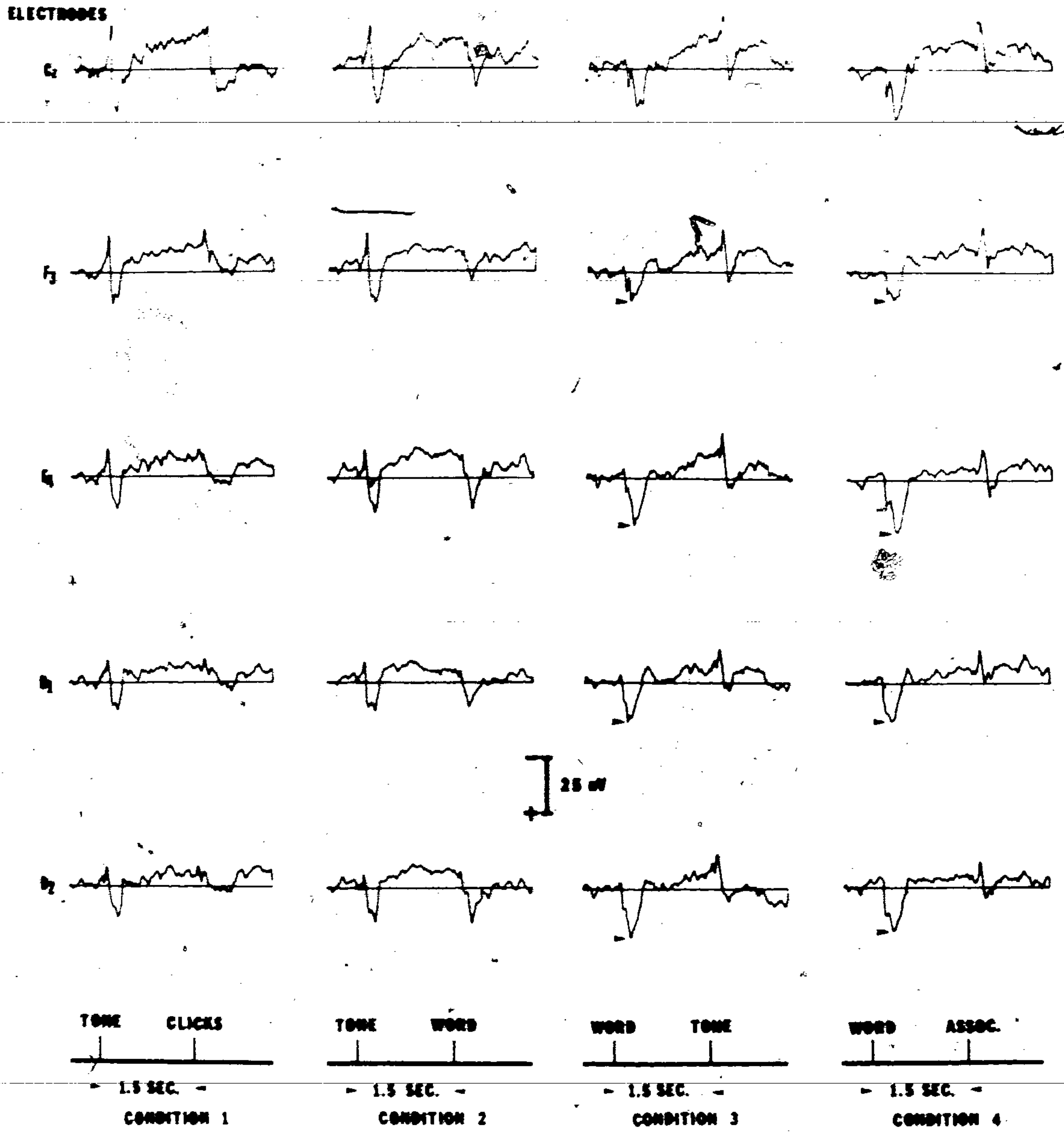
Symmetrical and Asymmetrical CNV Averages
for Subject A. K. in Each of the
Experimental Conditions


ELECTRODES
Cz
F3
F4
P1
P2
25 µV
TONE
CLICKS
1.5 SEC.
CONDITION 1
TONE
WORD
1.5 SEC.
CONDITION 2
WORD
TONE
1.5 SEC.
CONDITION 3
WORD
ASSOC.
1.5 SEC.
CONDITION 4

activity over the left hemisphere. In contrast, the averaged records of subject I. M. (male) are shown in Figure 59. Compared to either the standard or Condition 2, there was an increase in CNV activity in Conditions 3 and 4 over the right hemisphere. The asymmetries, when they occurred, did not always include both left side placements or both right side placements. Similarly, the instances of inconsistency for the production of asymmetrical slow potentials were noted for both females and males. Individual examples of marked asymmetries were also found for the experimental conditions described in Chapters 4 and 5.

Figure 59

Symmetrical and Asymmetrical CNV Averages
for Subject I. M. in Each of the
Experimental Conditions


ELECTRODES
C_z
F_3
C_4
O_1
O_2
25 μV
TONE
CLICKS
1.5 SEC.
CONDITION 1
TONE
WORD
1.5 SEC.
CONDITION 2
WORD
TONE
1.5 SEC.
CONDITION 3
WORD
ASSOC.
1.5 SEC.
CONDITION 4

Chapter 7

OVERVIEW

The results demonstrated that consistent slow wave asymmetries were not elicited during tasks designed to promote either right or left hemisphere activity. However the strict statistical rejection of lateralized effects was tempered by those individual examples where distinct asymmetries occurred. Although these asymmetries were not always in the predicted direction, this appeared justifiable since some hemispheric differences were as large as 5 μV to 12 μV.

A shortcoming of the tone and word experiments described here was that no separate behavioral indices of lateralized effects were collected. Without these separate measures it is arguable whether the experimental conditions actually induced the specialized hemispheric activity sought. As discussed in Chapter 3, Marsh and Thompson (1973) found that for verbal tasks there were no CNV differences between the hemispheres; in a nonverbal situation (line orientation) neither the behavioral data nor the CNVs showed any hemispheric differences. A design change in the experimental presentation of verbal and nonverbal tasks subsequently resulted in asymmetries being produced on correct trials. The hemisphere presumed to be primarily engaged in the task had smaller CNV amplitudes than the hemisphere that was considered secondarily involved. At the time of the report no data were given about the size of the hemispheric differences. Hillyard (1973) was not able to report asymmetrical CNVs in commissurotomized patients even though a clear behavioral differentiation was elicited (reaction times). The logical importance of establishing a behavioral measure or index against which to gauge CNV potentials is further lessened by the fact that behavioral differentiation itself is assumed to be reflective of brain activity. It almost goes without saying that those authors reporting hemispheric differentiation, behavioral or otherwise, do not advocate that particular stimulus processing is completely dominated by the activity of one hemisphere (Sperry, 1973). For example, visual right field (left hemisphere) superiority for the detection of verbal material does not exclude left field (right hemisphere) detections. The interplay that could have existed between the hemispheres in the small number of trials that were used in the present studies may have contributed to the occasionally large but unsystematic asymmetries observed in the CNV. Of the many strategies that could have been adopted to evaluate hemispheric differences, the 16-trial average represented a compromise between a single trial analysis and an average based on a larger number of trials. Adopting the latter approach increases the signal against resident background activity. At the same time, however, it is desirable by a single trial analysis to reduce possible sequence effects in order to reduce habituation and other processes which might occur as the result of repetition.

The results presented here for the left hemisphere tasks are at variance with the findings of other investigators examining hemispheric asymmetries in the CNV. Butler and Glass (1971) found that right-handed subjects awaiting numerical information had larger CNVs over the hemisphere contralateral to the preferred hand. Differences between the hemispheres were small and the overall significance of the asymmetries was evaluated using nonparametric procedures. In practical applications there is some risk that judgments based on relative size may, in some cases, result in differences that are outside the limits of resolution of the recording system.

The lack of consistent laterality effects from surface locations approximately over the areas of Wernicke and Broca were surprising in view of the literature which has implicated these areas as necessary for language processing and production. The electrode sites over these areas were selected because previous evoked or slow potential investigations reported data suggesting that these regions were sensitive to differential activity and were related to language processing. Zimmermann and Knott (Note 34) demonstrated that inferior frontal sites, presumably over the area of Broca, were larger on the left hemisphere than the right preceding speech production. As with much data showing lateralization effects, hemispheric differences were again very small. From the published records, CNV potentials barely exceeded baseline levels at the lateral sites. A similar shifting was observed in the present experiments when stimulus words appeared in the S_1 position. Low, Wada, and Fox (Note 32), recording from inferior-posterior frontal positions, found greater negativity over the left hemisphere preceding verbalization than over the right. Although most of the studies reporting asymmetrical CNVs had some form of control condition, most analyses did not incorporate direct comparisons of distribution changes within subjects among the experimental conditions. The method of analysis employed here to examine asymmetries required that the distribution of the CNV be established relative to the various placements (i.e., the standard condition) and that this distribution be changed for the different processing tasks. This represents a stringent but necessary criterion for demonstrating CNV asymmetries in normal subjects.

In addition to the asymmetries that were observed during the tone experiment in Chapter 4, the results indicated that the engagement of the subject's attention during the S_1-S_2 interval produced an enhancement of CNV amplitude (2.5 times) over the standard paradigm. Increases in CNV amplitude related to information processing have been associated with stimulus complexity (Low, Frost, Maulsby, & McSherry, 1968), whereas decreases in the CNV have been found with distraction induced by extraneous processing within the CNV interval (Tecce & Hamilton, 1973). The decline in the CNV during the presentation of the fourth tone was an unexpected finding that merits further investigation. Most of the subjects questioned agreed that the tone task was not difficult and that they were able to decide upon their response as soon as the fourth tone was presented. This positive direction of the slow potential at the fourth tone parallels the findings of evoked potential studies which show the positive or P300 component correlated with information delivery and the resolution of uncertainty (Sutton, Tueting, & Zubin, 1967).

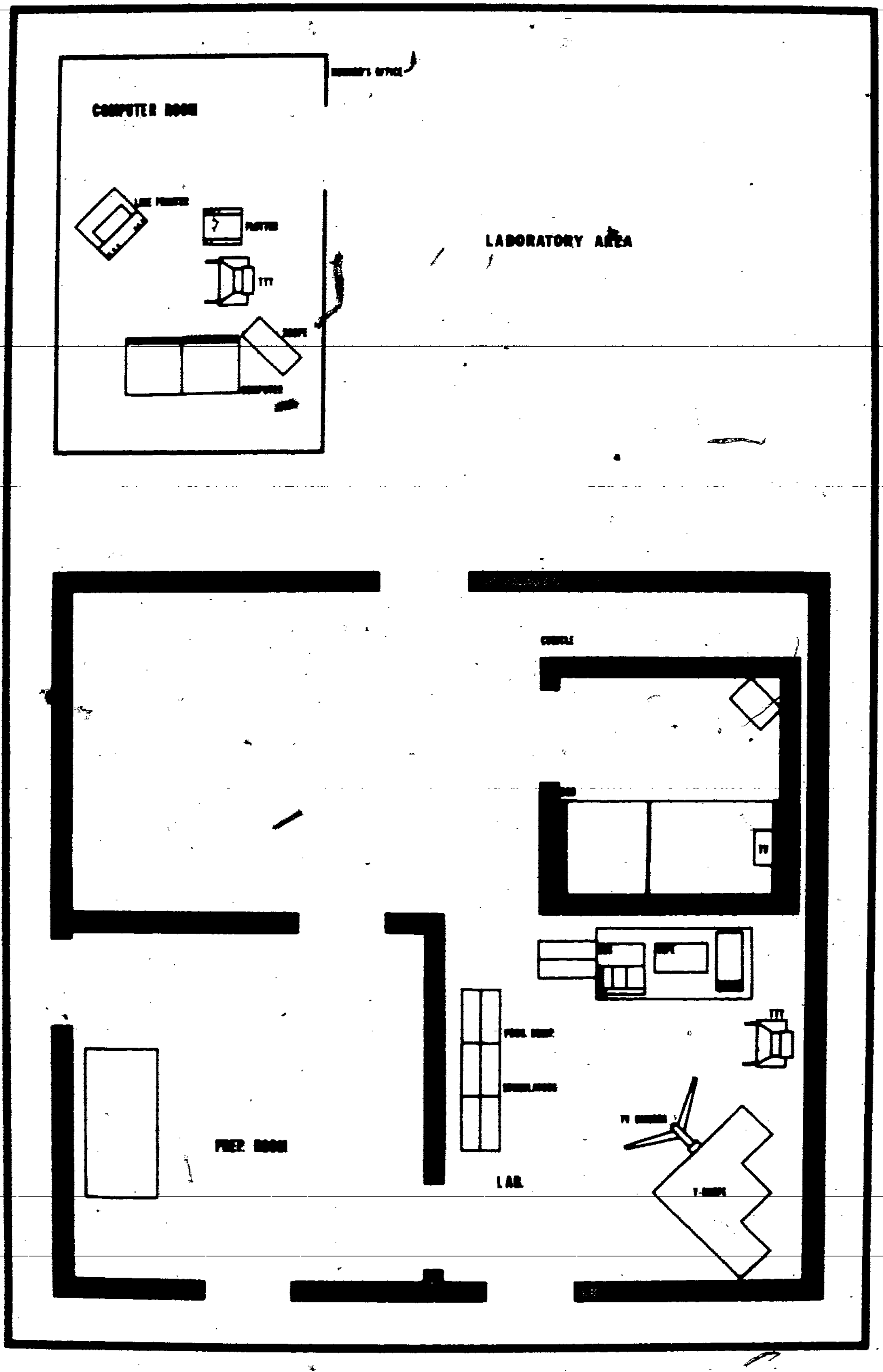
The word experiments of Chapters 5 and 6 were simple and may not have engaged verbal processing to any great extent during the CNV interval. It might be more useful to have a more obvious form of verbal activity during the interval with such procedures as sentence construction, word rhymes, and so on. It was interesting to note however that evoked potentials to word stimuli were generally larger at all electrode sites than for the other signal stimuli. Whether this positive aspect of the evoked potential was due to intrinsic properties of the stimuli themselves or was due to negative baseline shifts cannot be determined without further investigation.

Further research into the lateralization of slow potentials should probably first center around those individuals who clearly demonstrate asymmetries. This is, of course, a different approach to the question of asymmetries and is more concerned with the genesis of hemispheric differences than characteristics of all people insofar as differential information processing is concerned. Although this may distort the overall generalization of laterality effects, it may prove more useful in determining the parameters and significance of the differences than procedures based on the expectancy of uniform response patterns in all subjects.

APPENDICES

APPENDIX A

LABORATORY LAYOUT


COMPUTER ROOM
LINE PRINTER
PLOTTER
TTY
SCOPE
COMPUTER
LABORATORY AREA
CUBICLE
TV
TTY
TV CAMERA
PREP ROOM
LAB

APPENDIX B

FILTER CHARACTERISTICS

FILTER CHARACTERISTICS*

Individual data averages were digitally filtered prior to plotting. The data smoothing that occurred did not affect all frequencies equally. Although some cortical responses may have been subject to the <u>bouncing</u> portion of the filter characteristic, the frequencies associated with slow potentials were in the <u>safe</u> region of the filter. With the graph on page 285, the attenuation of a particular frequency can be found from log F = log $(f_o \times T_s)$, where f_o = the particular frequency and T_s = sweep time (seconds). When the obtained value is located on the abscissa, the attenuation may be read directly off the ordinate. The cutoff frequency (-3 dB) can be determined from $f_c = F_c/T_s$, where F_c = normalized frequency and T_s = sweep time.

