END
DATE
FILMED
2. -81
DTIC

AD A094537

LEVEL

DTIC
SELECT
FEB 4 1981

C

Brain Responses and Information Processing

Psychophysiology Laboratory
Department of Psychology
Baruch College
The City University of New York

81 2 2 204

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
AFOSR-TR-81-0078	AD-A094537	

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
BRAIN RESPONSES AND INFORMATION PROCESSING I: HEMISPHERIC ASYMMETRIES IN EVENT RELATED POTENTIALS DURING SIGNAL DETECTION	Interim Oct. 1, 1979 - Sept.30,1980
	6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
John L. Andreassi Charles S. Rebert Ferol F. Larsen	F49620-80-C-0013

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Baruch College of the City University of New York School of Liberal Arts & Sciences, New York, N.Y. 10010	61102F 2313A4

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Air Force Office of Scientific Research (NL) Bolling Air Force Base Washington, D.C.	Nov. 30, 1980
	13. NUMBER OF PAGES
	58

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

.Event Related Potentials
.Visual Evoked Potentials
.Signal Detection
.P300 Response

.Reaction Time
.Information Processing
.Hemispheric Latency Asymmetries

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Event-Related Potentials (ERPs) were recorded from over the two cerebral hemispheres (occipital and parietal areas) during a 78 minute vigilance task. Twelve right-handed male subjects served in two experimental sessions. These subjects focussed on a central fixation point and responded to signals presented at unpredictable times in one of three locations: 2.5 deg. to right of central fixation, central, and 2.5 deg. to the left of center. Subjects decided whether to press a response key with either the left or right hand with each presentation. Signals were letter Ts oriented either right-side up or upside down. Six

responded to T-up with right hands and six did the opposite. The ERPs were recorded from two scalp areas over left and right occipital cortex, and two sites above left and right parietal areas. Vertical and horizontal eye movements were also recorded.

Two major ERP components emerged: a negative peak occurring at about 180 msec. after the stimulus, and a positive component appearing at about 320 msec. ERP latency asymmetries occurred at all recording sites as a function of visual field of stimulation. That is, for the N180 component stimuli presented in the left visual field (LVF) resulted in shorter latency ERPs at the contralateral (right) hemisphere than at the ipsilateral (left) hemisphere. A contralateral advantage was also observed for stimuli presented in the RVF. Central presentations produced similar N 180 latencies at both hemispheres. The N 180 component was significantly larger at occipital locations, while the P 320 was larger at parietal than occipital areas. The N 180 component represents the cortical response to visual stimulation, while the P 320 component appears to be associated with discriminating the T-up or down and with decisions to respond with either the left or right hand.

There was no main effect of visual field on reaction time (RT) suggesting equal efficiency of left and right hemispheres in responding to signals. An error analysis also indicated equal accuracy for the two hemispheres in processing signals presented in either the RVF or LVF. Both RTs and N 180 latencies were shortest with CVF stimulation. RT did not seem to be as reliable an indicator of interhemispheric transfer time (IHTT) as differences in N 180 latencies recorded at the two hemispheres.

BRAIN RESPONSES AND INFORMATION PROCESSING I: HEMISPHERIC ASYMMETRIES

IN EVENT RELATED POTENTIALS DURING SIGNAL DETECTION

Prepared by:

John L. Andreassi

Charles S. Rebert

and

Ferol F. Larsen

412.1-9

Brain Responses and Information Processing I: Hemispheric Asymmetries in
Event Related Potentials During Signal Detection.

Prepared by: John L. Andreassi[1]

                 Psychophysiology Laboratory, Baruch College
                 City University of New York

                 Charles S. Rebert
                         and
                 Ferol F. Larsen

                 Neurosciences Department, SRI International,
                 Menlo Park California

Abstract

Event - Related Potentials (ERPs) were recorded from over the two
cerebral hemispheres (occipital and parietal areas) during a 78 minute
vigilance task. Twelve right-handed male subjects served in two experimental
sessions. These subjects focussed on a central fixation point and responded
to signals presented at unpredictable times in one of three locations: 2.5
deg. to right of central fixation, central, and 2.5 deg. to the left of
center. Subjects decided whether to press a response key with either the left
or right hand with each presentation. Signals were letter Ts oriented either
right-side up or upside down. Six responded to T-up with right hands and six
did the opposite. The ERPs were recorded from two scalp areas over left and
right occipital cortex, and two sites above left and right parietal areas.
Vertical and horizontal eye movements were also recorded.

Two major ERP components emerged: a negative peak occurring at about 180 msec after the stimulus, and a positive component appearing at about 320 msec. ERP latency asymmetries occurred at all recording sites as a function of visual field of stimulation. That is, for the N180 component stimuli presented in the left visual field (LVF) resulted in shorter latency ERPs at the contralateral (right) hemisphere than at the ipsilateral (left) hemisphere. A contralateral advantage was also observed for stimuli presented in the RVF. Central presentations produced similar N 180 latencies at both hemispheres. The N 180 component was significantly larger at occipital locations, while the P 320 was larger at parietal than occiptal areas. The N 180 component represents the cortical response to visual stimulation, while the P 320 component appears to be associated with discriminating the T-up or down and with decisions to respond with either the left or right hand.

There was no main effect of visual field on reaction time (RT) suggesting equal efficiency of left and right hemispheres in responding to signals. An error analysis also indicated equal accuracy for the two hemispheres in processing signals presented in either the RVF or LVF. Both RTs and N 180 Latencies were shortest with CVF stimulation. RT did not seem to be as reliable an indicator of interhemispheric transfer time (IHTT) as differences in N 180 latencies recorded at the two hemispheres.

ii

INTRODUCTION

It will be the purpose of this research to examine the nature of event related brain potentials (ERPs) in the detection and processing of infrequently occurring but critical signals. Davies and Parasuraman (1977) point out that there have been relatively few investigations of ERPs as related to vigilance performance. In an early study, Haider et al. (1964) measured visual ERPs to signal and non-signal stimuli during a prolonged viligance task. They noted that lower amplitude ERPs were associated with lapses in attention, i.e., failure to detect signals. Analysis of a prominent negative component of the ERP, which occurred at about 160 msec after stimulus presentation, indicated that the amplitude of this component to non-signal stimuli decreased from 12uV to 10uV over the period of the vigil (80 to 100 minutes). In addition, the latency of this component increased from a mean of 155 to 165 msec over this same period. Thus, this study provided some evidence for the relationship between vigilance decrement and visual ERP waveform.

Ritter and Vaughan (1969) investigated ERPs to both auditory and visual stimuli in a detection task. These investigators reported a late positive component in the auditory and visual ERPs which occurred to detected signals, but not to non-signals or missed signals. This late component occurred between 300 and 350 msec after the stimulus, and has subsequently been referred to as P300 by a number of investigators (see Beck, 1975).

A strategy that will be used in the present study involves the presentation of the infrequent signals in such a manner as to compare the performance of the left and right hemispheres in the vigilance task. That is,

if a person maintains a central fixation point then stimuli presented in the right visual field (RVF) will be projected to the left hemisphere of the brain and signals in the left visual field (LVF) will be projected to the right hemispnere. This basic fact is related to the organization of the visual system in which stimulation of the nasal retina of the left eye and temporal retina of the right eye result in right hemispheric stimulation; while points on the nasal retina of the right eye and temporal half of the left eye have projections to the left hemisphere. Thus, when stimuli are presented to the left or right of center we may expect a response (ERP) in the contralateral hemisphere which is different from the ipsilateral hemisphere.

Studies by Eason and Colleagues (Eason and Dudley, 1971; Eason and White, 1967) have shown that stimuli presented 20° and 40° out from center result in visual event-related-potential (ERPs) which are greater in amplitude in the contralateral hemisphere. Andreassi et al. (1975) found that visual stimulation at various locations, up to 4°, to left and right of central visual field (CVF) resulted in shorter visual ERP latencies at the contralateral hemisphere. For example, a RVF presentation produced shorter ERP latencies at the left hemisphere than at the right. Ledlow et al. (1978) also reported a contralateral latency advantage for early components of the visual ERP (labeled P130 and N170).

Since stimuli presented in RVF and LVF project primarily to left and right hemispheres, respectively, it is proposed that this technique be used to study the relative efficiency of the left and right hemispheres of the brain in detecting and responding to signals over an extended time period.

Dimond and Beaumont (1971) presented signals in LVF and RVF and measured detection performance. No measures of brain response were obtained. Forty-eight signals appeared randomly at four locations over an 80 minute period (ISI=100 secs). There was no difference in right and left hemisphere

detection. However, there were more false positives for the left hemisphere than for the right. This led to another study (Dimond and Beaumont 1973) in which signals were presented to only one or the other hemisphere in two groups of subjects. This yielded interesting findings in that subjects who had left hemisphere presentations showed superior detection performance which decreased over time. No decrement was seen in the right hemisphere group; they started at a low level of performance and stayed there throughout the 80 minutes of the task.

Dimond and Beaumont suggested that each hemisphere acts as a watchkeeper in its own right, i.e., the left operates at a high level which diminishes over time because vigilance is a demanding task, and the right maintains a steady low-level of vigilance performance. One of the questions we will examine in this study is whether there is differential performance by the right and left hemispheres of the brain and, if so, will these differences be accompanied by ERP differences. The measures of performance which we propose to use are reaction time and errors.

An ERP component which has been the focus of much research over the past 15 years is the so-called P300 response.[2] Initially discovered by Sutton et al. (1965), this large positive ERP component was observed to occur at about 300 msec after the stimulus and to be associated with a degree of uncertainity about stimulus occurrence. For example, in the paradigm used by Sutton and Colleagues the probability that an initial sound would be followed by another was 100% in one condition and 33% in another. A large positive wave occurred about 300 msec after the stimulus during the uncertain condition, not the certain one. Later investigations have confirmed the relation between

---

[2] Various investigators have considered large positive components occurring anywhere between 250-550 msec as belonging in the "P300" category.

stimulus probability and the occurrence of P300 (for example, see Ruchkin et al., 1975; K. Squires et al., 1977; N. Squires et al., 1975).