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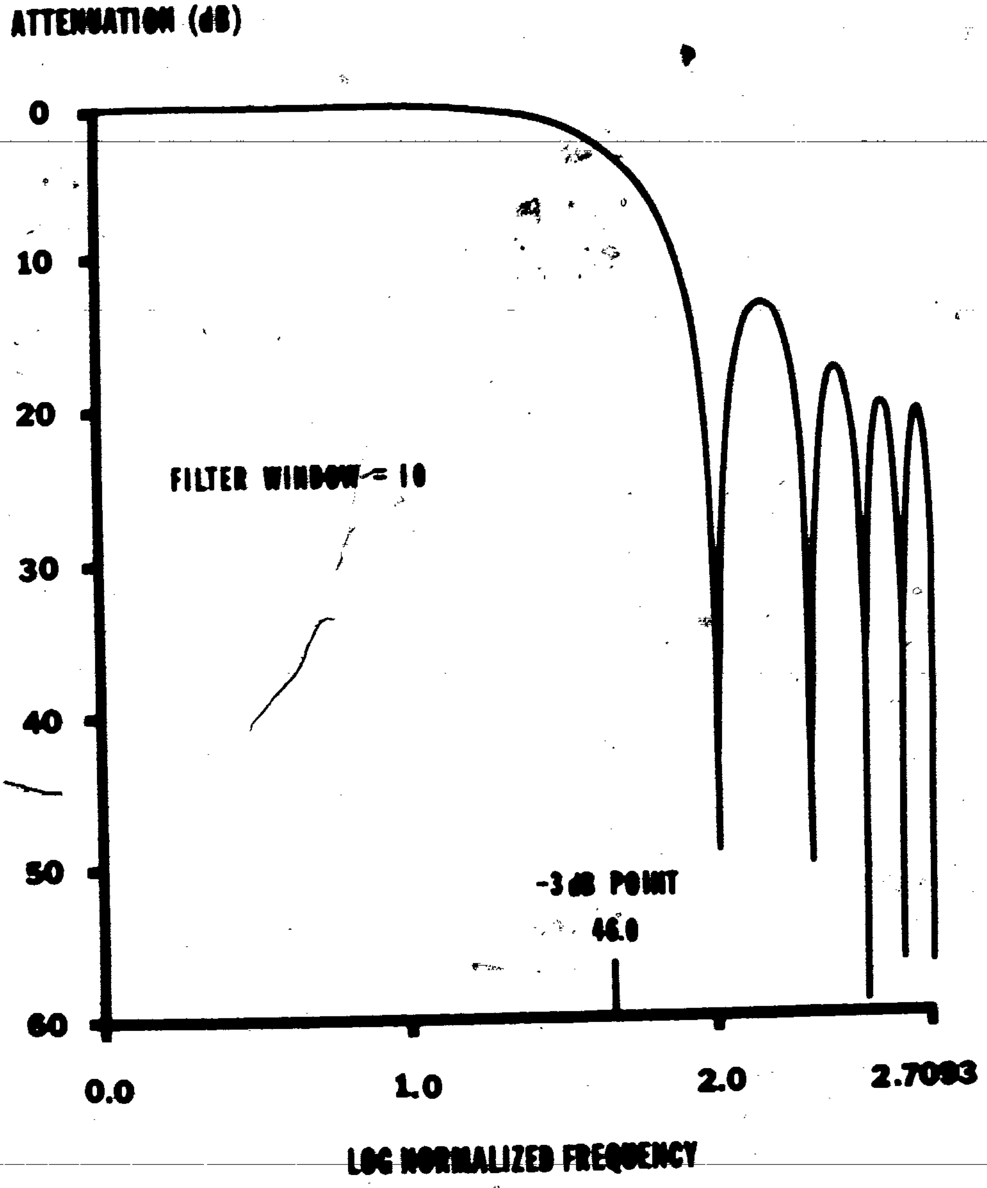
*The filter characteristic and accompanying graph were taken from <u>Documentation on a Brick-Wall Digital Low-Pass Filter</u> prepared by Howard F. Gabert for the Department of Psychology, Simon Fraser University, 1974.


ATTENUATION (dB)
0
10
20
30
40
50
60
FILTER WINDOW = 10
-3 dB POINT
46.0
0.0
1.0
2.0
2.7093
LOG NORMALIZED FREQUENCY

APPENDIX C

ANALYSIS OF VARIANCE TABLES

Table C1

Summary of the Analysis of Variance
for Amplitude Measures
(Experiment 1)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.6026E-03	.000	n.s.
B (Conditions)	SB(A)	1	124.9543	11.389	< .01
C (Electrodes)	SC(A)	4	18.5984	19.700	< .001
D (Times)	SD(A)	3	14.9320	9.910	< .001
S(A)		8	11.9919		
AB	SB(A)	1	.7375	.067	n.s.
AC	SC(A)	4	.6374	.675	n.s.
BC	SBC(A)	4	1.4032	1.845	n.s.
AD	SD(A)	3	.5133	.341	n.s.
BD	SBD(A)	3	6.9585	5.297	< .01
CD	SCD(A)	12	1.3439	7.936	< .001
SB(A)		8	10.9719		
SC(A)		32	.9440		
SD(A)		24	1.5068		
ABC	SBC(A)	4	.3003	.395	n.s.
ABD	SBD(A)	3	.5545	.422	n.s.
ACD	SCD(A)	12	.1009	.596	n.s.
BCD	SBCD(A)	12	.7401	7.897	< .001
SBC(A)		32	.7604		
SBD(A)		24	1.3136		
SCD(A)		96	.1693		
ABCD	SBCD(A)	12	.3057E-01	.343	n.s.
SBCD(A)		96	.8917E-01		

Note. Analysis of variance computations were carried out using direct measurements in cm.

Table C2

Summary of the Analysis of Variance for the Ratio Indices of Asymmetry (Experiment 1)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.1386	5.720	< .05
B (Conditions)	SB(A)	1	.3697E-02	.130	n.s.
C (Electrodes)	SC(A)	1	.1661E-01	.156	n.s.
S(A)		8	.2423E-01		
AB	SB(A)	1	.2551E-01	.898	n.s.
AC	SC(A)	1	.1779E-01	1.668	n.s.
BC	SBC(A)	1	.1928E-01	4.011	n.s.
SB(A)		8	.2842E-01		
SC(A)		8	.1067E-01		
ABC	SBC(A)	1	.2350E-03	.049	n.s.
SBC(A)		8	.4807E-02		

Table C3

Summary of the Analysis of Variance for Cross-Correlations II (Experiment 1)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.6613E-03	.011	n.s.
B (Conditions)	SB(A)	1	.1034E-01	1.157	n.s.
C (Electrodes)	SC(A)	3	.5789E-01	7.935	< .001
S(A)		8	.6050E-01		
AB	SB(A)	1	.3240E-01	3.622	n.s.
AC	SC(A)	3	.2042E-01	2.799	n.s.
BC	SBC(A)	3	.2115E-02	.539	n.s.
SB(A)		8	.8944E-02		
SC(A)		24	.7296E-02		
ABC	SBC(A)	8	.2990E-02	.762	n.s.
SBC(A)		24	.3925E-02		

Table C4

Summary of the Analysis of Variance
for Cross-Correlations III
(Experiment 1)

Source	Error Terms	df	MS	F	p
A (Sex)	S(A)	1	.2249E-02	.184	n.s.
B (Conditions)	SB(A)	1	.2703E-01	10.440	< .025
C (Electrodes)	SC(A)	1	.3025E-01	11.122	< .025
S(A)		8	.1223E-01		
AB	SB(A)	1	.1089E-01	4.205	n.s.
AC	SC(A)	1	.7839E-02	2.882	n.s.
BC	SBC(A)	1	.1008E-04	.012	n.s.
SB(A)		8	.2589E-02		
SC(A)		8	.2719E-02		
ABC	SBC(A)	1	--	--	--
SBC(A)		8	.8174E-03		

Table C5

Summary of the Analysis of Variance for Cross-Correlations IV (Experiment 1)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.1199	2.014	n.s.
B (Conditions)	SB(A)	1	.7562E-02	1.121	n.s.
C (Electrodes)	SC(A)	1	.1562E-02	.255	n.s.
S(A)		8	.5954E-01		
AB	SB(A)	1	.5636E-03	.084	n.s.
AC	SC(A)	1	.1823E-02	.297	n.s.
BC	SBC(A)	1	.1102E-02	.356	n.s.
SB(A)		8	.6743E-02		
SC(A)		8	.6135E-02		
ABC	SBC(A)	1	.2401E-02	.776	n.s.
SBC(A)		8	.3096E-02		

Table C6

Summary of the Analysis of Variance for Area Measurements of CNV Activity (Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.3911	.326	n.s.
B (Conditions)	SB(A)	2	.8051	2.382	n.s.
C (Electrodes)	SC(A)	4	1.3457	29.624	< .001
S(A)		8	1.1993		
AB	SB(A)	2	.2778	.822	n.s.
AC	SC(A)	4	.1422	3.132	< .05
BC	SBC(A)	8	.6469E-01	2.381	< .05
SB(A)		16	.3380		
SC(A)		32	.4542E-01		
ABC	SBC(A)	8	.1702E-01	.626	n.s.
SBC(A)		64	.2717E-01		

Note. The analysis of variance computations were performed upon the direct planimetric areas (inches^2).

Table C7

Summary of the Analysis of Variance for Vertical
Measurements of CNV Amplitude
(Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.4184	1.639	n.s.
B (Conditions)	SB(A)	2	1.8396	8.496	< .005
C (Electrodes)	SC(A)	4	.2722	23.482	< .001
S(A)		8	.2553		
AB	SB(A)	2	.1268	.586	n.s.
AC	SC(A)	4	.3807E-02	.328	n.s.
BC	SBC(A)	8	.4031E-01	3.527	< .005
SB(A)		16	.2165		
SC(A)		32	.1159E-01		
ABC	SBC(A)	8	.1496E-01	1.309	n.s.
SBC(A)		64	.1142E-01		

Note. The analysis of variance computations were performed upon the direct measurements of vertical amplitude (inches).

Table C8

Summary of the Analysis of Variance for the Ratio Indices of Asymmetry (Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.3850E-01	2.088	n.s.
B (Conditions)	SB(A)	2	.2166E-04	.006	n.s.
C (Electrodes)	SC(A)	1	.4860E-02	1.365	n.s.
S(A)		8	.1844E-01		
AB	SB(A)	2	.5121E-02	1.378	n.s.
AC	SC(A)	1	.2645E-01	7.433	< .05
BC	SBC(A)	2	.5450E-03	.226	n.s.
SB(A)		16	.3715E-02		
SC(A)		8	.3559E-02		
ABC	SBC(A)	2	.8450E-03	.350	n.s.
SBC(A)		16	.2413E-02		

Table C9

Summary of the Analysis of Variance for Evoked Potential Amplitudes at S_1 (Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.2398E-01	.048	n.s.
B (Conditions)	SB(A)	2	.6269	1.668	n.s.
C (Electrodes)	SC(A)	4	.3996	14.536	< .001
S(A)		8	.4989		
AB	SB(A)	2	.8809	2.343	n.s.
AC	SC(A)	4	.1413E-01	.514	n.s.
BC	SBC(A)	8	.2077E-01	2.382	< .05
SB(A)		16	.3759		
SC(A)		32	.2749E-01		
ABC	SBC(A)	8	.1656E-01	1.899	n.s.
SBC(A)		64	.8722E-02		

Note. The analysis of variance computations were performed upon the direct measurements of evoked potential amplitude (inches).

Table C10

Summary of the Analysis of Variance
for Cross-Correlations I
(Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.1528	.221	n.s.
B (Conditions)	SB(A)	1	2.9755	2.952	n.s.
C (Electrodes)	SC(A)	4	.2037E-01	.680	n.s.
S(A)		8	.6931		
AB	SB(A)	1	.4369	.434	n.s.
AC	SC(A)	4	.1099E-01	.367	n.s.
BC	SBC(A)	4	.1212E-01	.646	n.s.
SB(A)		8	1.0078		
SC(A)		32	.2994E-01		
ABC	SBC(A)	4	.1691E-01	.901	n.s.
SBC(A)		32	.1876E-01		

Table C11

Summary of the Analysis of Variance for Cross-Correlations II (Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.6347E-01	1.117	n.s.
B (Conditions)	SB(A)	2	.4006E-01	.622	n.s.
C (Electrodes)	SC(A)	3	.3392	19.598	< .001
S(A)		8	.5680E-01		
AB	SB(A)	2	.3292E-02	.051	n.s.
AC	SC(A)	3	.2323E-01	1.342	n.s.
BC	SBC(A)	6	.1776E-02	.254	n.s.
SB(A)		16	.6442E-01		
SC(A)		24	.1730E-01		
ABC	SBC(A)	6	.2919E-02	.418	n.s.
SBC(A)		48	.6984E-02		

Table C12

Summary of the Analysis of Variance for Cross-Correlations III (Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.1499E-02	.070	n.s.
B (Conditions)	SB(A)	2	.4316E-03	.049	n.s.
C (Electrodes)	SC(A)	1	.2903E-01	2.693	n.s.
S(A)		8	.2131E-01		
AB	SB(A)	2	.3395E-02	.382	n.s.
AC	SC(A)	1	.2730E-01	2.533	n.s.
BC	SBC(A)	2	.4415E-02	1.568	n.s.
SB(A)		16	.8884E-02		
SC(A)		8	.1078E-01		
ABC	SBC(A)	2	.5511E-03	.196	n.s.
SBC(A)		16	.2816E-02		

Table C13

Summary of the Analysis of Variance
for Cross-Correlations IV
(Experiment 2)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.3681E-02	.292	n.s.
B (Conditions)	SB(A)	2	.1781E-02	.334	n.s.
C (Electrodes)	SC(A)	1	.1320E-01	.710	n.s.
S(A)		8	.1262E-01		
AB	SB(A)	2	.5931E-02	1.112	n.s.
AC	SC(A)	1	.5953E-01	3.202	n.s.
BC	SBC(A)	2	.7117E-03	.449	n.s.
SB(A)		16	.5333E-02		
SC(A)		8	.1859E-01		
ABC	SBC(A)	2	.1294E-02	.817	n.s.
SBC(A)		16	.1584E-02		

Table C14

Summary of the Analysis of Variance for Area Measurements of CNV Activity (Experiment 3)

Source	Error Term	*df*	*MS*	*F*	*p*
A (Sex)	S(A)	1	.5750E-01	.043	n.s.
B (Conditions)	SB(A)	3	.5236	2.882	< .05
C (Electrodes)	SC(A)	4	2.4278	63.782	< .001
S(A)		16	1.3325		
AB	SB(A)	3	.1519	.836	n.s.
AC	SC(A)	4	.1835	4.823	< .001
BC	SBC(A)	12	.1945	9.648	< .001
SB(A)		48	.1816		
SC(A)		64	.3806E-01		
ABC	SBC(A)	12	.1646E-01	.817	n.s.
SBC(A)		192	.2016E-01		

Note. The analysis of variance computations were performed upon the direct planimetric areas (inches^2).

Table C15

Summary of the Analysis of Variance for Vertical Measurements of CNV Amplitude (Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.1693	.672	n.s.
B (Conditions)	SB(A)	3	2.1043	18.484	< .001
C (Electrodes)	SC(A)	4	.6334	33.286	< .001
S(A)		16	.2518		
AB	SB(A)	3	.7177E-01	.630	n.s.
AC	SC(A)	4	.6737E-02	.354	n.s.
BC	SBC(A)	12	.3659E-01	4.166	< .001
SB(A)		48	.1138		
SC(A)		64	.1903E-01		
ABC	SBC(A)	12	.7065E-02	.804	n.s.
SBC(A)		192	.8782E-02		

Note. The analysis of variance computations were performed upon the direct measurements of vertical amplitude (inches).

Table C16

Summary of the Analysis of Variance for the Ratio Indices of Asymmetry (Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.3803E-02	.489	n.s.
B (Conditions)	SB(A)	3	.5448E-02	.932	n.s.
C (Electrodes)	SC(A)	1	.2177E-02	1.145	n.s.
S(A)		16	.7779E-02		
AB	SB(A)	3	.4767E-02	.815	n.s.
AC	SC(A)	1	--	--	--
BC	SBC(A)	3	.3837E-03	.337	n.s.
SB(A)		48	.5846E-02		
SC(A)		16	.1901E-02		
ABC	SBC(A)	3	.6052E-03	.532	n.s.
SBC(A)		48	.1138E-02		

Table C17

Summary of the Analysis of Variance for Evoked Potential Amplitudes at S_1 (Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.3049	.461	n.s.
B (Conditions)	SB(A)	3	.7540	5.510	< .005
C (Electrodes)	SC(A)	4	.4896	17.462	< .001
S(A)		16	.6613		
AB	SB(A)	3	.8755E-01	.640	n.s.
AC	SC(A)	4	.1271	4.536	< .005
BC	SBC(A)	12	.1695E-01	2.133	< .025
SB(A)		48	.1368		
SC(A)		64	.2804E-01		
ABC	SBC(A)	12	.1940E-02	.244	n.s.
SBC(A)		192	.7947E-02		

Note. The analysis of variance computations were performed upon the direct measurements of evoked potential amplitude (inches).