While relatively few studies relating ERPs to vigilance exist, there are a number of studies of early and late ERP components which could have implications in understanding brain activity correlates of vigilance. As a result of these studies the consensus among some investigators is that P300 is related to information processing and decision making, while earlier components (for example, those occurring at 100 msec or 200 msec after stimulus presentation) are concerned with the nature of the stimulus. An illustrative study is one by Hillyard et al. (1973), who recorded auditory ERPs in persons who listened to a series of tones in one ear and ignored simultaneous tones in the other ear. The negative component (N1) of the ERP (peaking at 80-110 msec) was enlarged for the attended tones. A later positive component, peaking at 250-400 msec (P300), also occurred to attended stimuli. These researchers interpreted the early ERP component as representing stimulus set and the later one as indicating a response set in this selective attention situation. They proposed that stimulus set preferentially admits all sensory input to an attended channel, while response set facilitates recognition of these specific, task-related stimuli.

This kind of interpretation is given further support by the results of a study conducted by Gomer et al. (1976). These investigators required their subjects to decide whether varying numbers of displayed letters belonged to previously memorized sets. The P300 response was greater in amplitude to those letters in the "previously memorized" category as compared to the unfamiliar letters. In addition, P300 latency increased as the number of letters in a given set was increased. Thus, P300 latencies appeared to reflect the increased information processing required to deal with the larger

number of items. This conclusion is supported by the fact that an earlier positive component (occurring at about 200 msec) did not show latency changes with differing numbers of letters, indicating that this earlier component merely registered stimulus input.

These research findings may be related to a vigilance situation in the following manner: the stimulus set may refer to detecting all visual signals on a radar scope, while the response set refers to making decisions about this visual signal if the signal meets some criteria, e.g., speed, number and course. If the P300 component does not occur, and the earlier one does, perhaps the individual has responded at a superficial level to a critical stimulus, but not at a level required to further process the important information. Thus, when a critical signal is presented there are potentially three varieties of evoked brain response:

(A) Early and late ERP components-indicating that the critical signal has been detected and a decision made about its importance;

(B) An early ERP, but not a late-indicating that the signal has been detected, but for some reason, perhaps related to attention fluctuations, its importance has not been recognized and further analysis is not accomplished;

(C) Neither early nor late ERP components appear in response to the stimulus thus indicating that the stimulus has been completely missed.

The perceptual possibility of B was noted by Mackworth[3] who found, through his analyses of eye movements while persons scanned columns of letters or numbers for a partiular item, that people sometimes looked directly at a

---

[3]   N.H. Mackworth, Personal Communication.

number for which they were searching and did not report it. In other words, they presumably saw the target item, but did not recognize it. Mackworth has referred to this phenomenon as "looking without seeing", implying that a person (or his nervous system) receives the stimulus but does not process it.

Hillyard et al. (1971) used a signal detection procedure in which the subject's task was to decide on each trial whether or not an auditory signal (at threshold) had been added to continuous background noise. They found that P300 was several times larger when signals were detected than when they were not detected. It was concluded that the P300 was enlarged only when stimulus information was being actively processed and that it was associated with the occurrence of a signal and its correct detection. Thus, it appears that the detection of some significant stimulus can produce a P300 response. Other investigators have related P300 to decision making (a poststimulus event) rather than to adjustments made in preparation for a stimulus (Smith et al., 1970; Rohrbaugh et al., 1974). Rohrbaugh et al. (1974) devised an experimental situation in which only the second of two rapidly successive and relevant visual stimuli permitted subjects to make a decision. Analysis of the ERPs indicated that only the second stimulus produced a prominent and enhanced P300. Since P300 was not reliably enhanced in response to the first stimulus the researchers concluded that neither relevance nor information delivery per se, determines the amplitude of P300. Rohrbaugh et al. emphasized that the subject's activity as an information processor determined the amplitude of P300. Squires et al. (1973) reported that confidence in a decision regarding detection was related to P3 amplitude, i.e., higher amplitudes were associated with greater degrees of confidence. In another study, Kutas, McCarthy and Donchin (1977) measured latencies of P300 components on individual trials and correlated these with choice RTs. The

correlations were higher under instructions to respond as accurately as possible (r=+.61) as compared to a condition where they were instructed to respond as quickly as possible (r=+.26). When error trials were removed the correlations increased to r=+.66 and r=+.48 for the accuracy and speed conditions, respectively. The authors concluded that under accuracy instructions, where response selection is contingent on stimulus evaluation, the two processes are closely related with RT frequently longer than P300 latency. When subjects operate under speed instructions stimulus evaluation is more loosely related to response selec n and responses may be generated before the stimulus has been fully evaluated. During the speed RT condition RT exceeded P300 by 23 msec, while under the accurate RT condition the RT was, on the average, 91 msec longer than P300 latencies.

In summary, rather consistent findings have associated the P300 response with a number of cognitive activities including signal detection, discrimination, and decision making. A number of researchers have suggested that P300 is related to active processing of stimulus information (Beck, 1975; Hillyard et al., 1971; Squires et al., 1975). A similar suggestion by Donchin et al. (1973) was that the amplitude of P300 is a function of the complexity of information processing required of a subject, following the presentation of a stimulus. All of the processes reviewed in this section, including signal detection, discrimination and selective attention are aspects of active processing of stimuli. Hence, the function involved in the active processing of information may be common denominator in the production of the P300.

It is common for stimuli to elicit P300 responses in an RT experiment (Donchin et al., 1973). This fact, plus our intention to have subjects decide which hand to use for responding with each trial should allow us to observe a substantial P300 response in the present experiment. There is another aspect

of RT literature which must be considered in this introduction. A number of investigators have used the left and right visual field paradigm along with RT to estimate time for a visual stimulus to travel across the cerebral commissures. The logic in this is that if right-handed subjects are used and the visual stimulus is in the LVF, RTs will be shorter for left-hand responses than right-hand responses. This is because the LVF projects the stimulus to the right hemisphere which controls motor responses of the left hand. Thus, the perception of the stimulus and initiation of the motor response occurs in the same hemisphere. This is an instance where the field of stimulation is ipsilateral to the hand of response. When the field of stimulation is contralateral to the hand of response the RTs are longer by the amount of time it takes for stimuli to cross the cerebral commissures so that the reaction may take place. Thus, it takes x msec for an ipsilateral response to be made and $x + t$ for a contralateral response (t being time to cross the commissures). Figure 1 illustrates this conceptual model.

Poffenberger (1912) was the first to use the RT approach to estimate interhemispheric transfer time (IHTT). His estimate of IHTT was 6 msec, a figure which is consistent with predictions based on neural conduction and synaptic delay time. Similar results were obtained by Berlucchi et al. (1971), and Jeeves (1969, 1972). For all of these experiments a simple RT paradigm was used and stimulus location was known. When stimulus location is unknown the ipsilateral-contralateral differences are larger. For example, Filbey and Gazzaniga (1969) found a 33 msec difference, while Ledlow et al. (1978) found a 22 msec difference when stimulus location was unpredictable. There has been some disagreement about using ipsilateral-contralateral RT differences as an estimate of IHTT. Broadbent (1974) has argued that the laterality effects observed are due to stimulus-response compatibility, i.e.,
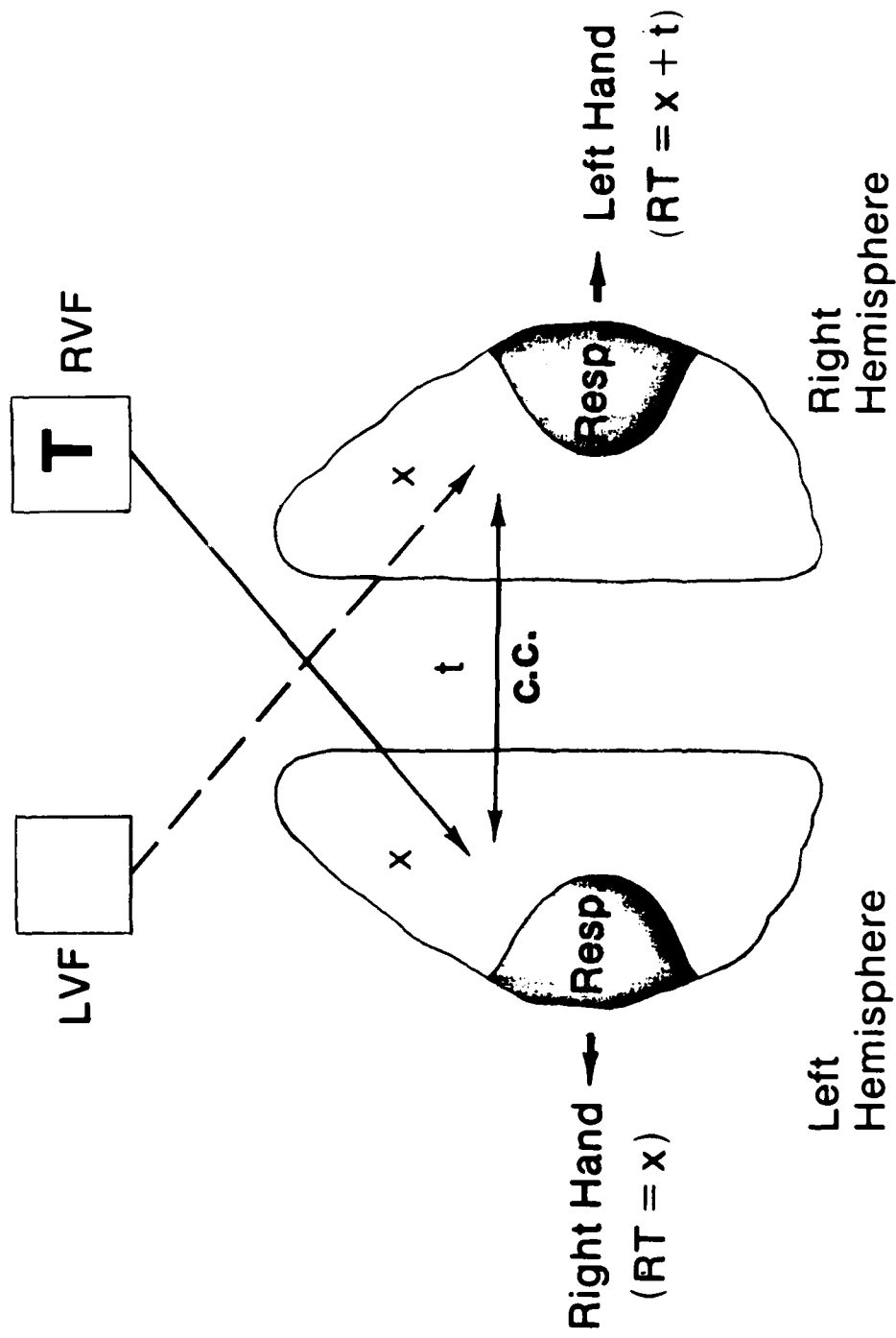
FIGURE 1 Model of RT as a measure of interhemispheric transfer time (IHTT)

the ipsilateral hand RT is faster because the response is to the stimulus on the same side. Broadbent based his argument on findings which indicated that crossing the hands result in shorter contralateral RTs (Wallace, 1971). Berlucchi et al. (1977) countered Broadbent's position by having subjects respond on half the trials with their hands in a crossed-position. The hands-crossed condition would presumably upset the S-R compatibility; however, Berlucchi and colleagues reported that ipsilateral hand responses were still faster, even when crossed. Harvey (1978) had his subjects use their left and right hands in response to stimuli located in left and right visual fields. He reported ipsilateral choice RTs to be 25 msec faster than contralateral RTs. Ledlow et al. (1978) used both RT and ERP measures of IHTT and concluded that RT was not a good estimate since they found that slight changes in hand position could change the ipsilateral-contralateral differences. Two ERP components (P130 and N170), however, occurred about 20 msec sooner in the hemisphere contralateral to stimulation. The stimuli were 2.5 deg in either CVR or RVF. Similar results were obtained by Andreassi et al. (1975) for stimuli located 2.67^{o} in LVF and RVF, i.e., this was for a negative ERP component peaking at about 170 msec. Andreassi et al., interpreted this difference as representing the time taken for the crossover of impulses from one hemisphere to the other via the corpus callosum. Thus, the ERP might be a more reliable estimate of IHTT than RT. Kinsbourne et al. (1977) suggested that RT measures are confounded by attentional variables, which produce RT variations greater than the IHTT that it is intended to measure.

Contralateral ERP latency advantages have also been reported for auditory stimulation (Butler et al., 1969, Majowski et al., 1971) and for somatosensory stimulation (Salamy, 1978).

Method

Subjects -- The subjects were 12 male right-handed staff members of SRI International, recruited through an institute newsletter. They ranged in age from 24 to 45 years. There was no personal or familial history of left-handedness. None had visual system defects other than myopia which was corrected to at least 20/25. All subjects participated in two experimental sessions conducted on two separate days, no more than two weeks apart. When they reported for their first session the subjects were given a brief explanation of the overall goals of the experiment. Then they were given the following instructions to read:

"You will be participating in an experiment designed to measure your brain activity while you detect signals. There will be two sessions, the one today and one on another day. Signals will be presented in one of three small squares in front of you. It will be very important that you fixate your eyes on the small green point of light, at the center of the display, at all times. The signals will come at unpredictable intervals and at different locations. Therefore, you must be watchful at all times. Since the signal will be presented for only a short duration try to minimize your eye blinks since it would be possible to miss a signal while blinking. Do not stare at the fixation point, just look at it. Staring will tend to fatigue your eyes. If you must blink, wait until after you have responded to a signal.

Now we will explain your responses to the two types of signals. One of these will be a capital letter T and you will respond by pressing the key just in front of your _____ forefinger; the other is an upside down T, and you will be asked to respond to it by pressing the key in front of your _____ forefinger. You will have some practice trials in which you will see each

type of signal at each location, and get some practice in reacting to them by pressing either the left or right hand key. During the actual experiment we will be keeping a record of your reaction times, so please try to respond as quickly as possible, without making any mistakes. If you find yourself making a mistake you may correct your response by pressing the other key before two seconds have elapsed.

The procedures we will be using are entirely safe. They have been used time and again with thousands of subjects. We will be able to show you samples of your brain activity, and tell you more about the experiment, after your data have been collected.

Any questions?

Reminder: Fixate on the green light at all times. Respond as quickly as possible without making mistakes."

Subsequent to reading instructions, subjects read and signed consent forms, approved by the Human Subjects committee at SRI, which insured that each subject understood the conditions of the experiment.

Six Ss responded to the T-up orientation with the right hand and to the T-down with the left, while the other six did the opposite. The subjects were randomly assigned to each group.

There were a total of 156 signals presented in a 78 minute experimental session. The stimuli appeared at one of three locations, in an up or down orientation, in a random sequence. The inter-signal-interval varied from 15 sec to 60 sec, with an average of 30 sec between signals. The session was designed so that T-ups and T-downs appeared in each visual field (left, center and right) an equal number of times. In addition, an equal number of T-ups and T-downs appeared in the first and second halves of the session.

Apparatus and Procedure -- Subjects were seated in a comfortable chair in
an electrically shielded, sound-attenuated, Industrial Acoustics Corporation,
(IAC) chamber. The arms of the chair were modified to incorporate a telegraph
key for each hand. The position of the key was adjustable to allow for
differences in arm length. The force required to produce key closure was
calibrated at 68 gm for each key. An adjustable chin rest allowed the
subjects to maintain their heads in a stable orientation while fixating a
small green L.E.D. positioned 45 in. (114.3 cm) from the nasion, directly in
front of them at eye level. The stimuli were back projected onto a ground
glass screen by means of a Kodak Carousel slide projector. They appeared at
the center of one of three 1.5 cm by 1.5 cm square apertures in a shield
placed over both the ground glass screen and the window of the IAC chamber.
The fixation point was positioned directly over the center of the central
aperture. The two lateral apertures were each 5 cm to left or right of the
central one. The stimulus T was 1 cm high and, at the distance used (114.3
cm), produced a visual angle of 0.5 deg. The 5 cm displacement to left or
right produced a visual angle of 2.5 deg. Thus, the T appeared at either the
center of the visual field (CVF) or 2.5 deg to the left or right of center. A
schematic of the experimental set-up is shown in Figure 2.

The intensity of a steady state T, measured by a Tektronix J-16
photometer at a distance of 45 in, was 5.0 millilamberts (mL). This
measurement was done with the lights out in the IAC chamber and the external
room, the same viewing conditions provided for the subjects. The duration (50
msec) of each presentation was controlled by a pulse from an Iconix Time Base
Logic Unit to a Uniblitz shutter mounted in front of the Carousel projector.
A wratten neutral densilty filter of 1.0 was placed over the shutter to reduce
the flash intensity. Two other filters of 0.1 and 0.3 were used to equalize
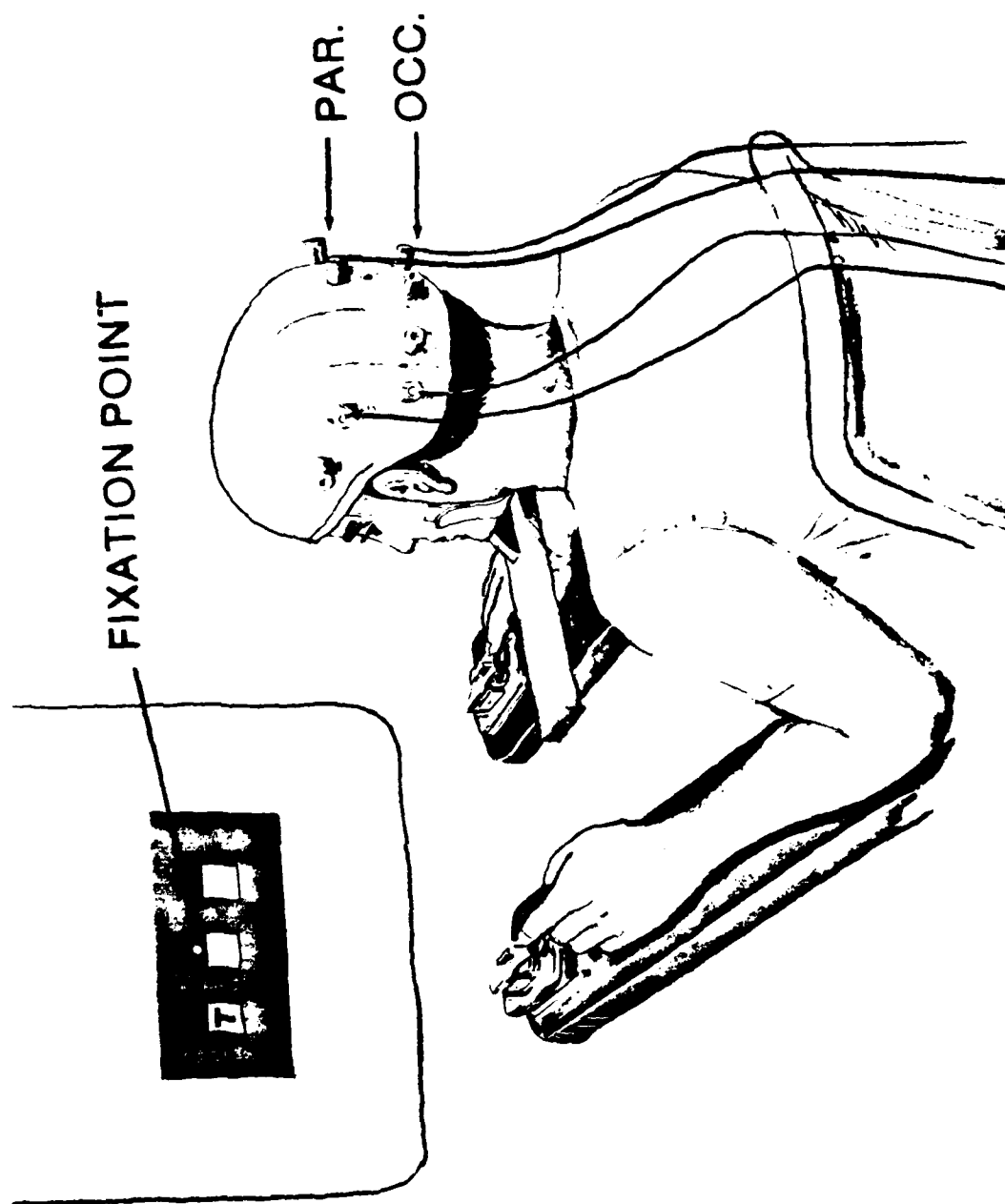light intensity in the three visual fields.

FIGURE 2 Schematic of experimental arrangement used in the present study

The electroencephalogram (EEG) was recorded on a Grass Model 78 EEG and

Polygraph Data Recording Systemm. The EEG was recorded with Beckman

electrodes fitted into plastic electrode holders mounted in an elastic cap.