Table C18

Summary of the Analysis of Variance for Cross-Correlations I (Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.8579	1.449	n.s.
B (Conditions)	SB(A)	2	6.8772	40.067	< .001
C (Electrodes)	SC(A)	4	.2115	7.797	< .001
S(A)		16	.5920		
AB	SB(A)	2	.1409	.821	n.s.
AC	S[illegible](A)	4	.7975E-01	2.940	< .05
BC	SBC(A)	8	.2156E-01	1.980	n.s.
SB(A)		32	.1716		
SC(A)		64	.2712E-01		
ABC	SBC(A)	8	.1541E-01	1.416	n.s.
SBC(A)		128	.1088E-01		

Table C19

Summary of the Analysis of Variance for Cross-Correlations II (Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.2351	2.287	n.s.
B (Conditions)	SB(A)	3	.5123	10.790	< .001
C (Electrodes)	SC(A)	3	.7961	47.991	< .001
S(A)		16	.1028		
AB	SB(A)	3	.7525E-01	1.585	n.s.
AC	SC(A)	3	.5238E-01	3.157	< .05
BC	SBC(A)	9	.1369E-01	1.852	n.s.
SB(A)		48	.4748E-01		
SC(A)		48	.1659E-01		
ABC	SBC(A)	9	.9890E-02	1.338	n.s.
SBC(A)		144	.7392E-02		

Table C20

Summary of the Analysis of Variance
for Cross-Correlations III
(Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.3270E-01	1.892	n.s.
B (Conditions)	SB(A)	3	.7943E-01	7.268	< .001
C (Electrodes)	SC(A)	1	.1755E-01	3.389	n.s.
S(A)		16	.1728E-01		
AB	SB(A)	3	.9588E-02	.877	n.s.
AC	SC(A)	1	.7084E-02	1.367	n.s.
BC	SBC(A)	3	.9606E-02	9.005	< .001
SB(A)		48	.1092E-01		
SC(A)		16	.5180E-02		
ABC	SBC(A)	3	.2222E-03	.208	n.s.
SBC(A)		48	.1066E-02		

Table C21

Summary of the Analysis of Variance for Cross-Correlations IV (Experiment 3)

Source	Error Term	df	MS	F	p
A (Sex)	S(A)	1	.4622E-01	4.600	< .05
B (Conditions)	SB(A)	3	.2672E-01	3.343	< .05
C (Electrodes)	SC(A)	1	.1440E-01	2.575	n.s.
S(A)		16	.1004E-01		
AB	SB(A)	3	.7082E-02	.886	n.s.
AC	SC(A)	1	.2178E-02	.389	n.s.
BC	SBC(A)	3	.1784E-01	.856	n.s.
SB(A)		48	.7994E-02		
SC(A)		16	.5591E-02		
ABC	SBC(A)	3	.4975E-03	.239	n.s.
SBC(A)		48	.2085E-02		

APPENDIX D

DUNCAN'S MULITPLE-RANGE TABLES

DUNCAN'S MULTIPLE-RANGE TABLES

Duncan range tests were used to compare overall differences among ordered means for main effects as well as to test row differences in the three-way classifications. Individual cells are differences resulting from subtracting the largest mean from the smallest, largest minus the next smallest, and so on. Depending on the number of means separating the comparisons, those cells exceeding the appropriate critical ranges are marked with an asterisk (*) to indicate the specific significance level achieved. The α-level used in the calculation of the critical ranges was the same level as the significant *F* ratio; in those cases where the *F* ratio was not significant, the .05 level was used. The standard error of the means was derived from $[MS_W/(n)]^{1/2}$, where MS_W = within treatment mean square and n = the number of observations on which each mean is based. In addition to n, each table also gives the number of means (k) involved and the degrees of freedom (*df*) associated with MS_W. Comparisons between two means are not shown.

Table D1

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	T_3 = 10.492	T_4 = 11.588	F_3 = 12.309	F_4 = 14.249	C_z = 23.742	Shortest Significant Ranges
T_3 = 10.492	---	1.096	1.817	3.757	13.250*	R2 = 6.222
T_4 = 11.588		---	0.721	2.661	12.154*	R3 = 6.433
F_3 = 12.309			---	1.940	11.433*	R4 = 6.577
F_4 = 14.249				---	9.493*	R5 = 6.688

Note. $k = 5$, $df = 32$, $n = 80$. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D2

Duncan's Multiple-Range Test among the Means for Times (Factor D)

Means	D4 = 8.303	D3 = 15.426	D2 = 15.935	D1 = 18.240	Shortest Significant Ranges
D4 = 8.303	---	7.123	7.632*	9.937*	R2 = 7.221
D3 = 15.426		---	0.509	2.814	R3 = 7.477
D2 = 15.935			---	2.305	R4 = 7.643

Note. *k* = 4, *df* = 24, *n* = 100. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

$^{*}p < .001$.

Table D3

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) for Electrodes (Factor C)

Means	T_3 = 5.555	F_3 = 5.599	F_4 = 6.399	T_4 = 7.166	C_z = 16.587	Shortest Significant Ranges
T_3 = 5.555	---	0.044	0.844	1.611	11.032*	R2 = 4.421
F_3 = 5.599		---	0.800	1.567	10.988*	R3 = 4.644
F_4 = 6.399			---	0.767	10.188*	R4 = 4.788
T_4 = 7.166				---	9.421*	R5 = 4.899

Note. k = 5, df = 32, n = 40. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .05$.

Table D4

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) for Electrodes (Factor C)

Means	T_3 = 15.420	T_4 = 15.998	F_3 = 19.009	F_4 = 22.086	C_z = 30.874	Shortest Significant Ranges
T_3 = 15.420	---	0.578	3.589	6.666*	15.454*	R2 = 4.421
T_4 = 15.998		---	3.011	6.088*	14.876*	R3 = 4.644
F_3 = 19.009			---	3.077	11.865*	R4 = 4.788
F_4 = 22.086				---	8.788*	R5 = 4.899

Note. *k* = 5, *df* = 32, *n* = 40. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .05$.

Table D5

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) for Times (Factor D)

Means	D4 = 5.699	D3 = 5.777	D2 = 8.943	D1 = 12.609	Shortest Significant Ranges
D4 = 5.699	---	0.078	3.244	6.910	R2 = 7.121
D3 = 5.777		---	3.166	6.832	R3 = 7.421
D2 = 8.943			---	3.666	R4 = 7.632

Note. *k* = 4, *df* = 24, *n* = 50. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

$p > .01$.

Table D6

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) for Times (Factor D)

Means	D4 = 10.887	D2 = 22.908	D1 = 23.853	D3 = 25.053	Shortest Significant Ranges
D4 = 10.887	---	12.021*	12.966*	14.166*	R2 = 7.121
D2 = 22.908		---	0.945	2.145	R3 = 7.421
D1 = 23.853			---	1.200	R4 = 7.632

Note. *k* = 4, *df* = 24, *n* = 50. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .01$.

Table D7

Duncan's Multiple-Range Test among the Means at the Vertex (C_z) Electrode Site (C = 1) for Times (Factor D)

Means	D4 = 18.931	D2 = 24.675	D3 = 24.686	D1 = 26.641	Shortest Significant Ranges
D4 = 18.931	---	5.744*	5.755*	7.710*	R2 = 4.999
D2 = 24.675		---	0.011	1.966	R3 = 5.166
D3 = 24.686			---	1.955	R4 = 5.277

Note. $k = 4$, $df = 96$, $n = 20$. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D8

Duncan's Multiple-Range Test among the Means at the Left Frontal (F_3) Electrode Site (C = 2) for Times (Factor D)

Means	D4 = 3.766	D3 = 11.443	D2 = 13.054	D1 = 20.942	Shortest Significant Ranges
D4 = 3.766	---	7.677*	9.288*	17.176*	R2 = 4.999
D3 = 11.443		---	1.611	9.499*	R3 = 5.166
D2 = 13.054			---	7.888*	R4 = 5.277

Note. *k* = 4, *df* = 96, *n* = 20. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D9

Duncan's Multiple-Range Test among the Means at the Right Frontal (F_4) Electrode Site (C = 3) for Times (Factor D)

Means	D4 = 4.599	D3 = 14.643	D2 = 17.476	D1 = 20.242	Shortest Significant Ranges
D4 = 4.599	---	10.044*	12.877*	15.643*	R2 = 4.999
D3 = 14.643		---	2.833	5.599*	R3 = 5.166
D2 = 17.476			---	2.766	R4 = 5.277

Note. $k = 4$, $df = 96$, $n = 20$. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D10

Duncan's Multiple-Range Test among the Means at the Left Temporal (T_3) Electrode Site (C = 4) for Times (Factor D)

Means	D4 = 6.921	D2 = 10.621	D3 = 11.565	D1 = 12.843	Shortest Significant Ranges
D4 = 6.921	---	3.700	4.644	5.922*	R2 = 4.999
D2 = 10.621		---	0.944	2.222	R3 = 5.166
D3 = 11.565			---	1.278	R4 = 5.277

Note. *k* = 4, *df* = 96, *n* = 20. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*p < .001.

Table D11

Duncan's Multiple-Range Test among the Means at the Right Temporal (T_4) Electrode Site (C = 5) for Times (Factor D)

Means	D4 = 7.265	D1 = 10.499	D2 = 13.820	D3 = 14.754	Shortest Significant Ranges
D4 = 7.265	---	3.234	6.555*	7.489*	R2 = 4.999
D1 = 10.499		---	3.321	4.255	R3 = 5.166
D2 = 13.820			---	0.934	R4 = 5.277

Note. $k = 4$, $df = 96$, $n = 20$. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D12

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) at the Vertex (C_z) Electrode Site (C = 1) for Times (Factor D)

Means	D4 = 11.554	D3 = 12.543	D2 = 18.220	D1 = 24.042	Shortest Significant Ranges
D4 = 11.544	---	0.989	6.666*	12.488*	R2 = 4.844
D3 = 12.543		---	5.677*	11.499*	R3 = 4.995
D2 = 18.220			---	5.822*	R4 = 5.110

Note. _k_ = 4, _df_ = 96, _n_ = 10. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

$^*p < .001$.

Table D13

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) at the Left Frontal (F_3) Electrode Site (C = 2) for Times (Factor D)

Means	D3 = 1.544	D4 = 2.510	D2= 5.266	D1 = 13.065	Shortest Significant Ranges
D3 = 1.544	---	0.966	3.722	11.521*	R2 = 4.844
D4 = 2.510		---	2.756	10.555*	R3 = 4.995
D2 = 5.266			---	7.799*	R4 = 5.110

Note. $k = 4$, $df = 96$, $n = 10$. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D14

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) at the Right Frontal (F_4) Electrode Site (C = 3) for Times (Factor D)

Means	D4 = 2.610	D3 = 3.810	D2 = 8.154	D1 = 10.998	Shortest Significant Ranges
D4 = 2.610	---	1.200	5.544*	8.388*	R2 = 4.844
D3 = 3.810		---	4.344	7.188*	R3 = 4.995
D2 = 8.154			---	2.844	R4 = 5.110

Note. k = 4, df = 96, n = 10. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*p < .001.

Table D15

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) at the Left Temporal (T_3) Electrode Site (C = 4) for Times (Factor D)

Means	D3 = 3.377	D2 = 4.610	D4 = 5.588	D1 = 8.632	Shortest Significant Ranges
D3 = 3.377	---	1.233	2.211	5.255*	R2 = 4.844
D2 = 4.610		---	0.978	4.022	R3 = 4.995
D4 = 5.588			---	3.044	R4 = 5.110

Note. *k* = 4, *df* = 96, *n* = 10. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

$^*p < .001$.

Table D16

Duncan's Multiple-Range Test among the Means of the Standard Condition (B = 1) at the Right Temporal (T_4) Electrode Site (C = 5) for Times (Factor D)

Means	D4 = 6.243	D1 = 6.299	D3 = 7.632	D2 = 8.488	Shortest Significant Ranges
D4 = 6.243	---	0.056	1.389	2.245	R2 = 4.844
D1 = 6.299		---	1.333	2.189	R3 = 4.995
D3 = 7.632			---	0.856	R4 = 5.110

Note. $k = 4$, $df = 96$, $n = 10$. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

$p > .001$.

Table D17

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) at the Vertex (C_z) Electrode Site (C = 1) for Times (Factor D)

Means	D4 = 26.308	D1 = 29.241	D2 = 31.130	D3 = 36.840	Shortest Significant Ranges
D4 = 26.308	---	2.933	4.822	10.532*	R2 = 4.844
D1 = 29.241		---	1.889	7.599*	R3 = 4.995
D2 = 31.130			---	5.710*	R4 = 5.110

Note. $k = 4$, $df = 96$, $n = 10$. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D18

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) at the Left Frontal (F_3) Electrode Site (C = 2) for Times (Factor D)

Means	D4 = 5.021	D2 = 20.853	D3 = 21.353	D1 = 28.819	Shortest Significant Ranges
D4 = 5.021	---	15.832*	16.332*	23.798*	R2 = 4.844
D2 = 20.853		---	0.500	7.966*	R3 = 4.995
D3 = 21.353			---	7.466*	R4 = 5.110

Note. $k = 4$, $df = 96$, $n = 10$. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D19

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) at the Right Frontal (F_4) Electrode Site (C = 3) for Times (Factor D)

Means	D4 = 6.599	D3 = 25.475	D2 = 26.808	D1 = 29.485	Shortest Significant Ranges
D4 = 6.599	---	18.876*	20.209*	22.886*	R2 = 4.844
D3 = 25.475		---	1.333	4.010	R3 = 4.995
D2 = 26.808			---	2.677	R4 = 5.110

Note. k = 4, df = 96, n = 10. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D20

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) at the Left Temporal (T_3) Electrode Site (C = 4) for Times (Factor D)

Means	D4 = 8.243	D2 = 16.620	D1 = 17.053	D3 = 19.753	Shortest Significant Ranges
D4 = 8.243	---	8.377*	8.810*	11.510*	R2 = 4.844
D2 = 16.620		---	0.433	3.133	R3 = 4.995
D1 = 17.053			---	2.700	R4 = 5.110

Note. *k* = 4, *df* = 96, *n* = 10. The means are amplitudes expressed in μV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D21

Duncan's Multiple-Range Test among the Means of the Tone Analysis Condition (B = 2) at the Right Temporal (T_4) Electrode Site (C = 5) for Times (Factor D)

Means	D4 = 8.299	D1 = 14.698	D2 = 19.142	D3 = 21.875	Shortest Significant Ranges
D4 = 8.299	---	6.399*	10.843*	13.576*	R2 = 4.844
D1 = 14.698		---	4.444	7.177*	R3 = 4.995
D2 = 19.142			---	2.733	R4 = 5.110

Note. $k = 4$, $df = 96$, $n = 10$. The means are amplitudes expressed in µV from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C1.

*$p < .001$.

Table D22

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	F_3 = .729	F_4 = .756	T_3 = .826	T_4 = .840	Shortest Significant Ranges
F_3 = .729	---	.026	.097	.111*	R2 = 0.101
F_4 = .756		---	.070	.084	R3 = 0.104
T_3 = .826			---	.014	R4 = 0.107

Note. $k = 4$, $df = 24$, $n = 20$. The means are Cross-Correlation II values from Experiment 1. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C3.

*$p < .001$.

Table D23

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	W_2 = 20.174	W_1 = 21.919	F_4 = 25.096	F_3 = 25.759	C_z = 34.879	Shortest Significant Ranges
W_2 = 20.174	---	1.745	4.922	5.585	14.705*	R2 = 5.373
W_1 = 21.919		---	3.177	3.840	12.960*	R3 = 5.558
F_4 = 25.096			---	0.663	9.783*	R4 = 5.684
F_3 = 25.759				---	9.120*	R5 = 5.781

Note. $k = 5$, $df = 32$, $n = 30$. The means are densities (normalized areas) expressed in $\mu\overline{V}$ from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C6.

*$p < .001$.

Table D24

Duncan's Multiple-Range Test among the Means for Females (A = 1) across Electrodes (Factor C)

Means	W_1 = 20.676	W_2 = 21.965	F_3 = 26.385	F_4 = 26.995	C_z = 38.668	Shortest Significant Ranges
W_1 = 20.676	---	1.289	5.709*	6.319*	17.992*	R2 = 4.258
W_2 = 21.965		---	4.420*	5.030*	16.703*	R3 = 4.476
F_3 = 26.385			---	0.610	12.283*	R4 = 4.618
F_4 = 26.995				---	11.673*	R5 = 4.718

Note. k = 5, *df* = 32, n = 15. The means are densities (normalized areas) expressed in µV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C6.

*p < .05.

Table D25

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Electrodes (Factor C)

Means	W_2 = 18.383	W_1 = 23.163	F_4 = 23.200	F_3 = 25.134	C_z = 31.095	Shortest Significant Ranges
W_2 = 18.383	---	4.780*	4.817*	6.751*	12.712*	R2 = 4.258
W_1 = 23.163		---	0.037	1.971	7.932*	R3 = 4.476
F_4 = 23.200			---	1.934	7.895*	R4 = 4.618
F_3 = 25.134				---	5.961*	R5 = 4.718

Note. $k = 5$, $df = 32$, $n = 15$. The means are densities (normalized areas) expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C6.

*$p < .05$.

Table D26

Duncan's Multiple-Range Test among the Means for Condition A (B = 1) across Electrodes (Factor C)

Means	W_2 = 20.515	W_1 = 21.294	F_4 = 26.638	F_3 = 26.987	C_z = 39.795	Shortest Significant Ranges
W_2 = 20.515	---	0.779	6.123*	6.472*	19.280*	R2 = 3.958
W_1 = 21.294		---	5.344*	5.693*	18.501*	R3 = 4.164
F_4 = 26.638			---	0.349	13.157*	R4 = 4.301
F_3 = 26.987				---	9.808*	R5 = 4.399

Note. k = 5, df = 64, n = 10. The means are densities (normalized areas) expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C6.

*p < .05.

Table D27

Duncan's Multiple-Range Test among the Means
for Condition B (B = 2) across
Electrodes (Factor C)

Means	W_2 = 22.099	W_1 = 24.328	F_4 = 27.712	F_3 = 28.437	C_z = 37.352	Shortest Significant Ranges
W_2 = 22.099	---	2.229	5.613*	6.338*	15.253*	R2 = 3.958
W_1 = 24.328		---	3.384	4.109	13.024*	R3 = 4.164
F_4 = 27.712			---	0.725	9.640*	R4 = 4.301
F_3 = 28.437				---	8.915*	R5 = 4.399

Note. k = 5, df = 64, n = 10. The means are densities (normalized areas) expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C6.

*$p < .05$.

Table D28

Duncan's Multiple-Range Test among the Means for Condition C (B = 3) across Electrodes (Factor C)

Means	W_2 = 17.910	W_1 = 20.139	F_4 = 20.945	F_3 = 21.858	C_z = 27.497	Shortest Significant Ranges
W_2 = 17.910	---	2.229	3.035	3.948	9.587*	R2 = 3.958
W_1 = 20.139		---	0.806	1.719	7.358*	R3 = 4.164
F_4 = 20.945			---	0.913	6.552*	R4 = 4.301
F_3 = 21.858				---	5.639*	R5 = 4.399

Note. *k* = 5, *df* = 64, *n* = 10. The means are densities (normalized areas) expressed in µV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C6.

*$p < .05$.

Table D29

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Condition C = -3.615[a]	Condition B = 9.196	Condition A = 15.153	Shortest Significant Ranges
Cond. C = -3.615	---	12.811	18.768*	R2 = 15.102
Cond. B = 9.196		---	5.957	R3 = 15.752

Note. *k* = 3, *df* = 16, *n* = 50. The means are amplitudes expressed in µV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C7.

[a] The negative polarity represented a shift below baseline levels.

*$p < .005$.

Table D30

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	W_1 = 2.195	W_2 = 4.085	F_3 = 5.886	F_4 = 7.264	C_z = 14.572	Shortest Significant Ranges
W_1 = 2.195	---	1.890	3.691	5.069	12.377*	R2 = 5.050
W_2 = 4.085		---	1.801	3.179	10.487*	R3 = 5.200
F_3 = 5.886			---	1.378	8.686*	R4 = 5.351
F_4 = 7.264				---	7.308*	R5 = 5.401

Note. $k = 5$, $df = 32$, $n = 30$. The means are amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C7.

*$p < .001$.

Table D31

Duncan's Multiple-Range Test among the Means for Condition A (B = 1) across Electrodes (Factor C)

Means	W_1 = 8.141	W_2 = 9.416	F_3 = 13.402	F_4 = 16.137	C_z = 28.680	Shortest Significant Ranges
W_1 = 8.141	---	1.275	5.261	7.996*	20.539*	R2 = 6.946
W_2 = 9.416		---	3.986	6.721	19.264*	R3 = 7.221
F_3 = 13.402			---	2.735	15.278*	R4 = 7.406
F_4 = 16.137				---	12.543*	R5 = 7.541

Note. $k = 5$, $df = 64$, $n = 10$. The means are amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C7.

*$p < .005$.

Table D32

Duncan's Multiple-Range Test among the Means for Condition B (B = 2) across Electrodes (Factor C)

Means	W_2 = 6.871	W_1 = 6.971	F_3 = 9.046	F_4 = 9.161	C_z = 13.952	Shortest Significant Ranges
W_2 = 6.871	---	0.100	2.175	2.290	7.081	R2 = 6.946
W_1 = 6.971		---	2.075	2.190	6.981	R3 = 7.221
F_3 = 9.046			---	0.115	4.906	R4 = 7.406
F_4 = 9.161				---	4.791	R5 = 7.541

Note. *k* = 5, *df* = 64, *n* = 10. The means are amplitudes expressed in µV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C7.

$p > .005$.

Table D33

Duncan's Multiple-Range Test among the Means for Condition C (B = 3) across Electrodes (Factor C)

Means	W_1 = -8.521^a	F_3 = -4.790^a	W_2 = -4.030^a	F_4 = -1.820^a	C_z = 1.085	Shortest Significant Ranges
W_1 = -8.521	---	3.731	4.491	6.701	9.606*	R2 = 6.946
F_3 = -4.790		---	0.760	2.970	5.875	R3 = 7.221
W_2 = -4.030			---	2.210	5.115	R4 = 7.406
F_4 = -1.820				---	2.905	R5 = 7.541

Note. *k* = 5, *df* = 64, *n* = 10. The means are amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C7.

[a] The negative polarity represented a shift below baseline levels.

$^*p < .005$.

Table D34

Duncan's Multiple-Range Test among the Means for Females (A = 1) across Conditions (Factor B) for Frontal Ratios (C = 1)

Means	Condition A = .476	Condition B = .486	Condition C = .500	Shortest Significant Ranges
Cond. A = .476	---	.010	.024	R2 = .396
Cond. B = .486		---	.014	R3 = .397

Note. *k* = 3, *df* = 16, *n* = 5. The interaction (A × B × C) represented by these means did not reach a significant level in Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C8.

$p > .05$.

Table D35

Duncan's Multiple-Range Test among the Means for
Females (A = 1) across Conditions (Factor B)
for Posterior Ratios (C = 2)

Means	Condition A = .444	Condition B = .458	Condition C = .488	Shortest Significant Ranges
Cond. A = .444	---	.014	.044	R2 = .396
Cond. B = .458		---	.030	R3 = .397

Note. *k* = 3, *df* = 16, *n* = 5. The interaction (A × B × C) represented by these means did not reach a significant level in Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C8.

$p > .05$.

Table D36

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Conditions (Factor B) for Frontal Ratios (C = 1)

Means	Condition C = .472	Condition A = .504	Condition B = .512	Shortest Significant Ranges
Cond. C = .472	---	.032	.040	R2 = .396
Cond. A = .504		---	.008	R3 = .397

Note. *k* = 3, *df* = 16, *n* = 5. The interaction (A × B × C) represented by these means did not reach a significant level in Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C8.

$p > .05$.

Table D37

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Conditions (Factor B) for Posterior Ratios (C = 2)

Means	Condition C = .544	Condition B = .552	Condition A = .572	Shortest Significant Ranges
Cond. C = .544	---	.008	.028	R2 = .396
Cond. B = .552		---	.020	R3 = .397

Note. $k = 3$, $df = 16$, $n = 5$. The interaction (A × B × C) represented by these means did not reach a significant level in Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C8.

$p > .05$.

Table D38

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	W_2 = 15.937	W_1 = 18.513	F_4 = 21.598	F_3 = 23.449	C_z = 31.065	Shortest Significant Ranges
W_2 = 15.937	---	2.576	5.661	7.512	15.128*	R2 = 7.786
W_1 = 18.513		---	3.085	4.936	12.552*	R3 = 8.056
F_4 = 21.598			---	1.851	9.467*	R4 = 8.241
F_3 = 23.449				---	7.616	R5 = 8.381

Note. *k* = 5, *df* = 32, *n* = 30. The means are evoked potential amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C9.

*$p < .001$.

Table D39

Duncan's Multiple-Range Test among the Means
for Condition A (B = 1) across
Electrodes (Factor C)

Means	W_1 = 12.777	W_2 = 12.907	F_3 = 16.458	F_4 = 16.843	C_z = 21.248	Shortest Significant Ranges
W_1 = 12.777	---	0.130	3.681	4.066	8.471*	R2 = 4.177
W_2 = 12.907		---	3.551	3.936	8.341*	R3 = 4.395
F_3 = 16.458			---	0.385	4.790*	R4 = 4.538
F_4 = 16.843				---	4.405	R5 = 4.644

Note. *k* = 5, *df* = 64, *n* = 10. The means are evoked potential amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C9.

$^*p < .05$.

Table D40

Duncan's Multiple-Range Test among the Means for Condition B (B = 2) across Electrodes (Factor C)

Means	W_2 = 15.197	W_1 = 19.318	F_4 = 21.418	F_3 = 25.204	C_z = 34.916	Shortest Significant Ranges
W_2 = 15.197	---	4.121	6.221*	10.007*	19.719*	R2 = 4.177
W_1 = 19.318		---	2.100	5.886*	15.598*	R3 = 4.395
F_4 = 21.418			---	3.786	13.498*	R4 = 4.538
F_3 = 25.204				---	9.712*	R5 = 4.644

Note. $k = 5$, $df = 64$, $n = 10$. The means are evoked potential amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C9.

*$p < .05$.

Table D41

Duncan's Multiple-Range Test among the Means for Condition C (B = 3) across Electrodes (Factor C)

Means	W_2 = 19.718	W_1 = 23.404	F_4 = 26.539	F_3 = 28.685	C_z = 37.036	Shortest Significant Ranges
W_2 = 19.718	---	3.686	6.821*	8.967*	17.318*	R2 = 4.177
W_1 = 23.404		---	3.135	5.281*	13.632*	R3 = 4.395
F_4 = 26.539			---	2.146	10.497*	R4 = 4.538
F_3 = 28.685				---	8.351*	R5 = 4.644

Note. $k = 5$, $df = 64$, $n = 10$. The means are evoked potential amplitudes expressed in μV from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C9.

$^*p < .05$.

Table D42

Duncan's Multiple-Range Test among the Means for Condition B (B = 1) across Electrodes (Factor C)

Means	W_2 = .477	W_1 = .515	F_3 = .573	F_4 = .586	C_z = .591	Shortest Significant Ranges
W_2 = .477	---	.038	.096	.109	.114	R2 = .125
W_1 = .515		---	.058	.071	.076	R3 = .131
F_3 = .573			---	.013	.018	R4 = .135
F_4 = .586				---	.005	R5 = .138

Note. *k* = 5, *df* = 32, *n* = 10. The means are Cross-Correlation I values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C10.

$p > .05$.

Table D43

Duncan's Multiple-Range Test among the Means for Condition C (B = 2) across Electrodes (Factor C)

Means	W_1 = .159	F_3 = .197	F_4 = .215	W_2 = .219	C_z = .227	Shortest Significant Ranges
W_1 = .159	---	.038	.056	.060	.068	R2 = .125
F_3 = .197		---	.018	.022	.030	R3 = .131
F_4 = .215			---	.004	.012	R4 = .135
W_2 = .219				---	.008	R5 = .138

Note. $k = 5$, $df = 32$, $n = 10$. The means are Cross-Correlation I values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C10.

$p > .05$.

Table D44

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	W_2 = .690	W_1 = .727	F_4 = .883	F_3 = .898	Shortest Significant Ranges
W_2 = .690	---	.037	.193*	.208*	R2 = .127
W_1 = .727		---	.156*	.171*	R3 = .131
F_4 = .883			---	.015	R4 = .134

Note. $k = 4$, $df = 24$, $n = 30$. The means are Cross-Correlation II values from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C11.

*$p < .001$.

Table D45

Duncan's Multiple-Range Test among the Means for Condition A (B = 1) across Electrodes (Factor C)

Means	W_2 = .729	W_1 = .774	F_3 = .919	F_4 = .923	Shortest Significant Ranges
W_2 = .729	---	.045	.190*	.194*	R2 = .132
W_1 = .774		---	.145*	.149*	R3 = .137
F_3 = .919			---	.004	R4 = .140

Note. $k = 4$, $df = 48$, $n = 10$. The means are Cross-Correlation II values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C11.

*$p < .001$.

Table D46

Duncan's Multiple-Range Test among the Means for Condition B (B = 2) across Electrodes (Factor C)

Means	W_2 = .675	W_1 = .699	F_4 = .879	F_3 = .885	Shortest Significant Ranges
W_2 = .675	---	.025	.205*	.215*	R2 = .132
W_1 = .699		---	.180*	.186*	R3 = .137
F_4 = .879			---	.006	R4 = .140

Note. *k* = 4, *df* = 48, *n* = 10. The means are Cross-Correlation II values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C11.

*$p < .001$.

Table D47

Duncan's Multiple-Range Test among the Means for Condition C (B = 3) across Electrodes (Factor C)

Means	W_2 = .668	W_1 = .709	F_4 = .848	F_3 = .891	Shortest Significant Ranges
W_2 = .668	---	.041	.180*	.223*	R2 = .132
W_1 = .709		---	.139*	.182*	R3 = .137
F_4 = .848			---	.043	R4 = .140

Note. k = 4, df = 48, n = 10. The means are Cross-Correlation II values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 2. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C11.

*$p < .001$.

Table D48

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Cond. 3 = 21.013	Cond. 4 = 21.610	Cond. 2 = 24.459	Cond. 1 = 25.143	Shortest Significant Ranges
3 = 21.013	---	0.597	3.446	4.130*	R2 = 3.448
4 = 21.610		---	2.849	3.530	R3 = 3.626
2 = 24.459			---	0.684	R4 = 3.742

Note. $k = 4$, $df = 48$, $n = 90$. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .05$.

Table D49

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	B_2 = 19.430	B_1 = 19.643	F_4 = 21.914	F_3 = 22.806	C_z = 31.487	Shortest Significant Ranges
B_2 = 19.430	---	0.213	2.484	3.376*	12.057*	R2 = 3.010
B_1 = 19.643		---	2.271	3.163*	11.844*	R3 = 3.109
F_4 = 21.914			---	0.892	9.573*	R4 = 3.176
F_3 = 22.806				---	8.681*	R5 = 3.277

Note. $k = 5$, $df = 64$, $n = 72$. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .001$.

Table D50

Duncan's Multiple-Range Test among the Means for Females (A = 1) across Electrodes (Factor C)

Means	B_2 = 17.572	B_1 = 18.147	F_4 = 21.758	F_3 = 23.175	C_z = 32.929	Shortest Significant Ranges
B_2 = 17.572	---	0.575	4.186*	5.603*	15.357*	R2 = 3.599
B_1 = 18.147		---	3.611*	5.028*	14.782*	R3 = 3.740
F_4 = 21.758			---	1.417	11.171*	R4 = 3.836
F_3 = 23.175				---	9.754*	R5 = 3.908

Note. *k* = 5, *df* = 64, *n* = 36. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .005$.

Table D51

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Electrodes (Factor C)

Means	B_1 = 21.139	B_2 = 21.288	F_4 = 22.070	F_3 = 22.435	C_z = 30.042	Shortest Significant Ranges
B_1 = 21.139	---	0.149	0.931	1.296	8.903*	R2 = 3.599
B_2 = 21.288		---	0.782	1.147	8.754*	R3 = 3.740
F_4 = 22.070			---	0.365	7.972*	R4 = 3.836
F_3 = 22.435				---	7.607*	R5 = 3.908

Note. $k = 5$, $df = 64$, $n = 36$. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .005$.

Table D52

Duncan's Multiple-Range Test among the Means for Condition 1 (B = 1) across Electrodes (Factor C)

Means	B_2 = 18.227	B_1 = 18.394	F_4 = 24.495	F_3 = 25.598	C_z = 38.990	Shortest Significant Ranges
B_2 = 18.227	---	0.167	6.268*	7.371*	20.763*	R2 = 4.280
B_1 = 18.394		---	6.101*	7.204*	20.596*	R3 = 4.417
F_4 = 24.495			---	1.103	14.495*	R4 = 4.511
F_3 = 25.598				---	13.392*	R5 = 4.581

Note. $k = 5$, $df = 192$, $n = 18$. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .001$.

Table D53

Duncan's Multiple-Range Test among the Means for Condition 2 (B = 2) across Electrodes (Factor C)

Means	B_1 = 19.826	B_2 = 20.333	F_4 = 23.913	F_3 = 24.749	C_z = 33.474	Shortest Significant Ranges
B_1 = 19.826	---	0.507	4.087	4.923*	13.648*	R2 = 4.280
B_2 = 20.333		---	3.580	4.417*	13.141*	R3 = 4.417
F_4 = 23.913			---	0.836	9.561*	R4 = 4.511
F_3 = 24.749				---	8.725*	R5 = 4.581

Note. $k = 5$, $df = 192$, $n = 18$. The means are densities (normalized areas) expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .001$.

Table D54

Duncan's Multiple-Range Test among the Means for Condition 3 (B = 3) across Electrodes (Factor C)

Means	B_1 = 19.167	B_2 = 19.304	F_4 = 19.943	F_3 = 20.139	C_z= 26.509	Shortest Significant Ranges
B_1 = 19.167	---	0.137	0.776	0.972	7.342*	R2 = 4.280
B_2 = 19.304		---	0.639	0.835	7.205*	R3 = 4.417
F_4 = 19.943			---	0.196	6.566*	R4 = 4.511
F_3 = 20.139				---	6.370*	R5 = 4.581

Note. $k = 5$, $df = 192$, $n = 18$. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C14.