These holders were placed into the cap so that they were approximately over

visual association areas (3 cm anterior to O_1 and O_2) of the 10-20 system

(Jasper, 1958). Pilot work suggested that latency differences between

responses at left and right hemispheres to lateralized stimuli could be

reliably obtained with these recording sites. For the parietal areas the

electrodes were placed midway between P_3 and T_3 over the left hemisphere

and midway between P_4 and T_4 over the right hemisphere. The attempt here

was to place the recording electrode approximately over the angular gyri of

the two hemispheres, in order to study possible language and cognitive

functions associated with these parietal areas. Recording electrodes were

referenced to Grass silver clip electrodes linked to the two earlobes. Thus,

four channels were devoted to recording EEG (Amplifier, Model 7P511). Two

more channels were used to record vertical and horizontal eye movements (low

level D.C. Amplifier,1 Model 7P122). Vertical electro-oculography (EOG) was

measured by placing electrodes above and below the right eye; horizontal EOG

was recorded by placing leads at the outer canthi of the left and right eyes.

Electrode impedance was checked for all sites with a Grass electrode impedance

meter. Impedance measures of 5,000 Ohms were considered acceptable. A ground

electrode was placed in the middle of the forehead. All electrodes were

inserted into a Grass mini-electrode board which led to the Grass recorder. A

Grass selector panel was used to obtain the various electrode combinations for

the purpose of recording. Gain settings were adjusted to 30uv per cm for EEG

and 100uv per cm for the EOG channels. A bandpass of 0.3 to 100 Hz was used

for the EEG signals. A time constant of 0.8 sec and high frequency cut-off of

35 Hz was used for the EOG. An Emde on-line calibrator unit was used to produce 10uv square waves recorded in series with EEG samples and 25uv square waves for EOG samples.

The entire experimental sequence was initiated by a Lafayette interval timer. The various intersignal intervals were punched into a film strip fed into the Lafayette timer which then triggered an Iconix logic panel and timer at appropriate intervals. The Iconix provided timed trigger signals to initiate on-line digitizations of the EEG by a Linc-8 computer, activate the Emde calibrator, open the Uniblitz shutter, and simultaneously start two Berl (Model 160A) reaction timers. If the subject did not respond to the signal within 2.8 sec the timers were automatically stopped and reset before the next trial. The slide projector was advanced 12.5 sec after initiation of a trial. When the subject responded to a given signal the left hand timer would stop when the left hand was used, and the right hand timer would stop when the right hand was used. The experimenter recorded reaction times to the nearest msec on data sheets in the appropriate column. Each EEG sample (4 channels) and EOG sample (2 channels) was digitized, using 16 msec sampling intervals and 256 data points, on-line by the Linc-8. The samples were then stored on Linc-8 data tapes. The tape on drive 0 was used to store EEG samples taken from the parietal leads and the vertical EOG, and the tape on drive 1 stored samples from occipital leads and the horizontal EOG. After each experimental session, the data tapes were edited by viewing them on the Linc-8 CRT prior to averaging. Individual trials were excluded if (1) the record showed excessive lateral or vertical eye movement for that trial, (2) the sample was saturated, i.e., the entire EEG sample was not obtained, or (3) the subject responded with the wrong hand, did not respond at all, or made an extremely long or short RT (i.e., greater than $\pm$ 3 S.D.). The averaged event-related potential

(ERP) based on remaining samples was obtained by averaging across individual trials for each experimental condition. Subsequent to obtaining averages for various conditions the ERPs were plotted from the stored locations on data tapes with a Hewlett-Packard (Model 7034 A) X-Y Plotter. An example of an acceptable EEG trial is shown in Figure 3 in which, from top to bottom, is shown a response recorded from occipital and parietal areas and lateral and vertical EOGs. Figure 4 is an example of a trial which was excluded because of eye movement contamination. An eye blink shows up in the vertical EOG very prominently, and also in the other records. The maximum number of samples comprising an event-related potential (ERP) for a given condition was 26. Typically, one to five samples were rejected for a given condition. Thus, the averaged ERP was usually based on 20-25 EEG samples.

At the end of session one, the subjects were told nothing more about the experiment or its purpose beyond the information given in the instructions. Before the start of session two the instructions were briefly reviewed, but no practice trials were given. At the end of the second session, questions about the study were answered as fully as possible. Thus, session two was essentially the same as session one and provided an estimate of the reliability of the experiment through a replicated session.
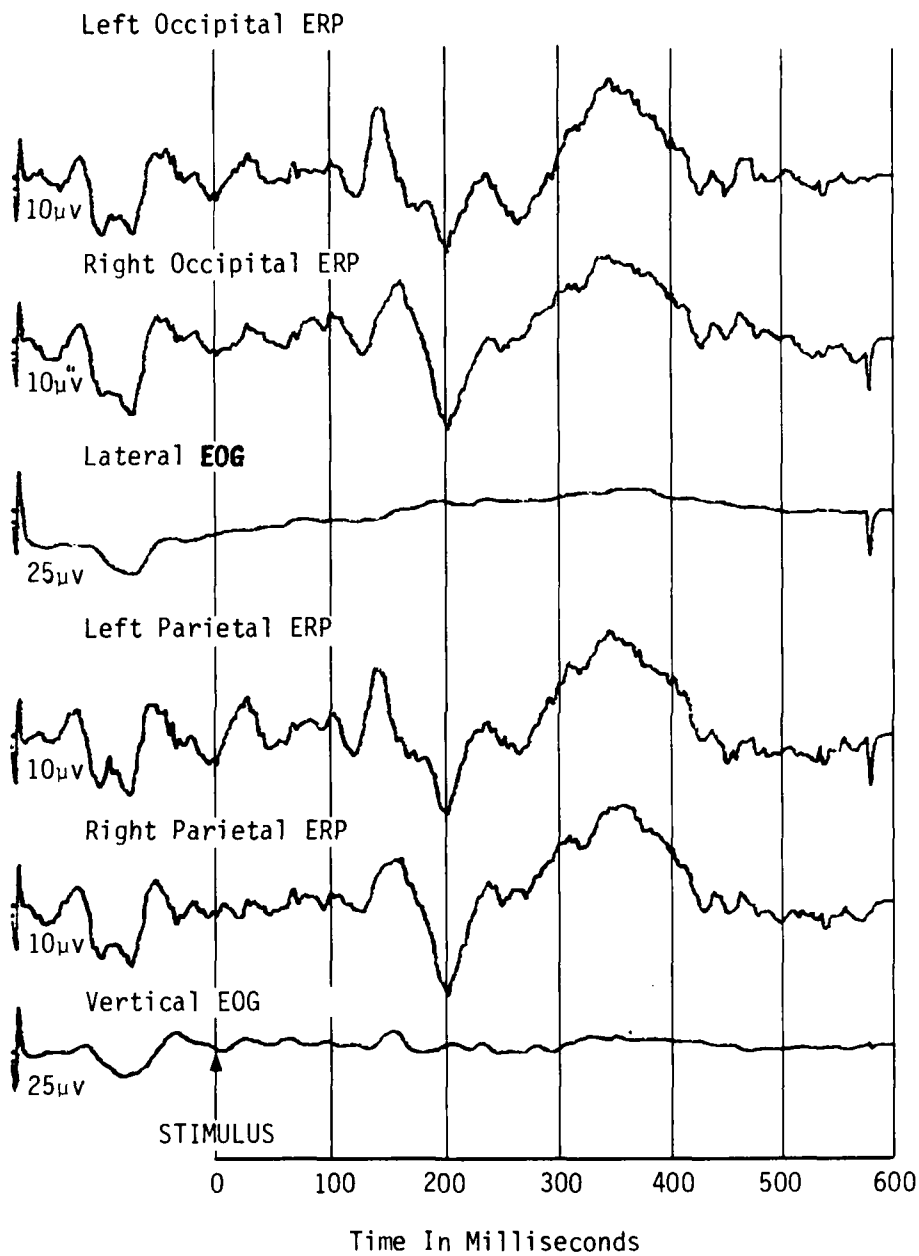
FIGURE 3 Example of an acceptable trial. From top to
bottom are shown responses recorded from occipital
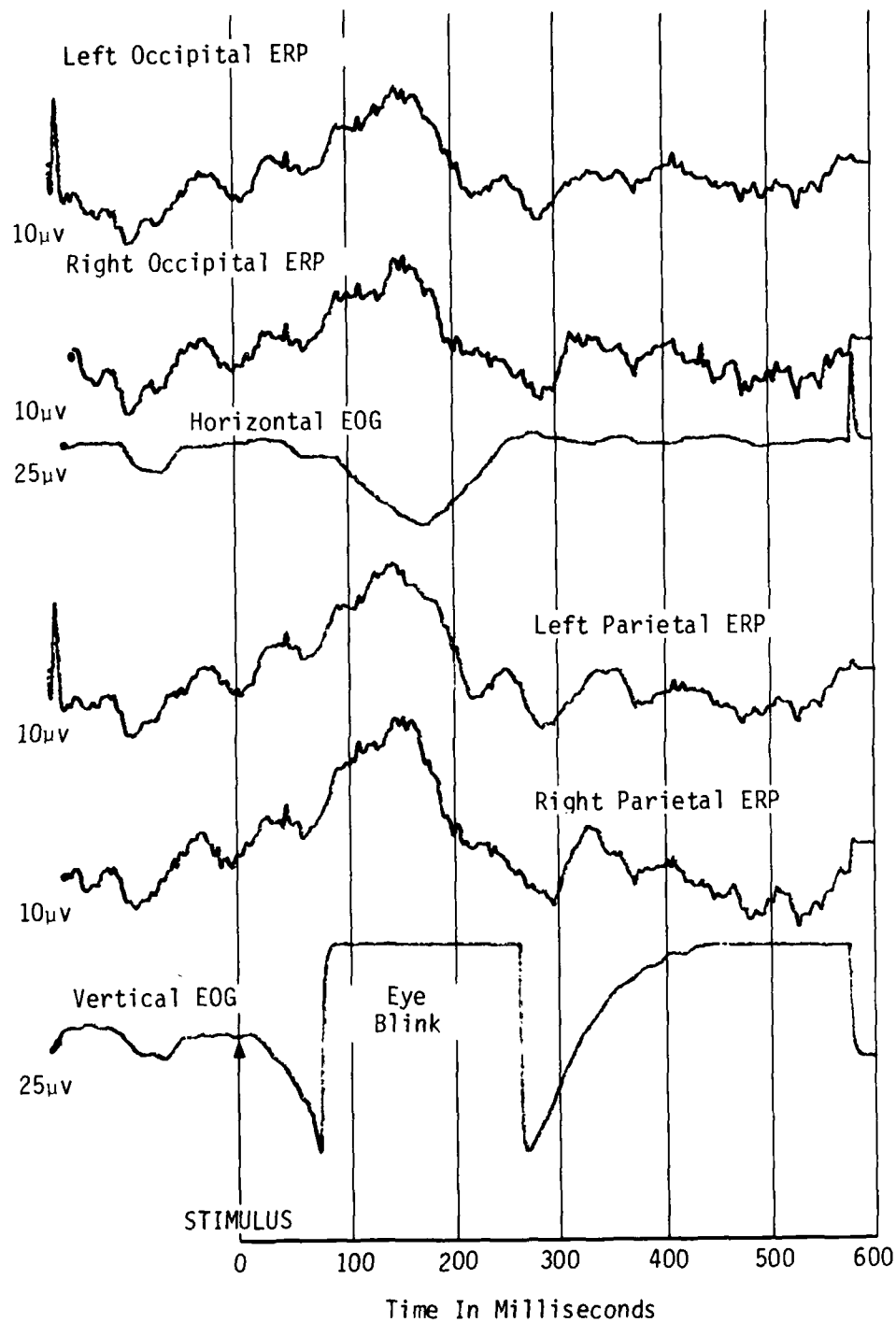and parietal areas and **lateral and vertical** EOGs

FIGURE 4 Example of trial excluded because of eye
movement contamination

Results

Event Related Potentials (ERPs) - The ERPs for the various scalp placements were averaged across subjects to obtain a grand average (see Figure 5). Two major ERP components emerged: a negative peak occurring at about 180 msec after the stimulus, and a positive component appearing at about 320 msec. These two peaks can also be seen in the individual ERP traces shown in Figures 6 and 7. Statistical analyses of ERPs are based on the latencies and amplitudes of these major components.

Occipital ERPs - Latencies (in msec) and amplitudes (V) were measured for the X-Y tracings which were plotted from the ERPs stored on tape. For each session 12 occipital plots were obtained. These were: left and right occipital areas (2), LVF, RVF and CVF (3) and response to T-up and T-down (2). The N180 component was taken as the large negative-going wave which appeared anywhere from 150 msec to 210 msec after the stimulus, according to the experimental condition. The amplitude was measured from the X-Y trace baseline to the trough of this first major negative wave. The P320 amplitude was measured from the X-Y trace baseline just after the response to the peak of this component. This was done to avoid measuring a positive wave, occurring after 200 msec in some subjects, as part of this later positive component (P320). The P320 latencies varied from 280 to 360 msec after presentation of the stimulus. Latencies (or time after stimulus presentation) were measured to the midpoints of each positive and negative peak. If the "peak" was flat, and appeared more as a plateau, the midpoint of the plateau was taken as the latency measurement.

The mean latencies, for each visual field, across the 12 subjects are shown in Table 1 for the two occipital locations. The mean amplitudes are presented in Table 2. Occipital ERPs for two of our subjects (J.W. and J.C.) are shown in Figures 6 and 7.

Table 1

Mean Latencies (msec) for Major Occipital ERP
Components, Three Visual Fields (N=12)

SCALP LOCATION	ERP COMPONENT	VISUAL FIELD		
		LEFT	CENTER	RIGHT
OCCIPITAL	N180	193	172	182
(LEFT HEMIS)	P320	327	318	323
OCCIPITAL	N180	186	171	197
(RIGHT HEMIS)	P320	321	309	325

Table 2

Mean Amplitudes (uV) for Major ERP Occipital
Components, Three Visual Fields (N=12)

SCALP LOCATION	ERP COMPONENT	VISUAL FIELD		
		LEFT	CENTER	RIGHT
OCCIPITAL	N180	7.82	11.05	8.05
(LEFT HEMIS)	P320	9.74	8.92	9.28
OCCIPITAL	N180	7.80	9.22	6.47
(RIGHT HEMIS)	P320	10.72	9.68	10.33

The latency and amplitude data were subjected to analyses of variance (ANOVA). A five-way ANOVA was calculated in which visual field (3), placement (2), hand used (2), days (2), and group (2) were main effects and subjects were replicates.
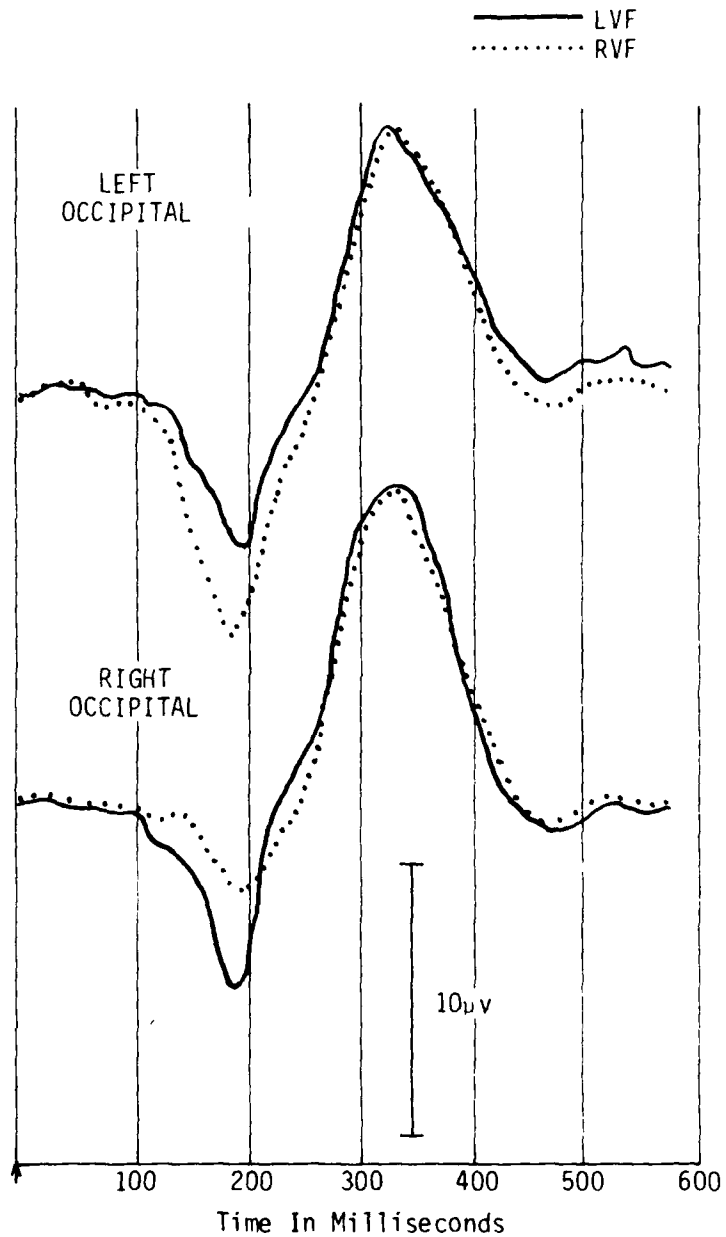
FIGURE 5 Grand ERPs averaged across 11 subjects as a function
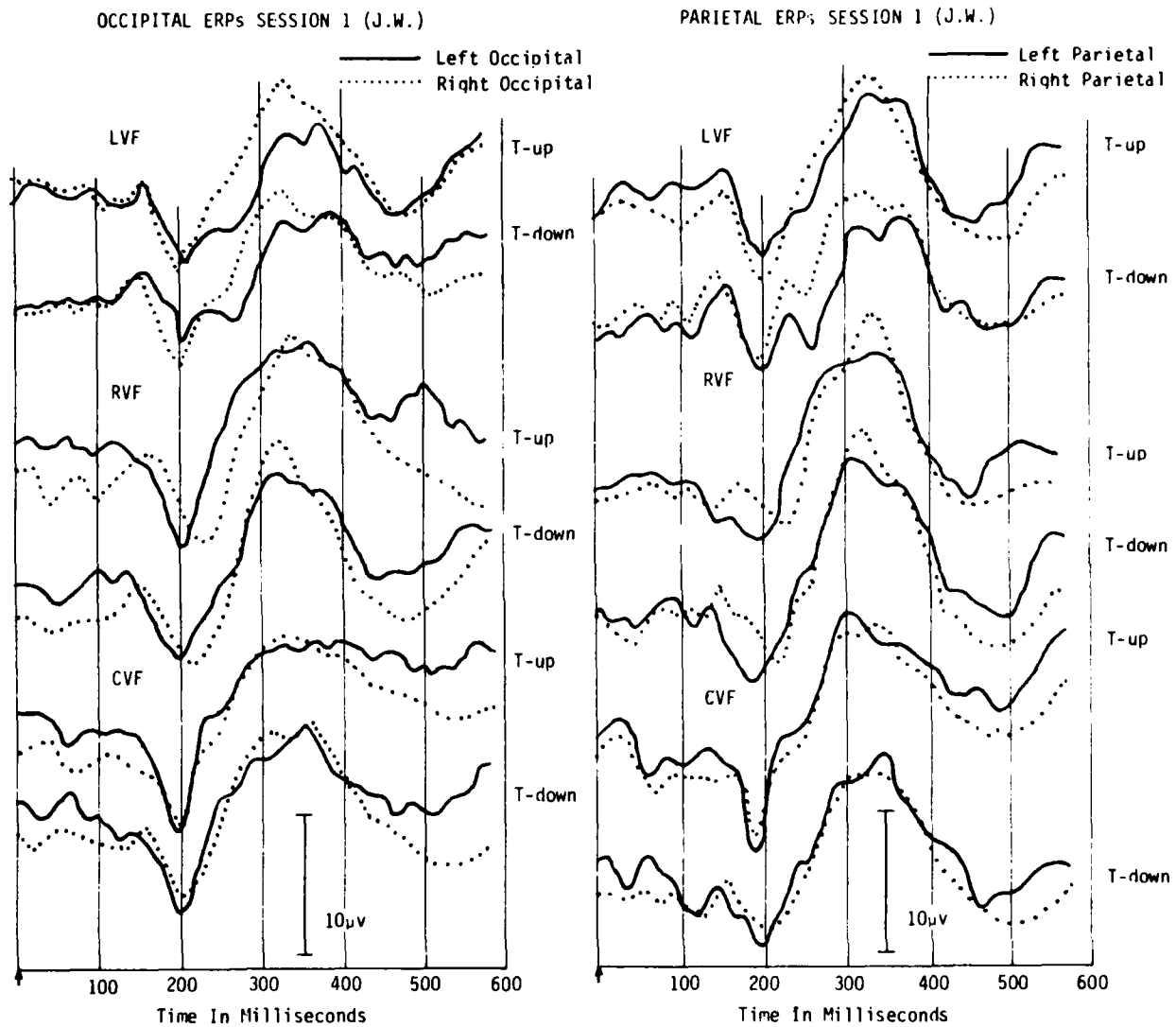of field of stimulation and recording site