*$p < .001$.

Table D55

Duncan's Multiple-Range Test among the Means
for Condition 4 (B = 4) across
Electrodes (Factor C)

Means	F_4 = 19.301	B_2 = 19.855	F_3 = 20.735	B_1 = 21.184	C_z = 26.971	Shortest Significant Ranges
F_4 = 19.301	---	0.554	1.434	1.883	7.670*	R2 = 4.280
B_2 = 19.855		---	0.880	1.329	7.116*	R3 = 4.417
F_3 = 20.735			---	0.449	6.236*	R4 = 4.511
B_1 = 21.184				---	5.787*	R5 = 4.581

Note. *k* = 5, *df* = 192, *n* = 18. The means are densities (normalized areas) expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table, C14.

*$p < .001$.

Table D56

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Cond. 4 = -0.606[a]	Cond. 3 = 0.376	Cond. 2 = 7.853	Cond. 1 = 15.838	Shortest Significant Ranges
4 = -0.606	---	0.982	8.459	16.444*	R2 = 8.931
3 = 0.376		---	7.477	15.462*	R3 = 9.231
2 = 7.853			---	7.985*	R4 = 9.441

Note. $\underline{k} = 4$, $\underline{df} = 48$, $\underline{n} = 90$. The means are amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C15.

[a] The negative polarity represented a shift below baseline levels.

*$\underline{p} < .001$.

Table D57

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	B_1 = 2.265	B_2 = 2.395	F_4 = 4.665	F_3 = 6.296	C_z = 13.701	Shortest Significant Ranges
B_1 = 2.265	---	0.130	2.400	4.031	11.436*	R2 = 3.975
B_2 = 2.395		---	2.270	3.901	11.306*	R3 = 4.105
F_4 = 4.665			---	1.631	9.036*	R4 = 4.195
F_3 = 6.296				---	7.405*	R5 = 4.265

Note. $k = 5$, $df = 64$, $n = 72$. The means are amplitudes expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C15.

*$p < .001$.

Table D58

Duncan's Multiple-Range Test among the Means for Condition 1 (B = 1) across Electrodes (Factor C)

Means	B_1 = 9.310	B_2 = 11.335	F_3 = 14.732	F_4 = 15.263	C_z 28.549	Shortest Significant Ranges
B_1 = 9.310	---	2.025	5.422	5.953*	19.239*	R2 = 5.265
B_2 = 11.335		---	3.397	3.928	17.214*	R3 = 5.436
F_3 = 14.732			---	0.531	13.817*	R4 = 5.551
F_4 = 15.263				---	13.286*	R5 = 5.641

Note. _k_ = 5, _df_ = 192, _n_ = 18. The means are amplitudes expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C15.

*$p < .001$.

Table D59

Duncan's Multiple-Range Test among the Means for Condition 2 (B = 2) across Electrodes (Factor C)

Means	B_1 = 4.370	B_2 = 5.691	F_3 = 7.116	F_4 = 7.406	C_z = 14.677	Shortest Significant Ranges
B_1 = 4.370	---	1.321	2.746	3.036	10.307*	R2 = 5.265
B_2 = 5.691		---	1.425	1.715	8.986*	R3 = 5.436
F_3 = 7.116			---	0.290	7.561*	R4 = 5.551
F_4 = 7.406				---	7.271*	R5 = 5.641

Note. k = 5, df = 192, n = 18. The means are amplitudes expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C15.

*$p < .001$.

Table D60

Duncan's Multiple-Range Test among the Means for Condition 3 (B = 3) across Electrodes (Factor C)

Means	$B_2 =$ -2.636^a	$B_1 =$ -2.411^a	$F_4 =$ -0.650^a	$F_3 =$ 1.389	$C_z =$ 6.186	Shortest Significant Ranges
$B_2 = -2.636$	---	0.225	1.986	4.025	8.822*	R2 = 5.265
$B_1 = -2.411$		---	1.761	3.800	8.597*	R3 = 5.436
$F_4 = -0.650$			---	2.039	6.836*	R4 = 5.551
$F_3 = 1.389$				---	4.797	R5 = 5.641

Note. *k* = 5, *df* = 192, *n* = 18. The means are amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C15.

[a] The negative polarity represented a shift below baseline levels.

$^*p < .001$.

Table D61

Duncan's Multiple-Range Test among the Means for Condition 4 (B = 4) across Electrodes (Factor C)

Means	B_2 = -4.809[a]	F_4 = -3.350[a]	B_1 = -2.205[a]	F_3 = 1.947	C_z = 5.386	Shortest Significant Ranges
B_2 = -4.809	---	1.459	2.604	6.756*	10.195*	R2 = 5.265
F_4 = -3.350		---	1.145	5.297	8.736*	R3 = 5.436
B_1 = -2.205			---	4.152	7.591*	R4 = 5.551
F_3 = 1.947				---	3.439	R5 = 5.641

Note. _k_ = 5, _df_ = 192, _n_ = 18. The means are amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C15.

[a] The negative polarity represented a shift below baseline levels.

*$p < .001$.

Table D62

Duncan's Multiple-Range Test among the Means across Conditions for Frontal Ratios (C = 1)

Means	Cond. 2 = .506	Cond. 1 = .511	Cond. 3 = .512	Cond. 4 = .527	Shortest Significant Ranges
2 = .506	---	.005	.006	.021	R2 = .022
1 = .511		---	.001	.016	R3 = .024
3 = .512			---	.015	R4 = .025

Note. *k* = 4, *df* = 48, *n* = 18. The interaction (B × C) represented by these means did not reach a significant level in Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C16.

$p > .05$.

Table D63

Duncan's Multiple-Range Test among the Means across Conditions for Inferior Frontal Ratios (C = 2)

Means	Cond. 2 = .492	Cond. 1 = .501	Cond. 3 = .502	Cond. 4 = .528	Shortest Significant Ranges
2 = .492	---	.009	.010	.036*	R2 = .022
1 = .501		---	.001	.027*	R3 = .024
3 = .502			---	.026*	R4 = .025

Note. k = 4, df = 48, n = 18. The interaction (B × C) represented by these means did not reach a significant level in Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C16.

$*p < .05$.

Table D64

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Cond. 1 = 15.792	Cond. 2 = 17.313	Cond. 4 = 22.699	Cond. 3 = 25.581	Shortest Significant Ranges
1 = 15.792	---	1.521	6.907	9.789*	R2 = 8.176
2 = 17.313		---	5.386	8.268	R3 = 8.501
4 = 22.699			---	2.882	R4 = 8.716

Note. $k = 4$, $df = 48$, $n = 90$. The means are evoked potential amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

*$p < .005$.

Table D65

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	B_2 = 16.728	B_1 = 17.467	F_4 = 20.083	F_3 = 20.278	C_z = 27.172	Shortest Significant Ranges
B_2 = 16.728	---	0.739	3.355	3.750	10.444*	R2 = 4.820
B_1 = 17.467		---	2.616	2.811	9.705*	R3 = 4.985
F_4 = 20.083			---	0.195	7.089*	R4 = 5.095
F_3 = 20.278				---	6.894*	R5 = 5.180

Note. _k_ = 5, _df_ = 64, _n_ = 72. The means are evoked potential amplitudes expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

*$p < .001$.

Table D66

Duncan's Multiple-Range Test among the Means for Females (A = 1) across Electrodes (Factor C)

Means	B_2 = 12.782	B_1 = 14.292	F_4 = 19.198	F_3 = 19.738	C_z = 28.430	Shortest Significant Ranges
B_2 = 12.782	---	1.510	6.416*	6.956*	15.648*	R2 = 5.751
B_1 = 14.292		---	4.906	5.446	14.138*	R3 = 5.976
F_4 = 19.198			---	0.540	9.232*	R4 = 6.131
F_3 = 19.738				---	8.692*	R5 = 6.246

Note. *k* = 5, *df* = 64, *n* = 36. The means are evoked potential amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

*$p < .005$.

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Table D67

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Electrodes (Factor C)

Means	B_1 = 20.633	B_2 = 20.673	F_3 = 20.813	F_4 = 20.968	C_z = 25.909	Shortest Significant Ranges
B_1 = 20.633	---	0.040	0.180	0.335	5.276	R2 = 5.751
B_2 = 20.673		---	0.140	0.295	5.236	R3 = 5.976
F_3 = 20.813			---	0.155	5.096	R4 = 6.131
F_4 = 20.968				---	4.941	R5 = 6.246

Note. *k* = 5, *df* = 64, *n* = 36. The means are evoked potential amplitudes expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

$p > .005$.

Table D68

Duncan's Multiple-Range Test among the Means for Condition 1 (B = 1) across Electrodes (Factor C)

Means	B_2 = 11.087	B_1 = 12.160	F_4 = 15.147	F_3 = 17.133	C_z = 23.437	Shortest Significant Ranges
B_2 = 11.087	---	1.073	4.060*	6.046*	12.350*	R2 = 2.942
B_1 = 12.160		---	2.987*	4.973*	11.277*	R3 = 3.096
F_4 = 15.147			---	1.986	8.290*	R4 = 3.199
F_3 = 17.133				---	6.304*	R5 = 3.274

Note. k = 5, df = 192, n = 18. The means are evoked potential amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

*$p < .05$.

Table D69

Duncan's Multiple-Range Test among the Means for Condition 2 ($B = 2$) across Electrodes (Factor C)

Means	B_2 = 12.897	B_1 = 13.197	F_4 = 17.303	F_3 = 18.393	C_z = 24.765	Shortest Significant Ranges
B_2 = 12.897	---	0.300	4.406*	5.496*	11.868*	R2 = 2.942
B_1 = 13.197		---	4.106*	5.196*	11.568*	R3 = 3.096
F_4 = 17.303			---	1.090	7.462*	R4 = 3.199
F_3 = 18.393				---	6.372*	R5 = 3.274

Note. $k = 5$, $df = 192$, $n = 18$. The means are evoked potential amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

*$p < .05$.

Table D70

Duncan's Multiple-Range Test among the Means for Condition 3 (B = 3) across Electrodes (Factor C)

Means	B_2 = 22.149	B_1 = 22.629	F_3 = 24.139	F_4 = 25.271	C_z = 33.711	Shortest Significant Ranges
B_2 = 22.149	---	0.480	1.990	3.122	11.562*	R2 = 2.942
B_1 = 22.629		---	1.510	2.642	11.082*	R3 = 3.096
F_3 = 24.139			---	1.132	9.572*	R4 = 3.199
F_4 = 25.271				---	8.440*	R5 = 3.274

Note. *k* = 5, *df* = 192, *n* = 18. The means are evoked potential amplitudes expressed in µV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

$^*p < .05$.

Table D71

Duncan's Multiple-Range Test among the Means for Condition 4 (B = 4) across Electrodes (Factor C)

Means	B_2 = 20.783	F_3 = 21.438	B_1 = 21.873	F_4 = 22.609	C_z = 26.774	Shortest Significant Ranges
B_2 = 20.783	---	0.655	1.090	1.826	5.991*	R2 = 2.942
F_3 = 21.438		---	0.435	1.171	5.336*	R3 = 3.096
B_1 = 21.873			---	0.736	4.901*	R4 = 3.199
F_4 = 22.609				---	4.165*	R5 = 3.274

Note. _k_ = 5, _df_ = 192, _n_ = 18. The means are evoked potential amplitudes expressed in μV from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C17.

*$p < .05$.

Table D72

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Condition 3 = .183	Condition 4 = .282	Condition 2 = .703	Shortest Significant Ranges
Cond. 3 = .183	---	.099	.520*	R2 = .225
Cond. 4 = .282		---	.421*	R3 = .233

Note. k = 3, df = 32, n = 90. The means are Cross-Correlation I values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

*$p < .001$.

Table D73

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	B_1 = .327	B_2 = .370	F_3 = .370	F_4 = .385	C_z .494	Shortest Significant Ranges
B_1 = .327	---	.043	.043	.058	.167*	R2 = .109
B_2 = .370		---	.000	.015	.124*	R3 = .113
F_3 = .370			---	.015	.124*	R4 = .115
F_4 = .385				---	.109*	R5 = .109

Note. *k* = 5, *df* = 64, *n* = 54. The means are Cross-Correlation I values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

$^*p < .001$.

Table D74

Duncan's Multiple-Range Test among the Means for Females (A = 1) across Electrodes (Factor C)

Means	B_1 = .228	B_2 = .296	F_3 = .310	F_4 = .330	C_z = .500	Shortest Significant Ranges
B_1 = .228	---	.068	.082	.102*	.272*	R2 = .089
B_2 = .296		---	.014	.034	.204*	R3 = .094
F_3 = .310			---	.020	.190*	R4 = .097
F_4 = .330				---	.170*	R5 = .099

Note. $k = 5$, $df = 64$, $n = 27$. The means are Cross-Correlation I values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

*$p < .05$.

Table D75

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Electrodes (Factor C)

Means	B_1 = .425	F_3 = .430	F_4 = .440	B_2 = .444	C_z = .489	Shortest Significant Ranges
B_1 = .425	---	.005	.015	.019	.064	R2 = .089
F_3 = .430		---	.010	.014	.059	R3 = .094
F_4 = .440			---	.004	.049	R4 = .097
B_2 = .444				---	.045	R5 = .099

Note. $k = 5$, $df = 64$, $n = 27$. The means are Cross-Correlation I values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

$p > .05$.

Table D76

Duncan's Multiple-Range Test among the Means
for Condition 2 (B = 1) across
Electrodes (Factor C)

Means	B_1 = .622	B_2 = .649	F_4 = .718	F_3 = .737	C_z = .789	Shortest Significant Ranges
B_1 = .622	---	.027	.096*	.115*	.167*	R2 = .068
B_2 = .649		---	.069*	.088*	.140*	R3 = .071
F_4 = .718			---	.019	.071	R4 = .074
F_3 = .737				---	.052	R5 = .076

Note. k = 5, df = 128, n = 18. The means are Cross-Correlation I values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

*$p < .05$.

Table D77

Duncan's Multiple-Range Test among the Means
for Condition 3 (B = 2) across
Electrodes (Factor C)

Means	B_1 = .123	F_3 = .141	B_2 = .187	F_4 = .187	C_z = .276	Shortest Significant Ranges
B_1 = .123	---	.018	.064	.064	.153*	R2 = .068
F_3 = .141		---	.046	.046	.135*	R3 = .071
B_2 = .187			---	.000	.089*	R4 = .074
F_4 = .187				---	.089*	R5 = .076

Note. *k* = 5, *df* = 128, *n* = 18. The means are Cross-Correlation I values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

*$p < .05$.

Table D78

Duncan's Multiple-Range Test among the Means for Condition 4 (B = 3) across Electrodes (Factor C)

Means	F_3 = .232	B_1 = .235	F_4 = .248	B_2 = .275	C_Z = .418	Shortest Significant Ranges
F_3 = .232	---	.003	.016	.043	.186*	R2 = .068
B_1 = .235		---	.013	.040	.183*	R3 = .071
F_4 = .248			---	.027	.170*	R4 = .074
B_2 = .275				---	.143*	R5 = .076

Note. $k = 5$, $df = 128$, $n = 18$. The means are Cross-Correlation I values involved in the nonsignificant conditions by electrodes (B × C) interaction from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C18.

*$p < .05$.

Table D79

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Cond. 3 = .666	Cond. 4 = .685	Cond. 1 = .809	Cond. 2 = .832	Shortest Significant Ranges
Cond. 3 = .666	---	.019	.143*	.166*	R2 = .128
Cond. 4 = .685		---	.124	.147*	R3 = .132
Cond. 1 = .809			---	.023	R4 = .135

Note. $k = 4$, $df = 48$, $n = 72$. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

*$p < .001$.

Table D80

Duncan's Multiple-Range Test among the Means for Electrodes (Factor C)

Means	B_2 = .645	B_1 = .669	F_4 = .833	F_3 = .844	Shortest Significant Ranges
B_2 = .645	---	.024	.188*	.199*	R2 = .075
B_1 = .669		---	.164*	.175*	R3 = .078
F_4 = .833			---	.011	R4 = .080

Note. $k = 4$, $df = 48$, $n = 72$. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

*$p < .001$.

Table D81

Duncan's Multiple-Range Test among the Means for Females (A = 1) across Electrodes (Factor C)

Means	B_2 = .585	B_1 = .637	F_4 = .806	F_3 = .849	Shortest Significant Ranges
B_2 = .585	---	.052	.221*	.264*	R2 = .061
B_1 = .637		---	.169*	.212*	R3 = .064
F_4 = .806			---	.043	R4 = .066

Note. *k* = 4, *df* = 48, *n* = 36. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

*p < .05.