23

FIGURE 6   Occipital and parietal ERPs recorded from one subject
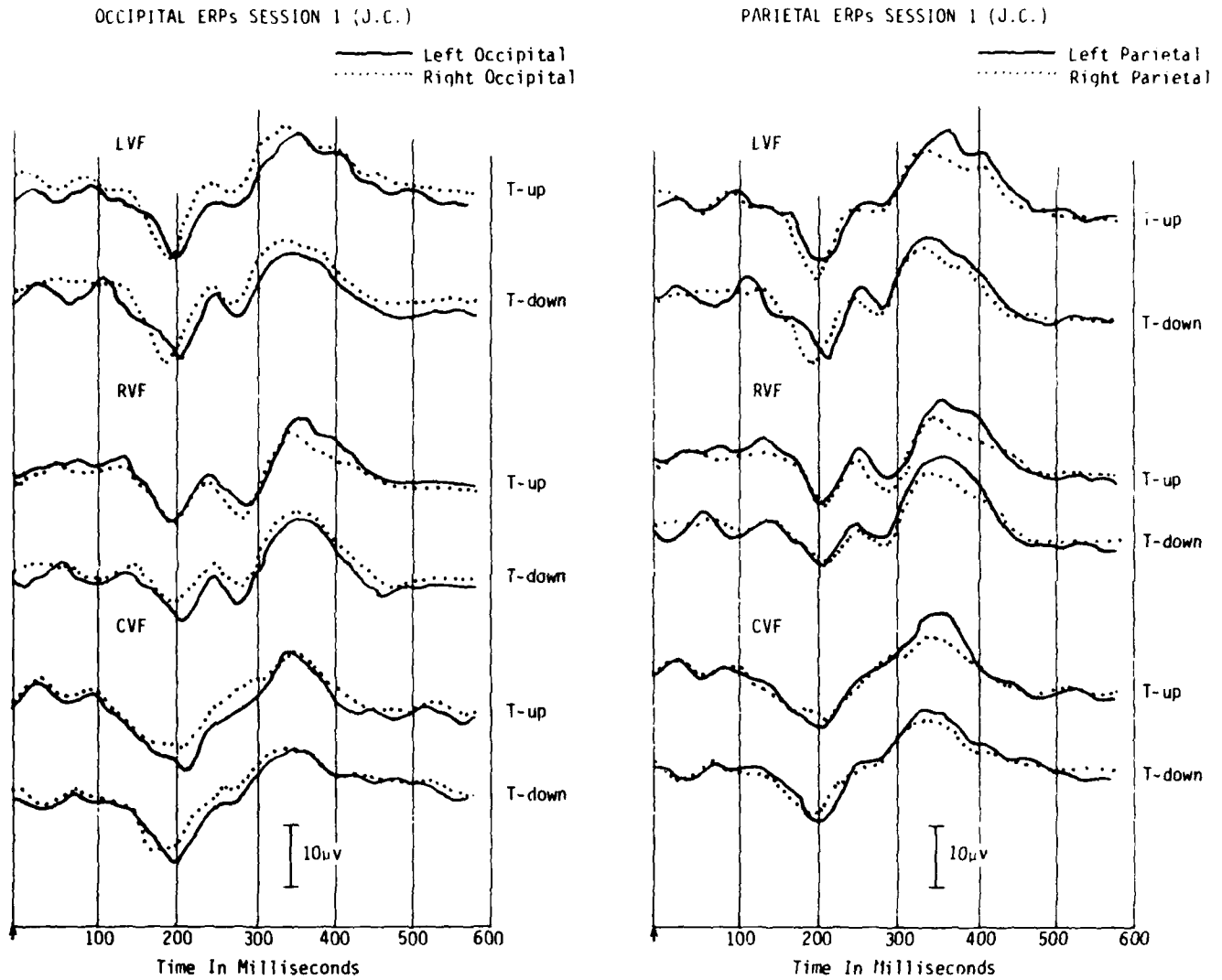(J.W.) as a function of various experimental conditions

24

FIGURE 7 Occipital and parietal ERPs recorded from one subject
(J.C.) as a function of various experimental conditions

There were three visual fields (left, center and right), two placements (left and right hemispheres), two hands used (left or right), two days, and two sub-groups (those who always responded to T-up with their right hands and those who responded to T-up with left hands). The ANOVA for N180 latency indicated a significant field effect, F (2, 20) = 31.32, P < .01; a placement x field interaction, F (2/20) = 11.57, p < .01; and Day X Group interaction, F (1,10) = 10.48, p < .01. The most important of these, the PXF interaction, is plotted in Figure 8. The plot shows that the latency of N180 varied at the two hemispheres as a function of visual field of stimulation.

The Newman-Keuls (N-K) multiple comparison test (Winer, 1962) was used to examine specific latency and amplitude comparisons. This test is two-tailed and, in addition, allows comparisons to be made with a minimal risk of Type I error. For N180 latency the N-K procedure indicated that when presentations were in the RVF there was a significant latency advantage for the left hemisphere (p < .01). The response was 15 msec faster at the left hemisphere, indicating a contralateral advantage. Presentations in the LVF led to shorter latencies at the right hemisphere (by 7 msec), but the N-K result was not significant. There were no latency differences at the two hemispheres with CVF presentations (171 vs 172 msec) as would be expected.

The N180 occipital latencies were subjected to separate ANOVAs according to subgroups of subjects, i.e., the six who responded to the T-up with the right hand (Right-up group) and the six who responded to T-up with the left hand (Left-up group). The Right-up group showed a significant Field effect, F (2,20) = 20.80, p < .01; and Placement X Field, F (2,20) = 6.40, p < .01 effect. The Placement X Field interactions for these groups are shown in Figures 9 and 10.

The N-K comparisons showed that for the Right-up group, right hemisphere occipital ERPs were shorter in latency (181 msec) than left hemisphere ERPs
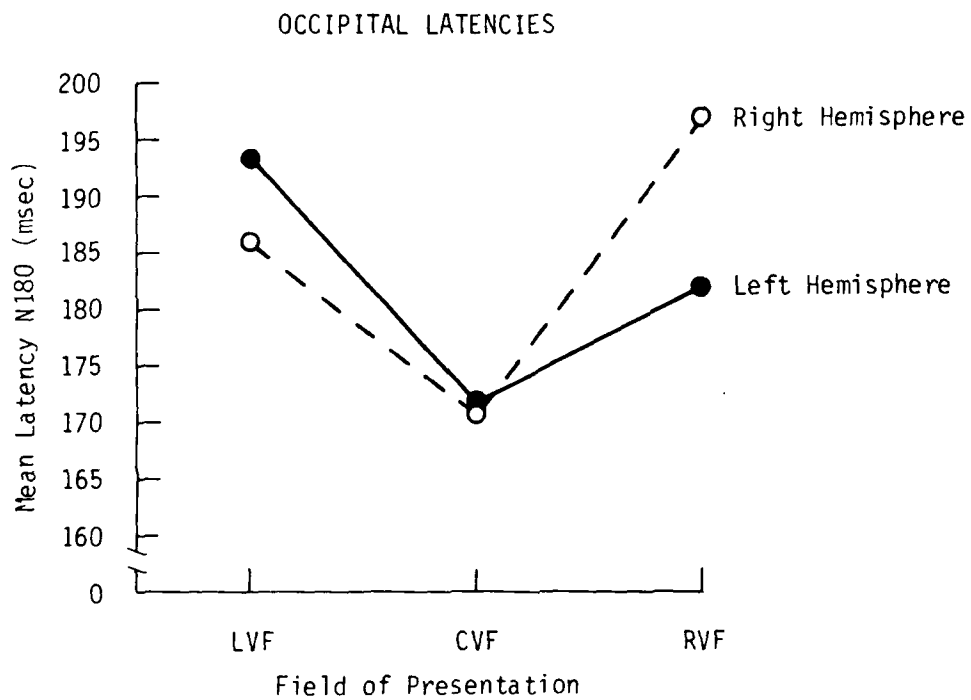
OCCIPITAL LATENCIES

FIGURE 8 Mean occipital ERP latencies for the N 180 component
as a function of field of presentation and recording
site (N=12)

OCCIPITAL LATENCIES (Right-up)

FIGURE 9   Placement X field interaction for N 180 occipital
component for six subjects who responded to T-up
with their right hands

OCCIPITAL LATENCIES (Left-up)

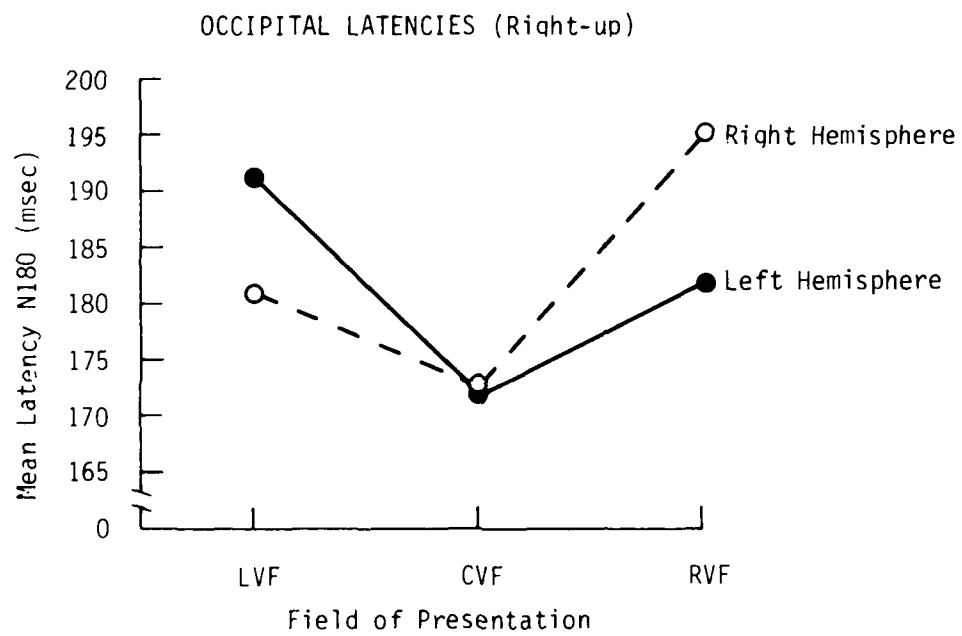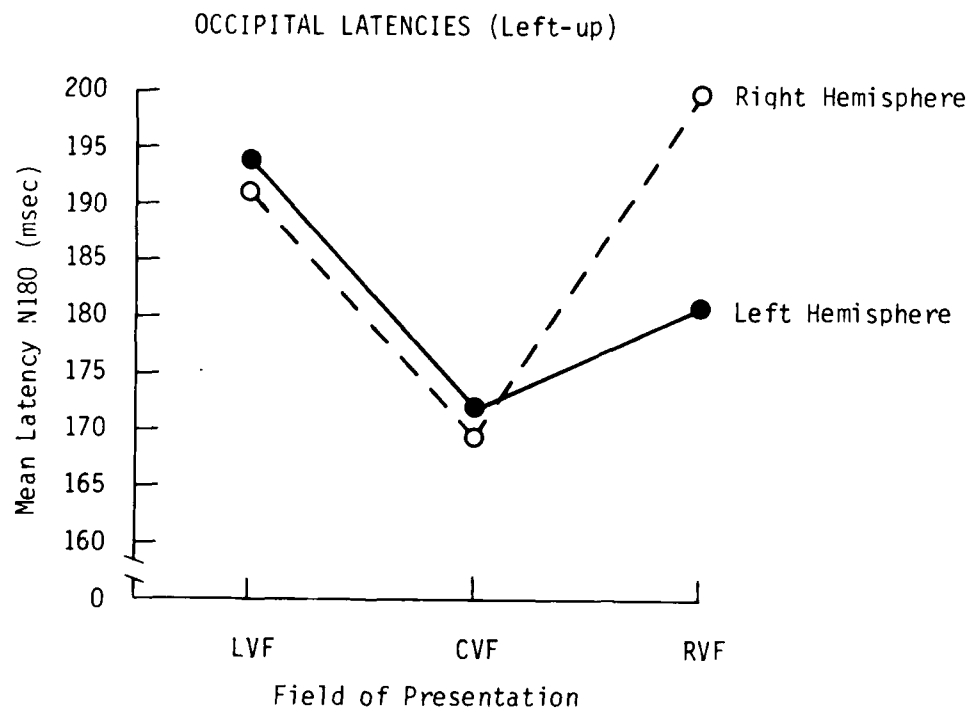
FIGURE 10   Placement X field interaction for N 180 occipital
            component for six subjects who responded to T-up
            with their left hands

(191 msec) with LVF stimulation (p < .01), indicating a contralateral latency advantage for LVF presenatations, which was not observed with the ANOVA on all 12 subjects. They also showed a contralateral advantage with RVF stimulation (p < .01) in which the left hemisphere latency was 283 msec and the right hemisphere latency was 195 msec. There was no difference in hemispheric latencies with CVF stimulation. The same comparisons for the Left-up group showed a contralateral advantage with RVF stimulation only (left hemisphere latency of 181 msec and right hemisphere latency of 200 msec, p < .01). The LVF and CVF did not produce hemispheric latency differences for this group.

The latency differences between the right and left occipital areas are plotted as a bar graph in Figure 11. One of the more striking aspects of this figure is the short ERP latencies at both right and left hemispheres with CVF stimulation. The N-K comparisons showed CVF presentations to result in significantly shorter latencies than either RVF or LVF presentations, while latencies for RVF vs LVF did not differ. The P320 latencies were also subjected to ANOVA and the only significant effect was for Field, $F_{(2, 20)}$ = 10.89, p < .01. Again CVF presentations produced the shortest latencies (314 msec) compared to RVF and LVF (both 324 msec). The N-K comparisons showed this difference to be significant at p < .01.

The results for N180 amplitudes indicated significant Placement, $F_{(1, 10)}$ = 5.52, p < .05 and Field, $F_{(2, 20)}$ = 4.47, p < .01, effects. The Placement effect indicates that the left hemisphere amplitude (N180) is greater (8.98uV) than the right (7.83uV), p < .05, when averaged across visual fields. The N180 amplitudes are plotted in Figure 12, and demonstrate the larger left hemisphere responses with CVF and RVF stimulation. Separate ANOVAs for the Right-up subjects and Left-up subjects yielded essentially the same results as the ANOVA based on the entire sample.
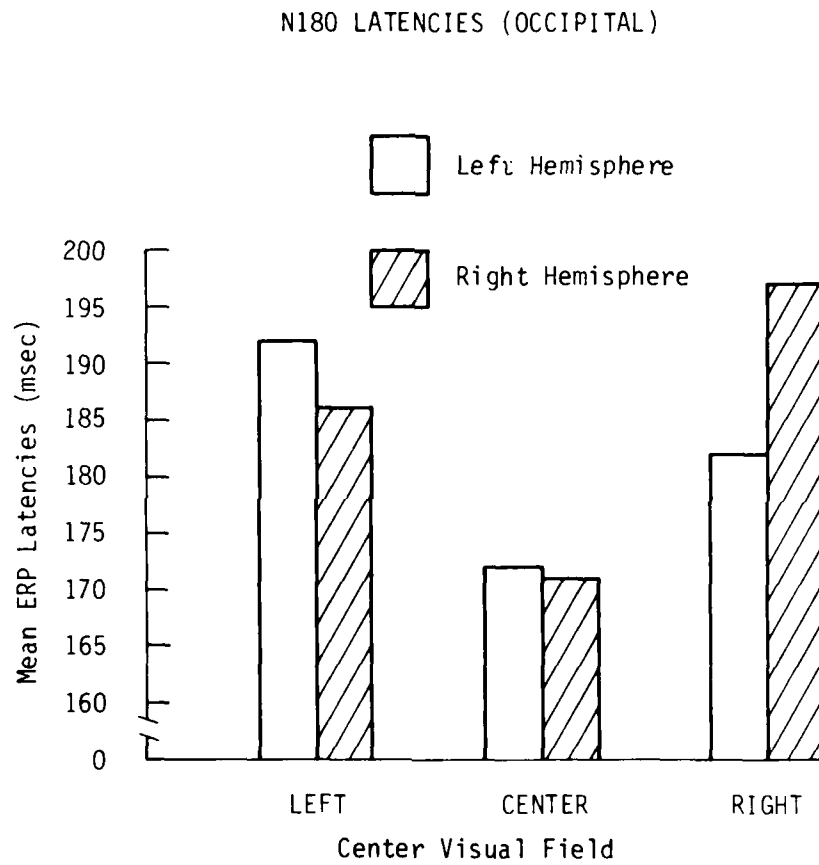
N180 LATENCIES (OCCIPITAL)

FIGURE 11 Mean N 180 latencies (occipital) as a function of field
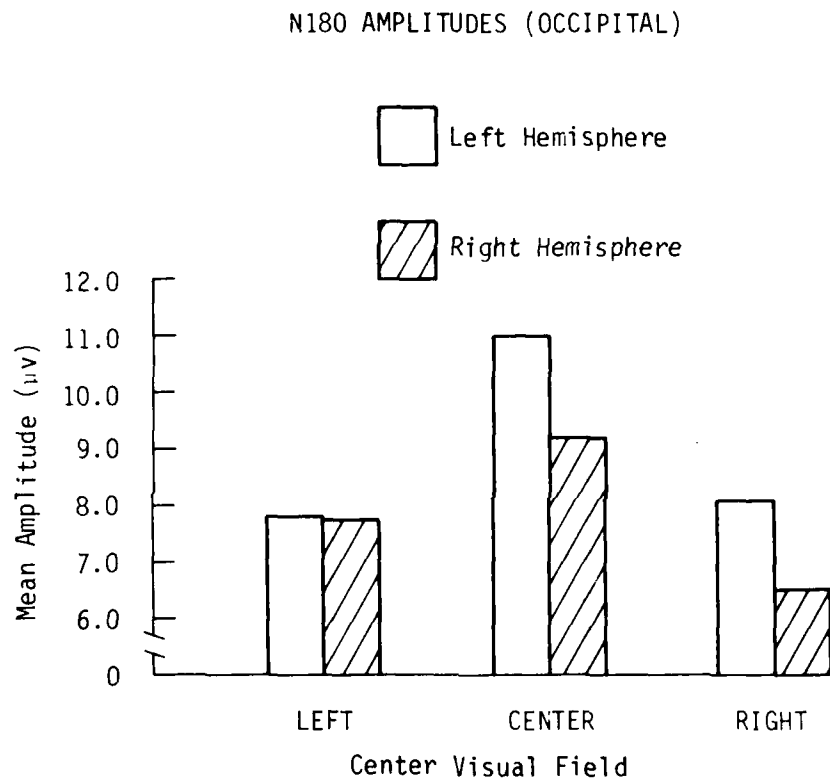of presentation and recording site

FIGURE 12   Mean N 180 amplitudes (occipital) as a function of
field of presentation and recording site

Parietal ERPs - The mean latencies for each visual field, across the 12 subjects are shown in Table 3 for the two parietal locations. The mean amplitudes are presented in Table 4. Parietal ERPs for two subjects (J.W. and J.C.) are shown in Figures 6 and 7. Four ANOVAs for N180 and P320 latencies and amplitudes were calculated. The significant effects for N180 were Field, $F (2, 20) = 22.94$, $P < .01$; Placement X Field, $F (2, 20) = 5.84$, $p < .05$; and Hand X Placement X Group, $F (1, 10) = 10.15$, $p < .01$. The N-K procedure showed that when presentations were in the RVF there was a significantly shorter latency ERP at the left hemisphere (180 msec) as compared to the right (189 msec) $p < .01$. There was no difference between the two hemispheres with CVF stimulation, or with LVF stimulation. This Placement X Field interaction is plotted in Figure 13. The latencies for right and left parietal areas, as a function of visual field, are plotted as a bar graph in Figure 14. The CVF presentations result in the shortest ERP latencies at parietal areas (169 msec) compared to LVF (184 msec) and RVF (185 msec). The difference between CVF and the others is significant at $p < .01$.