Table D82

Duncan's Multiple-Range Test among the Means for Males (A = 2) across Electrodes (Factor C)

Means	B_1 = .701	B_2 = .706	F_3 = .840	F_4 = .859	Shortest Significant Ranges
B_1 = .701	---	.005	.139*	.158*	R2 = .061
B_2 = .706		---	.134*	.153*	R3 = .064
F_3 = .840			---	.019	R4 = .066

Note. $k = 4$, $df = 48$, $n = 36$. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

*$p < .05$.

Table D83

Duncan's Multiple-Range Test among the Means for Condition 1 (B = 1) across Electrodes (Factor C)

Means	B_2 = .712	B_1 = .716	F_4 = .901	F_3 = .905	Shortest Significant Ranges
B_2 = .712	---	.004	.189*	.193*	R2 = .056
B_1 = .716		---	.185*	.189*	R3 = .059
F_4 = .901			---	.004	R4 = .061

Note. *k* = 4, *df* = 144, *n* = 18. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

$^*p < .05$.

Table D84

Duncan's Multiple-Range Test among the Means for Condition 2 (B = 2) across Electrodes (Factor C)

Means	B_2 = .761	B_1 = .772	F_4 = .893	F_3 = .901	Shortest Significant Ranges
B_2 = .761	---	.011	.132*	.140*	R2 = .056
B_1 = .772		---	.121*	.129*	R3 = .059
F_4 = .893			---	.008	R4 = .061

Note. *k* = 4, *df* = 144, *n* = 18. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

$^{*}p < .05$.

Table D85

Duncan's Multiple-Range Test among the Means for Condition 3 (B = 3) across Electrodes (Factor C)

Means	B_2 = .538	B_1 = .558	F_4 = .780	F_3 = .787	Shortest Significant Ranges
B_2 = .538	---	.020	.242*	.249*	R2 = .056
B_1 = .558		---	.222*	.229*	R3 = .059
F_4 = .780			---	.007	R4 = .061

Note. k = 4, df = 144, n = 18. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

*p < .05.

Table D86

Duncan's Multiple-Range Test among the Means for Condition 4 (B = 4) across Electrodes (Factor C)

Means	B_2 = .571	B_1 = .631	F_4 = .757	F_3 = .784	Shortest Significant Ranges
B_2 = .571	---	.060*	.186*	.213*	R2 = .056
B_1 = .631		---	.126*	.153*	R3 = .059
F_4 = .757			---	.027	R4 = .061

Note. *k* = 4, *df* = 144, *n* = 18. The means are Cross-Correlation II values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C19.

*$p < .05$.

Table D87

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Cond. 3 = .825	Cond. 4 = .834	Cond. 2 = .902	Cond. 1 = .917	Shortest Significant Ranges
Cond. 3 = .825	---	.009	.077	.092*	R2 = .087
Cond. 4 = .834		---	.068	.083	R3 = .090
Cond. 2 = .902			---	.015	R4 = .092

Note. *k* = 4, *df* = 48, *n* = 36. The means are Cross-Correlation III values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C20.

$*p < .001$.

Table D88

Duncan's Multiple-Range Test among the Means for Conditions (Factor B)

Means	Cond. 3 = .848	Cond. 4 = .891	Cond. 1 = .904	Cond. 2 = .907	Shortest Significant Ranges
Cond. 3 = .848	---	.043*	.056*	.059*	R2 = .042
Cond. 4 = .891		---	.013	.016	R3 = .044
Cond. 1 = .904			---	.003	R4 = .046

<u>Note</u>. <u>k</u> = 4, <u>df</u> = 48, <u>n</u> = 36. The means are Cross-Correlation IV values from Experiment 3. The summary of the analysis of variance for this experiment is shown in Appendix C, Table C21.

*$p < .05$.

APPENDIX E

STIMULUS WORDS

STIMULUS WORDS

CARLOAD
WRIST
HOOK
ELEPHANT
LIMESTONE
MUSTACHE
BANANA
PIGMENT
TREASURY
EPOXY
HEMLOCK
GASOLINE
PIN
FAUCET
GORILLA
CANDLE
BANDAGE
DIAPER
SENSUOUS
HANDBAG
ENAMEL
LEOPARD
CAMPGROUND
INK
HARPOON
SAUCER
NICKEL
SNOW
RADIATION
BUCKET
MAGAZINE
FATIGUE
IMAGINATION
BOOR
POPULATION
JINX
SHOEHORN
FANTASTIC
GEOMETRY
KNOWLEDGE
PAPERS
PANCAKE
JOKER
FLASK
DEFENSE
NOZZLE
MEMORIZE
DIAGRAM
BANKNOTE
ITCH
ACCOUNT
ALUMINUM
LAGOON
EYEWITNESS
OUTLOOK
UNIVERSE
APPLE
HERMIT
BEGINNER
AUTOGRAPH

APPENDIX F

EYE MOVEMENT QUESTIONS

EYE MOVEMENT QUESTIONS

1. How many letters are there in the word MONTREAL?
2. What is 123 times 6?
3. Tell me an English word that starts with L and ends with C.
4. What is the largest city in the U.S.?
5. Imagine for a few seconds that you are skiing down a mountain.
6. How many letters are there in your last name?
7. If you mix blue paint with yellow what color do you get?
8. Recite a few lines from your favorite poem or song that you know.
9. Give me a foreign word that you know that starts with T and ends with S.
10. Imagine for a few seconds that you are riding a bicycle.

REFERENCE NOTES

REFERENCE NOTES

1. Molfese, D. L. *Evoked potential indices of lateralization and development for speech stimuli*. A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

2. Cooper, R., McCallum, W. C., & Papakostopoulos, D. *A bimodal slow potential theory of cerebral processing*. A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

3. Otto, D. A., Houck, K., Finger, H., & Hart, S. *Event-related slow potentials in aphasic, dyslexic, and normal children during pictorial and letter-matching*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

4. Andreasen, N. J. C., Peters, J. F., & Knott, J. R. *CNVs in hyperactive children: Effects of chemotherapy*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

5. Becker, W., Iwase, K., Jürgens, R., & Kornhuber, H. H. *Brain potentials preceding slow and rapid hand movements*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

6. Loveless, N. E. *Distribution of response to non-signal stimuli*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

7. Bostem, F. H., & Delaunoy, J. C. *Comparative topographical study of slow cerebral potentials seen during epileptic discharge and CNV*. A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

8. Tecce, J. J., & Cole, J. O. *Effects of amphetamine on CNV and behavior in man*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

9. Rebert, C. S., Berry, R., & Merlo, J. *DC potential consequences of induced muscle tension: Effects on contingent negative variation*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

10. Tueting, P., & Sutton, S. *Auditory evoked potential and lift/no lift reaction time in relation to uncertainty--preliminary results*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

11. Karrer, R., & Ivins, J. *Post-warning signal positivity in relation to development, RT performance, and warning signal compounding*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

12. Papakostopoulos, D., & Crow, H. J. *Electrocorticographic studies of the contingent negative variation and P300 in man*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

13. Donchin, E., Ritter, W., Tueting, P., Kutas, M., & Heffley, E. *The interaction of the P300 and the CNV*. A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

14. Rebert, C. S. *Slow potentials in RT foreperiod*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

15. Borda, R. P., Hablitz, J. J., & McSherry, J. W. *Analysis of slow potentials in primates*. A paper presented at the International Symposium on Evoked Potentials in Man, Brussels, April 1974. (Abstract)

16. Knott, J. R., & Peters, J. F. *Further studies on CNV, stress, and sex using discrimination paradigms*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

17. Peters, J. F., & Knott, J. R. *CNV and post-response negativity with stressful auditory feedback*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

18. Karrer, R., & Ivins, J. *Event-related slow potentials in mental retardates*. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

19. McCallum, W. C., Papakostopoulos, D., & Griffith, H. B. Distribution of CNV and other slow potential changes in human brainstem structures. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

20. Low, M. D. Event-related potentials and the EEG in patients with proven brain lesions. A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

21. Zappoli, R., Papini, M., Briani, S., Benvenuti, P., & Pasquinelli, A. CNV in patients with frontal-lobe lesions and mental disturbances. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

22. Timsit-Berthier, M., Delaunoy, J., & Rousseau, J. C. Some problems and tentative solutions to questions raised by slow potential changes in psychiatry. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

23. Abraham, P., McCallum, W. C., & Gourlay, J. The CNV and its relation to specific psychiatric syndromes. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

24. Dubrovsky, B., & Dongier, M. Evaluation of ERSP in selected groups of psychiatric patients. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

25. Weinberg, H., & Papakostopoulos, D. Pattern discrimination in the spatial distribution of the contingent negative variation. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

26. Syndulko, K., & Lindsley, D. B. Topography of human CNV and cortical slow potential shifts related to sensory and motor set. A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

27. Donchin, E., & Kutas, M. Preliminary observations on the effects of response parameters on pre-response potentials. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

28. Donchin, E., & Kutas, M. Motor potentials, force of response, and handedness. A paper presented at the International Symposium

on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

29. Donchin, E., Johnson, R., Hernong, R., & Kutas, M. *Covariation of the magnitude of the CNV and P300 as a function of the subject's task.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

30. McCallum, W. C. *Brain slow potential changes and motor response in a vigilance situation.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

31. Marsh, G. R., Poon, L. W., & Thompson, L. W. *Some relationships between CNV, P300, and task demands.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

32. Low, M. D., Wada, J. A., & Fox, M. *Electroencephalographic localization of conative aspects of language production in the human brain.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

33. Low, M. D., Wada, J. A., & Fox, M. *Hemispheric specialization for language production: Some electrophysiological evidence.* A paper presented at the International Symposium on Cerebral Evoked Potentials in Man, Brussels, April 1974. (Abstract)

34. Zimmermann, G., & Knott, J. R. *Stuttering and CNV.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

35. Grözinger, B., Kriebel, J., & Kornhuber, H. H. *EEG investigation of hemispheric asymmetries preceding speech. The R-wave.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

36. Weinberg, H., Michalewski, H. J., & Koopman, R. *The "form" of the CNV: The relative effect of information in the ready and imperative stimuli.* Manuscript submitted for publication, 1974.

37. Billinger, T. W., Peters, J. F., & Knott, J. R. *Contingent negative variation in a verbal learning paradigm.* A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

38. Peters, J. F., Knott, J. R., & Hamilton, C. E. Further thoughts on measurement of the CNV. A paper presented at the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, August 1973.

REFERENCES

REFERENCES

Abraham, P., & McCallum, W. C. The CNV and the spiral after-effect. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Alford, L. B. Cerebral Localization. New York: Nervous and Mental Disease Monographs, 1948.

Bakan, P. Hypnotizability, laterality of eye-movements and functional brain asymmetry. Perceptual and Motor Skills, 1969, 28, 927-932.

Bakan, P., & Svorad, D. Resting EEG alpha and asymmetry of reflective eye movements. Nature, 1969, 223, 975-976.

Bakker, D. J. Ear-asymmetry with monaural stimulation: Relations to lateral dominance and lateral awareness. Neuropsychologia, 1970, 8, 103-117.

Beaumanoir, A., Ballis, T., Nahory, A., & Genies, M. Alterations of the CNV and GSR under the effect of alcohol. Electroencephalography and Clinical Neurophysiology, 1974, 36, 85. (Society Proceedings)

Beaumont, J. G., & Dimond, S. J. Transfer between the cerebral hemispheres in human learning. Acta Psychologica, 1973, 37, 87-91.

Berlucchi, G., Brizzolara, D., Marzi, C. A., Rizzolatti, G., & Umiltà, C. Can lateral asymmetries in attention explain interfield differences in visual perception. Cortex, 1974, 10, 177-185.

Bevan, J. The human auditory evoked response and contingent negative variation in hyperbaric air. Electroencephalography and Clinical Neurophysiology, 1971, 30, 198-204.

Bisiach, E., & Faglioni, P. Recognition of random shapes by patients with unilateral lesions as a function of complexity, association value, and delay. Cortex, 1974, 10, 101-110.

Blackmore, C. B., & Falconer, M. A. Long-term effects of anterior temporal lobectomy on certain cognitive functions. Journal of Neurology Neurosurgery and Psychiatry, 1967, 30, 364-367.

Blowers, G., Ongley, C., & Shaw, J. C. The effect of reducing temporal expectancy on the contingent negative variation. *Electroencephalography and Clinical Neurophysiology*, 1973, *34*, 259-264.

Blumstein, S., & Cooper, W. E. Hemispheric processing of intonation contours. *Cortex*, 1974, *10*, 146-158.

Bogen, J. E. The other side of the brain II: An appositional mind. *Bulletin of the Los Angeles Neurological Societies*, 1964, *34*, 135-162.

Boll, T. J. Right and left cerebral hemisphere damage and tactile perception: Performance of the ipsilateral and contralateral sides of the body. *Neuropsychologia*, 1974, *12*, 235-238.

Borda, R. P. The effect of altered drive states on the contingent negative variation (CNV) in rhesus monkeys. *Electroencephalography and Clinical Neurophysiology*, 1970, *29*, 173-180.

Borda, R. P. The relationship of CNV to behavior in animals. A review. In W. C. McCallum and J. R. Knott (Eds.), *Event-Related Slow Potentials of the Brain: Their Relations to Behavior.* Amsterdam: Elsevier, 1973.

Brown, W., Marsh, J., & Smith, J. Symposium on the neurophysiology of speech. *Winter Conference on Brain Research* (BIS Report No. 30). Los Angeles: Brain Information Service, 1973.

Bryden, M. P. Tachistoscopic recognition, handedness, and cerebral dominance. *Neuropsychologia*, 1965, *3*, 1-8.

Buchsbaum, M., & Fedio, P. Visual information and evoked responses from the left and right hemispheres. *Electroencephalography and Clinical Neurophysiology*, 1969, *26*, 266-272.

Buchsbaum, M., & Fedio, P. Hemispheric differences in evoked potentials to verbal and nonverbal stimuli in the left and right visual fields. *Physiology and Behavior*, 1970, *5*, 207-210.

Burian, K., Gestring, G. F., Gloning, K., & Haider, M. Correlation of verbal comprehension and CNV in aphasia. *Electroencephalography and Clinical Neurophysiology*, 1971, *30*, 170. (Society Proceedings)

Butler, S. R., & Glass, A. Inter-hemispheric asymmetry of contingent negative variation during numeric operations. *Electroencephalography and Clinical Neurophysiology*, 1971, *30*, 366. (Society Proceedings).

Butler, S. R., & Glass, A. Asymmetries in the electroencephalogram associated with cerebral dominance. *Electroencephalography and Clinical Neurophysiology*, 1974, *36*, 481-491.

Carmon, A., & Bechtoldt, H. P. Dominance of the right cerebral hemisphere for stereopsis. Neuropsychologia, 1969, 7, 29-39.

Carmon, A., & Benton, A. L. Tactile perception of direction and number in patients with unilateral disease. Neurology, 1969, 19, 525-532.

Carmon, A., & Gombos, G. M. A physiological vascular correlate of hand preference: Possible implications with respect to hemispheric cerebral dominance. Neuropsychologia, 1970, 8, 119-128.

Carmon, A., & Nachshon, I. Ear asymmetry in perception of emotional non-verbal stimuli. Acta Psychologica, 1973, 37, 351-357.

Cernacek, J., & Podivinsky, F. Ontogenesis of handedness and somatosensory cortical response. Neuropsychologia, 1971, 9, 219-232.

Cohen, B. D., Noblin, C. D., & Silverman, A. J. Functional asymmetry of the human brain. Science, 1968, 162, 475-477.

Cohen, J. Very slow brain potentials relating to expectancy: The CNV. In E. Donchin and D. B. Lindsley (Eds.), Average Evoked Potentials (NASA SP191). Washington, D.C.: National Aeronautics and Space Administration, 1969.

Cohen, J. Maturation of the contingent negative variation. Electroencephalography and Clinical Neurophysiology, 1970, 28, 99. (Society Proceedings)

Cohen, J. The contingent negative variation and visual attention. Electroencephalography and Clinical Neurophysiology, 1971, 31, 300. (Society Proceedings)

Cohen, J. The CNV in children with special reference to learning disabilities. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973. (a)

Cohen, J. Developmental aspects of the CNV. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973. (b)

Cohen, R. Differential cerebral processing of noise and verbal stimuli. Science, 1971, 172, 599-601.

Cooper, R., Osselton, J. W., & Shaw, J. C. EEG Technology. London: Butterworths, 1969.

Corkin, S. Tactually-guided maze learning in man: Effects of unilateral cortical excisions and bilateral hippocampal lesions. Neuropsychologia, 1965, 3, 339-351.

Critchley, M. The Parietal Lobes. New York: Hafner, 1969.

Curry, F. K. W. A comparison of left-handed and right-handed subjects on verbal and non-verbal dichotic listening tasks. Cortex, 1967, 3, 343-352.

Curry, F. K. W., & Rutherford, D. R. Recognition and recall of dichotically presented verbal stimuli by right- and left-handed persons. Neuropsychologia, 1967, 5, 119-126.

Darwin, C. J. Ear differences in the recall of fricatives and vowels. Quarterly Journal of Experimental Psychology, 1971, 22, 46-62.

Davis, A. E., & Wada, J. A. Hemispheric asymmetry: Frequency analysis of visual and auditory evoked responses to non-verbal stimuli. Electroencephalography and Clinical Neurophysiology, 1974, 37, 1-9.

Davson, H. The Physiology of the Eye. New York: Academic Press, 1972.

Day, M. E. An eye movement phenomenon relating to attention, thought, and anxiety. Perceptual and Motor Skills, 1964, 19, 443-446.

Day, M. E. An eye movement indicator of individual differences in the physiological organization of attentional processes and anxiety. Journal of Psychology, 1967, 66, 51-62.

Dee, H. L., & Hannay, H. Asymmetry in perception: Attention versus other determinants. Acta Psychologica, 1973, 37, 241-247.

Delse, F. C., Marsh, G. R., & Thompson, L. W. CNV correlates of task difficulty and accuracy of pitch discrimination. Psychophysiology, 1972, 9, 53-62.

De Renzi, E., Faglioni, P., & Spinnler, H. The performance of patients with unilateral brain damage in face recognition tasks. Cortex, 1968, 4, 17-34.

De Renzi, E., & Scotti, G. The influence of spatial disorders in impairing tactual discrimination of shapes. Cortex, 1969, 5, 53-62.

Dimond, S. J. A reappraisal of the concept of cerebral dominance. Journal of Motor Behavior, 1971, 3, 57-61.

Dimond, S. J. The Double Brain. London: Churchill Livingstone, 1972.

Dimond, S. J., & Beaumont, J. G. Hemispheric function and vigilance. Quarterly Journal of Experimental Psychology, 1971, 23, 443-448. (a)

Dimond, S. J., & Beaumont, J. G. The use of two cerebral hemispheres to increase brain capacity. Nature, 1971, 232, 270-271. (b)

Dimond, S. J., & Beaumont, J. G. Hemispheric control of hand function in the human brain. Acta Psychologica, 1972, 36, 32-36. (a)

Dimond, S. J., & Beaumont, J. G. On the nature of interhemispheric effects of fatigue. Acta Psychologica, 1972, 36, 443-449. (b)

Dolce, D., & Sannita, W. A CNV-like negative shift in deep coma. Electroencephalography and Clinical Neurophysiology, 1973, 34, 647-650.

Donchin, E., Gerbrandt, L. K., Leifer, L., & Tucker, L. R. Contingent negative variations and motor responses. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Donchin, E., & Smith, D. The CNV and the "late positive wave"--two sides of the same coin. Electroencephalography and Clinical Neurophysiology, 1970, 28, 90-105. (a)

Donchin, E., & Smith, D. The contingent negative variation and the late positive wave of the averaged evoked potential. Electroencephalography and Clinical Neurophysiology, 1970, 29, 201-203. (b)

Duke, J. D. Lateral eye movement behavior. Journal of General Psychology, 1968, 78, 189-195.

Dunford, M., & Kimura, D. Right hemisphere specialization for depth perception reflected in visual field differences. Nature, 1971, 231, 394-395.

Eason, R. G., Groves, P., White, C. T., & Oden, D. Evoked cortical potentials: Relation to visual field and handedness. Science, 1967, 156, 1643-1646.

Eason, R. G., Oden, D., & White, C. T. Visually evoked potentials and reaction time in relation to site of stimulation. Electroencephalography and Clinical Neurophysiology, 1967, 22, 313-324.

Eason, R. G., & White, C. T. Averaged occipital responses to stimulation in the nasal and temporal halves of the retina. Psychonomic Science, 1967, 7, 309-310.

Edwards, A. L. Experimental Design in Psychological Research. New York: Holt, Rinehart, and Winston, 1968.

Ehrlickman, H., Weiner, S. L., & Baker, A. H. Effects of verbal and spatial questions on initial gaze shifts. Neuropsychologia, 1974, 12, 265-277.

Fedio, R., & Buchsbaum, M. Unilateral temporal lobectomy and changes in evoked responses during recognition of verbal and nonverbal material in the left and right visual fields. Neuropsychologia, 1971, 9, 261-271.

Fenelon, B. Expectancy waves and other complex cerebral events in dyslexic and normal subjects. Psychonomic Science, 1968, 13, 253-254.

Friedman, D., Hakerem, G., Sutton, S., & Fleiss, J. L. Effects of stimulus uncertainty on the pupillary dilation response and the vertex evoked potential. Electroencephalography and Clinical Neurophysiology, 1973, 34, 475-484.

Gaillard, A. W., & Näätänen, R. Slow potential changes and choice reaction time as a function of interstimulus interval. Acta Psychologica, 1973, 37, 173-186.

Galin, D., & Ornstein, R. Lateral specialization of cognitive mode: An EEG study. Psychophysiology, 1972, 9, 412-418.

Garcia-Austt, E., Bogacz, J., & Vanzulli, A. Effects of attention and inattention upon visual evoked response. Electroencephalography and Clinical Neurophysiology, 1964, 17, 136-143.

Gazzaniga, M. S. The Bisected Brain. New York: Appleton Century Crofts, 1970.

Gazzaniga, M. S., & Sperry, R. W. Language after section of the cerebral commissures. Brain, 1967, 90, 131-148.

Geschwind, N. The organization of language and the brain. Science, 1970, 170, 940-944.

Giannitrapani, D. Laterality preference, representation of functions and the EEG. Electroencephalography and Clinical Neurophysiology, 1972, 33, 247. (Society Proceedings)

Gott, P. S., Rossiter, V. S., Galbraith, G. C., & Saul, R. E. Hemispheric evoked potentials to verbal and spatial stimuli in human commissurotomy patients. Cerebral Dominance (BIS Report No. 34). Los Angeles: Brain Information Service, 1974.

Gullickson, G. R. CNV and behavioral attention to a glide-tone warning of interesting non-moving or kaleidoscopic visual or auditory patterns in 2- and 3-year-old children. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Gullickson, G. R., & Darrow, C. W. Contingent negative variation modified by respiratory phase. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Hablitz, J. J. Operant conditioning on slow potential changes from monkey cortex. Electroencephalography and Clinical Neurophysiology, 1973, 34, 399-408.

Harmony, T., Ricardo, J., Otero, G., Fernandez, G., Llorente, S., & Valdes, P. Symmetry of the visual evoked potential in normal subjects. Electroencephalography and Clinical Neurophysiology, 1973, 35, 237-240.

Hécaen, H., & Ajuriaguerra, J. Left-Handedness. New York: Grune and Stratton, 1964.

Hermelin, B., & O'Connor, N. Right and left handed reading of Braille. Nature, 1971, 231, 470.

Hess, E. Pupillometrics: A method of studying mental, emotional, and sensory processes. In N. S. Greenfield and R. A. Sternback (Eds.), Handbook of Psychophysiology. New York: Holt, Rinehart and Winston, 1972.

Hillyard, S. A. Relationships between the contingent negative variation (CNV) and reaction time. Physiology and Behavior, 1969, 4, 351-357.

Hillyard, S. A. The CNV and human behavior. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Hillyard, S. A., & Galambos, R. Eye movement artifact in the CNV. Electroencephalography and Clinical Neurophysiology, 1970, 28, 173-182.

Hillyard, S. A., Squires, K. C., Bauer, J. W., & Lindsay, P. H. Evoked potential correlates of auditory signal detection. Science, 1971, 172, 1357-1360.

Hines, D., & Satz, P. Superiority of right visual half-fields in right-handers for recall of digits presented at varying rates. Neuropsychologia, 1971, 9, 21-25.

Hines, D., Satz, P., Schell, B., & Schmidline, S. Differential recall of digits in the left and right visual half-fields under free recall and fixed order of recall. Neuropsychologia, 1969, 7, 13-22.

Hoovey, Z. B., Heinemann, U., & Creutzfeldt, O. D. Interhemispheric "synchrony" of alpha waves. Electroencephalography and Clinical Neurophysiology, 1972, 31, 337-347.

Ingvar, D. H., & Schwartz, M. S. Blood flow patterns induced in the dominant hemisphere by speech and reading. Brain, 1974, 97, 273-288.

Jaffe, R., & Lusins, J. Clinical correlates of alpha amplitude asymmetry. Electroencephalography and Clinical Neurophysiology, 1971, 31, 418. (Society Proceedings)

Järvilehto, T., & Frühstorfer, H. Is the sound-evoked DC potentials a contingent negative variation? In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Jasper, H. H. Report of the committee on methods of clinical examination in electroencephalography. Electroencephalography and Clinical Neurophysiology, 1958, 10, 370-375.

John, E. R., Herrington, R. N., & Sutton, S. Effects of visual form on the evoked response. Science, 1967, 155, 1439-1442.

Julesz, B. Binocular depth perception without familiarity cues. Science, 1956, 145, 356-362.

Karrer, R., Kohn, H., & Ivins, J. Effects of varying the stimulus and response contingencies on the CNV. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Kimura, D. Right temporal damage. Archives of Neurology, 1963, 8, 264-271.

Kimura, D. Left-right differences in the perception of melodies. Quarterly Journal of Experimental Psychology, 1964, 14, 355-358.

Kimura, D. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 1966, 4, 275-285.

Kimura, D. Functional asymmetry of the brain in dichotic listening. Cortex, 1967, 3, 163-178.

Kimura, D. Spatial localization in left and right visual fields. Canadian Journal of Psychology, 1969, 23, 445-458.

Kimura, D. Manual activity during speaking I. Right-handers. Neuropsychologia, 1973, 11, 45-50.

Kinsbourne, M. The cerebral basis of lateral asymmetries in attention. Acta Psychologica, 1970, 33, 193-201.

Kinsbourne, M. Direction of gaze and distribution of cerebral thought processes. Neuropsychologia, 1974, 12, 279-281.

Kohn, H. M., Holy, P., Gullickson, G. R., & Griffith, J. Contingent negative variation as related to visual detection thresholds. Electroencephalography and Clinical Neurophysiology, 1971, 31, 300. (Society Proceedings)

Knott, J. R., Cohen, S. I., Van Veen, W., Miller, L. H., & Peters, J. F. Cognitive style and CNV. Electroencephalography and Clinical Neurophysiology, 1972, 32, 589. (Society Proceedings)

Knott, J. R., & Peters, J. F. Sex, stress and interstimulus interval. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Knox, C., & Kimura, D. Cerebral processing of nonverbal sounds in boys and girls. Neuropsychologia, 1970, 8, 227-237.

Kornhuber, H. H., und Deeke, L. Hirnpotentialänderungen bei Willkürbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiale. Pflügers Archiv fur die gesamte Physiologie des Menchen und der Tiere, 1965, 284, 1-17.

Lacey, J. I., & Lacey, B. C. Experimental association and dissociation of phasic bradycardia and vertex-negative waves: A psychophysiological study of attention and response-intention. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Lansing, R. W., & Barlow, J. S. Rhythmic after-activity to flashes in relation to the background alpha which precedes and follows the photic stimuli. Electroencephalography and Clinical Neurophysiology, 1972, 32, 149-160.

Lansing, R. W., & Thomas, H. The laterality of photic driving in normal adults. Electroencephalography and Clinical Neurophysiology, 1964, 16, 290-294.

Leford, G., Laffant, F., Sauvage, D., & Jusseaume, P. Etude Chez L'Homme D'Activities Evoquees Lentes Succedant Au Mouvement Volontaire et Au Langage Articule. Electroencephalography and Clinical Neurophysiology, 1973, 35, 113-124.

Lehmann, D., & Fender, D. H. Monocularly evoked electroencephalogram potentials: Influence of target structure presented to the other eye. Nature, 1967, 215, 204-205.

Lehmann, D., & Fender, D. H. Averaged visual evoked potentials in humans: Mechanism of dichoptic interaction studied in a subject with a split chiasma. Electroencephalography and Clinical Neurophysiology, 1969, 27, 142-145.

Lehmann, D., Kavanagh, N., & Fender, D. H. Field studies of averaged visually evoked EEG potentials in a patient with a split chiasm. Electroencephalography and Clinical Neurophysiology, 1969, 26, 193-199.

Lehtonen, J. B., & Lehtinen, I. Alpha rhythm and uniform visual field in man. Electroencephalography and Clinical Neurophysiology, 1972, 32, 139-147.

Leissner, P., Lindholm, L. E., & Petersen, I. Alpha amplitude dependence on skull thickness as measured by ultrasonic technique. Electroencephalography and Clinical Neurophysiology, 1970, 29, 392-399.

Levy, C. M., & Bowers, D. Hemispheric asymmetry of reaction time in a dichotic discrimination task. Cortex, 1974, 10, 18-25.

Liske, E., Hughes, H. M., & Stowe, D. E. Cross-correlation of human alpha activity: Normative data. Electroencephalography and Clinical Neurophysiology, 1967, 22, 429-436.

Lombroso, C. T. The CNV during tasks requiring choice. In C. R. Evans and T. B. Mulholland (Eds.), Attention in Neurophysiology. London: Butterworths, 1969.

Loveless, N. E. The contingent negative variation related to preparatory set in a reaction time situation with variable foreperiod. Electroencephalography and Clinical Neurophysiology, 1973, 35, 369-374.

Loveless, N. E., & Sanford, A. J. The CNV baseline: Considerations of internal consistency of data. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Low, M. D. In the discussion of J. Cohen's Very slow brain potentials relating to expectancy: The CNV. In E. Donchin and D. B. Lindsley (Eds.), Average Evoked Potentials (NASA SP191). Washington, D.C.: National Aeronautics and Space Administration, 1969.

Low, M. D., Borda, R. P., Frost, J. D., & Kellaway, P. Surface-negative, slow-potential shift associated with conditioning in man. Neurology, 1966, 16, 771-782.

Low, M. D., Borda, R. P., & Kellaway, P. "Contingent negative variation" in rhesus monkeys: An EEG sign of a specific mental process. *Perceptual Motor Skills*, 1966, *22*, 443-446.

Low, M. D., Frost, J. D., Maulsby, R. L., & McSherry, W. Electroencephalographic correlates of preparation set. *Electroencephalography and Clinical Neurophysiology*, 1968, *24*, 286. (Society Proceedings)

Low, M. D., & McSherry, A. B. Further observations of psychological factors involved in CNV genesis. *Electroencephalography and Clinical Neurophysiology*, 1968, *25*, 203-207.

Low, M. D., & Stoilen, L. CNV and EEG in children: Maturational characteristics and findings in the MCD syndrome. In W. C. McCallum and J. R. Knott (Eds.), *Event-Related Slow Potentials of the Brain: Their Relations to Behavior*. Amsterdam: Elsevier, 1973.

MacNeilage, P. F. EEG amplitude changes during different cognitive processes involving similar stimuli and responses. *Psychophysiology*, 1966, *2*, 280-286.

Marsh, G. R., & Thompson, L. W. Effects of verbal and non-verbal psychological set on hemispheric asymmetries in the CNV. In W. C. McCallum and J. R. Knott (Eds.), *Event-Related Slow Potentials of the Brain: Their Relations to Behavior*. Amsterdam: Elsevier, 1973.

Martinius, J. W., & Hoovey, Z. B. Bilateral synchrony of occipital alpha waves, oculomotor activity and "attention" in children. *Electroencephalography and Clinical Neurophysiology*, 1972, *32*, 349-356.

Matsumiya, Y., Tagliasco, V., Lombroso, C. T., & Goodglass, H. Auditory evoked response: Meaningfulness of stimuli and interhemispheric asymmetry. *Science*, 1972, *175*, 790-792.

McAdam, D. W. Increases in CNS excitability during negative cortical slow potentials in man. *Electroencephalography and Clinical Neurophysiology*, 1969, *26*, 216-219.

McAdam, D. W., Knott, J. R., & Rebert, C. S. Cortical slow potential changes in man related to interstimulus interval and to pre-trial prediction of interstimulus interval. *Psychophysiology*, 1969, *5*, 349-358.

McAdam, D. W., & Rubin, E. H. Readiness potential, vertex positive wave, contingent negative variation, and accuracy of perception. *Electroencephalography and Clinical Neurophysiology*, 1971, *30*, 511-517.

McAdam, D. W., & Seales, D. M. Bereitschaftspotential enhancement with increased level of motivation. Electroencephalography and Clinical Neurophysiology, 1969, 27, 73-75.

McAdam, D. W., & Whitaker, H. A. Language production: Electroencephalographic localization in the normal brain. Science, 1971, 172, 499-502. (a)

McAdam, D. W., & Whitaker, H. A. A reply to Morrel and Huntington. Science, 1971, 174, 1360-1361. (b)

McCallum, W. C. The contingent negative variation as a cortical sign of attention in man. In C. R. Evans and T. B. Mulholland (Eds.), Attention in Neurophysiology. London: Butterworths, 1969.

McCallum, W. C., & Cummins, B. The effects of brain lesions on the contingent negative variation in neurosurgical patients. Electroencephalography and Clinical Neurophysiology, 1973, 35, 449-456.

McCallum, W. C., & Papakostopoulos, D. The effects of sustained motor activity on the contingent negative variation. Electroencephalography and Clinical Neurophysiology, 1972, 33, 446. (Society Proceedings)

McCallum, W. C., & Papakostopoulos, D. The CNV and reaction time in situations of increasing complexity. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

McCallum, W. C., & Walter, W. G. The effects of attention and distraction on the contingent negative variation in normal and neurotic subjects. Electroencephalography and Clinical Neurophysiology, 1968, 25, 319-329.

McCallum, W. C., Walter, W. G., Winter, A., Scotton, L., & Cummins, B. The contingent negative variation in cases of known brain lesions. Electroencephalography and Clinical Neurophysiology, 1970, 28, 210. (Society Proceedings)

McKee, G., Humphrey, B., & McAdam, D. W. Scaled lateralization of alpha activity during linguistic and musical tasks. Psychophysiology, 1973, 10, 441-443.

McKeever, W. F., & Gill, K. M. Visual half-field differences in masking effects for sequential letter stimuli in the right and left handed. Neuropsychologia, 1972, 10, 111-117.

McKeever, W. F., & Huling, M. D. Lateral dominance in tachistoscopic word recognition performances obtained with simultaneous bilateral input. Neuropsychologia, 1971, 9, 15-20. (a)

McKeever, W. F., & Huling, M. D. Bilateral tachistoscopic word recognition as a function of hemisphere stimulated and interhemispheric transfer time. Neuropsychologia, 1971, 9, 281-288. (b)

McKinney, J. P. Handedness, eyedness and stability of the left and right visual fields. Neuropsychologia, 1967, 5, 339-344.

Miller, L. H., Van Veen, W., Sandman, C. A., & Knott, J. R. Intermodal and intramodal distraction and CNV. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Milner, B. Laterality effects in audition. In V. B. Mountcastle (Ed.), Interhemispheric Relations and Cerebral Dominance. Baltimore: John Hopkins, 1962.

Milner, B. Visually-guided maze learning in man: Effects of bilateral, frontal, and unilateral cerebral lesions. Neuropsychologia, 1965, 3, 317-338.

Milner, B. Visual recognition and recall after right temporal-lobe excision in man. Neuropsychologia, 1968, 6, 191-209.

Milner, B. Interhemispheric differences in the localization of psychological processes. British Medical Bulletin, 1971, 27, 272-277.

Milner, B., Branch, C., & Rasmussen, T. Observations on cerebral dominance. In A. V. S. de Reuck and M. O'Conner (Eds.), Disorders of Language. New York: CIBA Foundation Symposium, 1964.

Milner, B., & Taylor, L. Right-hemisphere superiority in tactile pattern-recognition after cerebral commissurotomy: Evidence for nonverbal memory. Neuropsychologia, 1972, 10, 1-15.

Milner, B., Taylor, L., & Sperry, R. W. Lateralized suppression of dichotically presented digits after commissural section in man. Science, 1968, 161, 184-186.

Milner, B., & Teuber, H. L. Alternation of perception and memory in man: Reflections on methods. In L. Weiskrantz (Ed.), Analysis of Behavioral Change. New York: Harper and Row, 1968.

Morgan, A. H., Macdonald, H., & Hilgard, E. R. EEG alpha: Lateral asymmetry related to task and hypnotizability. Psychophysiology, 1974, 11, 275-282.

Morgan, A. H., McDonald, R. J., & Macdonald, H. Differences in bilateral activity as a function of experimental task, with a note on lateral eye movements and hypnotizability. Neuropsychologia, 1971, 9, 459-469.

Morrel, L. K., & Huntington, D. A. Electrocortical localization of language production.. Science, 1971, 174, 1359-1360.

Morrel, L. K., & Salamy, J. G. Hemispheric asymmetry of electrocortical responses to speech stimuli. Science, 1971, 174, 164-166.

Murphy, E. H., & Venables, P. H. Ear asymmetry in the threshold of fusion of two clicks: A signal detection analysis. Quarterly Journal of Experimental Psychology, 1970, 22, 288-300.

Naitoh, P., & Johnson, L. C. Effects of total sleep stage deprivation on the CNV. Electroencephalography and Clinical Neurophysiology, 1972, 32, 99. (Society Proceedings)

Nebes, R. D. Dominance of the minor hemisphere in commissurotomized man on a test of figural unification. Brain, 1972, 95, 633-638.

Nebes, R. D. Perception of spatial relationships by the right and left hemispheres in commissurotomized man. Neuropsychologia, 1973, 11, 285-289.

Nebes, R. D. Hemispheric specialization in commissurotomized man. Psychological Bulletin, 1974, 81, 1-14.

Obrador, S. Nervous integration after hemispherectomy in man. In G. Schaltenbrand and C. N. Woolsey (Eds.), Cerebral Localization and Organization. Madison: University of Wisconsin Press, 1964.

Orbach, J. Differential recognition of Hebrew and English words in right and left visual fields as a function of cerebral dominance and reading habits. Neuropsychologia, 1967, 5, 127-134.

Otto, D. A., & Leifer, L. J. The effect of modifying response and performance feedback parameters on the CNV in humans. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Overton, W., & Wiener, M. Visual field position and word-recognition threshold. Journal of Experimental Psychology, 1966, 71, 249-253.

Papakostopoulos, D. CNV and autonomic function. A review. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Papakostopoulos, D., & McCallum, W. C. The CNV and autonomic change in situations of increasing complexity. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Papakostopoulos, D., Winter, A., & Newton, P. New techniques for the control of eye potential artefacts in multichannel CNV recordings. *Electroencephalography and Clinical Neurophysiology*, 1973, *34*, 651-653.

Papini, M., & Zappoli, R. The "expectancy wave" (CNV) in normal children. *Electroencephalography and Clinical Neurophysiology*, 1973, *35*, 438. (Society Proceedings)

Paul, D. D., & Sutton, S. Evoked potential correlates of response criterion in auditory signal detection. *Science*, 1972, *177*, 362-364.

Penfield, W., & Rasmussen, T. *The Cerebral Cortex of Man*. New York: Macmillan, 1950.

Peters, J. F., Knott, J. R., Miller, L. H., Van Veen, W., & Cohen, S. Response variables and magnitude of the contingent negative variation. *Electroencephalography and Clinical Neurophysiology*, 1970, *29*, 608-611.

Pfefferbaum, A., & Buchsbaum, M. Handedness and cortical hemisphere effects in sine wave stimulated evoked responses. *Neuropsychologia*, 1971, *9*, 237-240.

Picton, T. W., & Low, M. D. The CNV and semantic content of stimuli in the experimental paradigm: Effects of feedback. *Electroencephalography and Clinical Neurophysiology*, 1971, *31*, 451-456.

Prevec, T. S., Lokar, J., & Cernelc-Dularjeva, S. Use of CNV in audiometry. *Electroencephalography and Clinical Neurophysiology*, 1973, *35*, 100-101. (Society Proceedings)

Rebert, C. S. Slow potential correlates of anticipation in subcortex of the monkey brain. *Electroencephalography and Clinical Neurophysiology*, 1971, *31*, 299. (Society Proceedings)

Rebert, C. S. Cortical and subcortical slow potentials in the monkey's brain during a preparatory interval. *Electroencephalography and Clinical Neurophysiology*, 1972, *33*, 389-402.

Rebert, C. S. Elements of a general cerebral system related to CNV genesis. In W. C. McCallum and J. R. Knott (Eds.), *Event-Related Slow Potentials of the Brain: Their Relations to Behavior*. Amsterdam: Elsevier, 1973.

Rebert, C. S., & Knott, J. R. The vertex non-specific evoked potential and latency of the contingent negative variation. *Electroencephalography and Clinical Neurophysiology*, 1970, *28*, 561-565.

Rebert, C. S., McAdam, D. W., Knott, J. R., & Irwin, D. A. Slow potential change in the human brain related to level of motivation. *Journal of Comparative and Physiological Psychology*, 1967, *63*, 20-23.

Rebert, C. S., & Tecce, J. J. A summary of CNV and reaction time. In W. C. McCallum and J. R. Knott (Eds.), *Event-Related Slow Potentials of the Brain: Their Relations to Behavior*. Amsterdam: Elsevier, 1973.

Ritter, W., & Vaughan, H. G. Averaged evoked responses in vigilance and discrimination: A reassessment. *Science*, 1969, *164*, 326-328.

Rizzolatti, G., Umiltà, C., & Berlucchi, G. Opposite superiorities of of the right and left cerebral hemispheres in discriminative reaction time to physiognomical and alphabetical material. *Brain*, 1971, *94*, 431-442.

Roemer, R., & Thompson, R. Symposium on the Neurophysiology of speech. *Winter Conference on Brain Research* (BIS Report No. 30). Los Angeles: Brain Information Service, 1973.

Rubin, E. H., & McAdam, D. W. Slow potential concomitants of the retrieval process. *Electroencephalography and Clinical Neurophysiology*, 1972, *32*, 84-86.

Sampson, H. Recall of digits projected to temporal and nasal hemiretinas. *Quarterly Journal of Experimental Psychology*, 1969, *21*, 39-42.

Satterfield, J. H. Evoked response enhancement and attention in man. A study of responses to auditory and shock stimuli. *Electroencephalography and Clinical Neurophysiology*, 1965, *19*, 470-475.

Schafer, E. W. Cortical activity preceding speech: Semantic specificity. *Nature*, 1967, *216*, 1338-1339.

Schmit, V., & Davis, R. The role of hemispheric specialization in the analysis of Stroop stimuli. *Acta Psychologica*, 1974, *38*, 149-158.

Semmes, J. Hemispheric specialization: A possible clue to mechanism. *Neuropsychologia*, 1968, *6*, 11-26.

Shai, A., Goodglass, H., & Barton, M. Recognition of tachistoscopically presented verbal and non-verbal material after unilateral cerebral damage. *Neuropsychologia*, 1972, *10*, 185-191.

Shankweiler, D. Effects of temporal-lobe damage on perception of dichotically presented melodies. *Journal of Comparative and Physiological Psychology*, 1966, *62*, 115-119.

Shelburne, S. A. Visual evoked responses to word and nonsense syllable stimuli. *Electroencephalography and Clinical Neurophysiology*, 1972, *32*, 17-25.

Shelburne, S. A. Visual evoked responses to language in normal children. *Electroencephalography and Clinical Neurophysiology*, 1973, *34*, 135-143.

Skinner, J. E. Abolition of a conditioned, surface-negative, cortical potential during cryogenic blockade of the non-specific thalamo-cortical system. *Electroencephalography and Clinical Neurophysiology*, 1971, *31*, 197-209.

Sparks, R., & Geschwind, N. Dichotic listening in man after section of the neocortical commissures. *Cortex*, 1968, *4*, 3-16.

Sperry, R. W. Lateral specialization of cerebral function in the surgically separated hemispheres. In F. J. McGuigan and R. A. Schoonover (Eds.), *The Psychophysiology of Thinking*. New York: Academic Press, 1973.

Spong, P., Haider, M., & Lindsley, D. B. Selective attentiveness and cortical evoked responses to visual and auditory stimuli. *Science*, 1965, *148*, 395-397.

Sutton, S., Tueting, P., & Zubin, J. Information delivery and the sensory evoked potential. *Science*, 1967, *155*, 1436-1439.

Tecce, J. J. Contingent negative variation (CNV) and psychological processes in man. *Psychological Bulletin*, 1972, *77*, 73-108.

Tecce, J. J., & Hamilton, B. T. CNV reduction by sustained cognitive distraction. In W. C. McCallum and J. R. Knott (Eds.), *Event-Related Slow Potentials of the Brain: Their Relations to Behavior*. Amsterdam: Elsevier, 1973.

Timsit-Berthier, M., Delaunoy, J., Koninckx, N., & Rousseau, J. C. Slow potential changes in psychiatry. I. Contingent negative variation. *Electroencephalography and Clinical Neurophysiology*, 1973, *35*, 355-361.

Timsit-Berthier, M., Delaunoy, J., & Rousseau, J. C. Slow potential changes in psychiatry. II. Motor potential. *Electroencephalography and Clinical Neurophysiology*, 1973, *35*, 363-367.

Timsit-Berthier, M., Koninckx, N., Dargent, J., Fontaine, O., & Dongier, M. Variations Contingentes Négatives en Psychiatrie. *Electroencephalography and Clinical Neurophysiology*, 1970, *28*, 41-47.

Umiltà, C., Frost, N., & Hyman, R. Interhemispheric effects on choice reaction times to one-, two-, and three-letter displays. *Journal of Experimental Psychology*, 1972, *93*, 198-204.

Umiltà, C., Rizzolatti, G., Marzi, C. A., Zamboni, G., Franzini, C., Camarda, R., & Berlucchi, G. Hemispheric differences in the discrimination of line orientation. *Neuropsychologia*, 1974, *12*, 165-174.

Vaughan, H. G., Costa, L. D., & Ritter, W. Topography of the human motor potential. *Electroencephalography and Clinical Neurophysiology*, 1968, *25*, 1-10.

Velasco, M., & Velasco, F. Correlation between the psychological significance of stimuli and the amplitude of the cortical somatic evoked potential in man. *Electroencephalography and Clinical Neurophysiology*, 1972, *33*, 239. (Society Proceedings)

Volavka, J., Feldstein, S., Abrams, R., Dornbush, R., & Fink, M. EEG and clinical findings after bilateral and unilateral electroconvulsive therapy. *Electroencephalography and Clinical Neurophysiology*, 1972, *32*, 631-639.

Walter, W. G. Slow potential changes in the human brain associated with expectancy, decision and intention. In W. Cobb and C. Morocutti (Eds.), *The Evoked Potentials*. Amsterdam: Elsevier, 1967.

Walter, W. G. Can "attention" be defined in physiological terms? In C. R. Evans and T. B. Mulholland (Eds.), *Attention in Neurophysiology*. London: Butterworths, 1969.

Walter, W. G., Cooper, R., Aldridge, V. J., McCallum, W. C., & Winter, A. L. Contingent negative variation: An electric sign of sensorimotor association and expectancy in the human brain. *Nature*, 1964, *203*, 380-384.

Walter, W. C., Cooper, R., Crow, H. J., McCallum, W. ~~C.~~, Warren, W. J., Aldridge, V. J., Van Leeuwen, W., & Kamp, A. Contingent negative variation and evoked responses recorded by radio-telemetry in free-ranging subjects. *Electroencephalography and Clinical Neurophysiology*, 1967, *23*, 197-206.

Warrington, E. K., & Rabin, P. Perceptual matching in patients with cerebral lesions. *Neuropsychologia*, 1970, *8*, 475-487.

Waszak, M., & Obrist, W. D. Relation of slow potential changes to response speed and motivation in man. *Electroencephalography and Clinical Neurophysiology*, 1969, *27*, 113-120.

Weinberg, H. The contingent negative variation: Its relation to feedback and expectant attention. In W. C. McCallum and J. R. Knott (Eds.), Event-Related Slow Potentials of the Brain: Their Relations to Behavior. Amsterdam: Elsevier, 1973.

Weinberg, H., Walter, W. G., Cooper, R., & Aldridge, V. J. Emitted cerebral events. Electroencephalography and Clinical Neurophysiology, 1974, 36, 449-456.

Westmoreland, B. F., & Klass, D. W. Asymmetrical attenuation of alpha activity with arithmetical attention. Electroencephalography and Clinical Neurophysiology, 1971, 31, 634. (Society Proceedings)

Wilke, J. T., & Lansing, R. W. Variations in the motor potential with force exerted during voluntary movements in man. Electroencephalography and Clinical Neurophysiology, 1973, 35, 259-265.

Wilkinson, R. T., & Spence, M. T. Determinants of the post-stimulus resolution of the contingent negative variation (CNV). Electroencephalography and Clinical Neurophysiology, 1973, 35, 503-509

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

Witelson, S. F. Hemispheric specialization for linguistic and non-linguistic tactual perception. Cortex, 1974, 10, 3-17.

Wood, C. C., Goff, W. R., & Day, M. Auditory evoked potentials during speech perception. Science, 1971, 173, 1248-1251.

Wyke, M., & Ettlinger, G. Efficiency of recognition in left and right visual fields. Archives of Neurology, 1961, 5, 659-665.

Zangwill, O. L. Cerebral Dominance and Its Relation to Psychological Function. London: Oliver and Boyd, 1960.

Zappoli, R., Papini, M., Cabras, P., Benvenuti, P., & Binazzi, A. CNV and pulse wave patterns. Electroencephalography and Clinical Neurophysiology, 1973, 35, 399-400. (Society Proceedings)

Zurif, E. B., & Ramier, A. M. Some effects of unilateral brain damage on the perception of dichotically presented phoneme sequences and digits. Neuropsychologia, 1972, 10, 103-110.