The ANOVA for P320 latency showed an effect of Field, $F (2, 20) = 8.28$, $p < .01$; Placement X Group, $F (1, 10) = 5.10$, $p < .05$; and Hand X Day X Group, $F (1, 10) = 10.15$, $p < .01$. The most meaningful of these, the Field effect, showed significantly shorter CVF latency (316 msec) than either LVF (325 msec) or RVF (326 msec), $p < .01$ according to the N-K comparisons. The ANOVAs for N180 amplitudes and P320 amplitudes at the parietal area yielded no significant effects for the 12 subject analyses.

The parietal latency results for the Right-up subjects and Left-up subjects were analyzed by separate ANOVAs. The results were essentially the same as for the 12 subject analyses except that the Right-up group showed a

Table 3

Mean Latencies (msec) for Major Parietal ERP
Components, Three Visual Fields (N=12)

SCALP LOCATION	ERP COMPONENT	VISUAL FIELD		
		LEFT	CENTER	RIGHT
PARIETAL	N180	185	168	180
(LEFT HEMIS)	P320	327	316	326
PARIETAL	N180	183	171	189
(RIGHT HEMIS)	P320	323	315	326

Table 4

Mean Amplitudes (uV) for Major Parietal ERP
Components, Three Visual Fields (N=12)

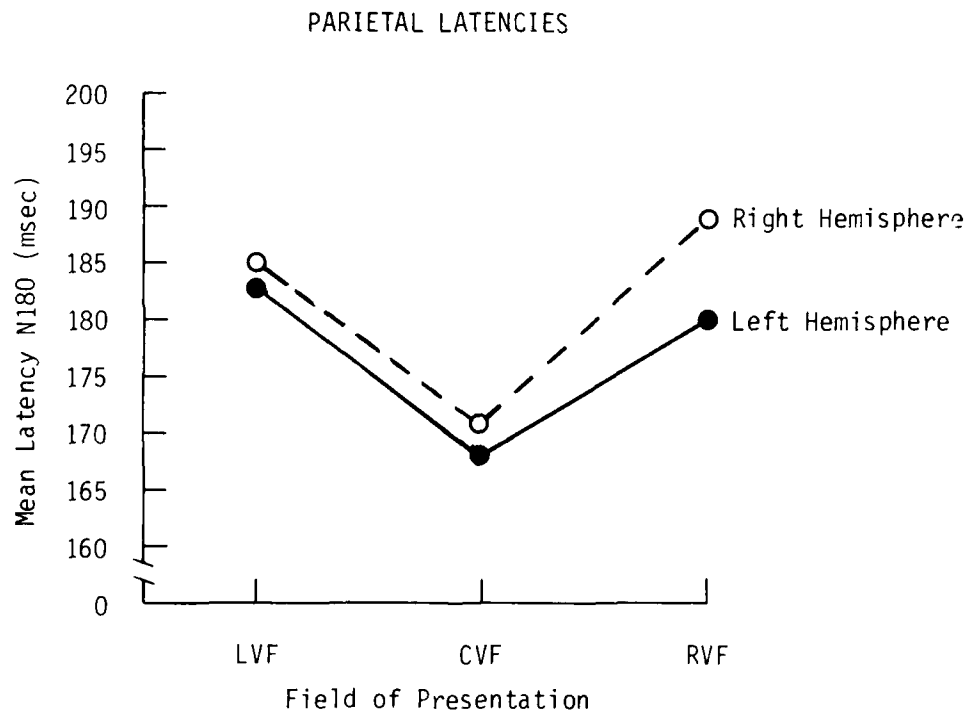| SCALP LOCATION	ERP COMPONENT	VISUAL FIELD		
		LEFT	CENTER	RIGHT
PARIETAL	N180	6.40	7.48	6.88
(LEFT HEMIS)	P320	12.33	11.19	12.40
PARIETAL	N180	6.72	6.48	5.75
(RIGHT HEMIS)	P320	13.48	12.12	13.00

PARIETAL LATENCIES

FIGURE 13   Placement X field interaction for N 180 parietal
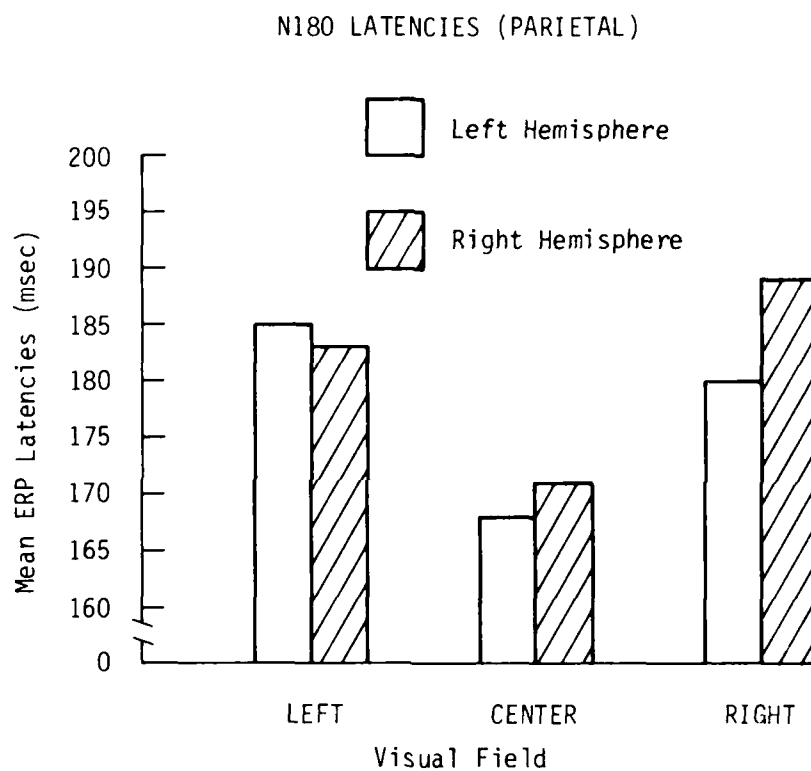   component for 12 subjects

FIGURE 14   Mean N 180 latencies (parietal) as a function of
visual field and recording sites

significant Placement X Field effect for the parietal N180 latency, F (2, 20)
= 17.45, p < .01. Thus, the Placement X Field interaction shown in Figure 13
is primarily due to this group. This can be observed in a plot of the
Placement X Field interaction for the Right-up group depicted in Figure 15.
The N-K comparisons show significantly shorter right hemisphere latencies
(197) vs left hemisphere (185) with LVF hemisphere (180 msec) than right
hemisphere (191 msec) with RVF stimulation, p < .01. Thus, there was a
contralateral latency advantage at each hemisphere for the parietal N180
component.

An examination of Tables 2 and 4 shows that N180 amplitudes were larger
at occipital than parietal sites under comparable conditions of visual field
stimulation. This relationship reverses with P320 amplitudes since for this
component the parietal areas give larger amplitude responses than occipital
sites under comparable conditions of stimulation. These relationships are
graphed in Figures 16 and 17. These differences were examined by ANOVAs and
significant effects were found between placements at each hemisphere for each
component. The Placement F-ratios were as follows: Amplitude, N180
component, F (1, 10) = 14.11, p < .01; amplitude P320 component, F (1, 10) =
14.13, p < .01. The N-K comparisons showed the N180 components to be
significantly greater at occipital locations and P320 to be larger at parietal
areas (p < .01 for all comparisons).

The ERPs for the first and second halves of the experimental sessions
were also examined by ANOVA. The latency results show that significant
latency delays occurred for the N180 component at both occipital and parietal
areas F (1, 10) = 16.14 and F (1, 10) = 31.31, respectively (p < .01 for
both). The actual first-second half differences were 189 msec to 195 for the
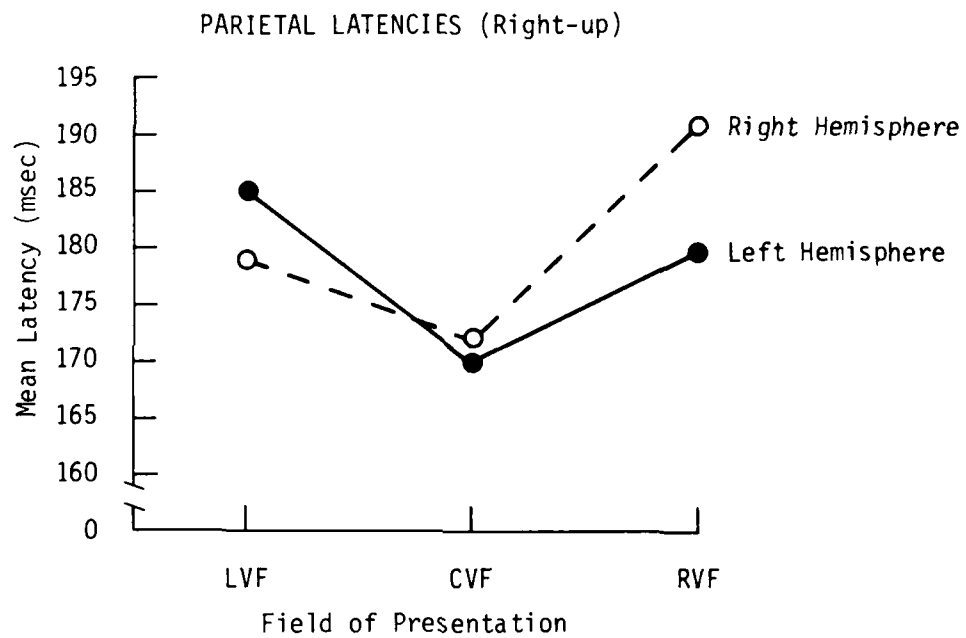occipital area and 186 to 192 msec for the parietal area. The P320 occipital

FIGURE 15 Placement X field interaction for N 180 parietal component
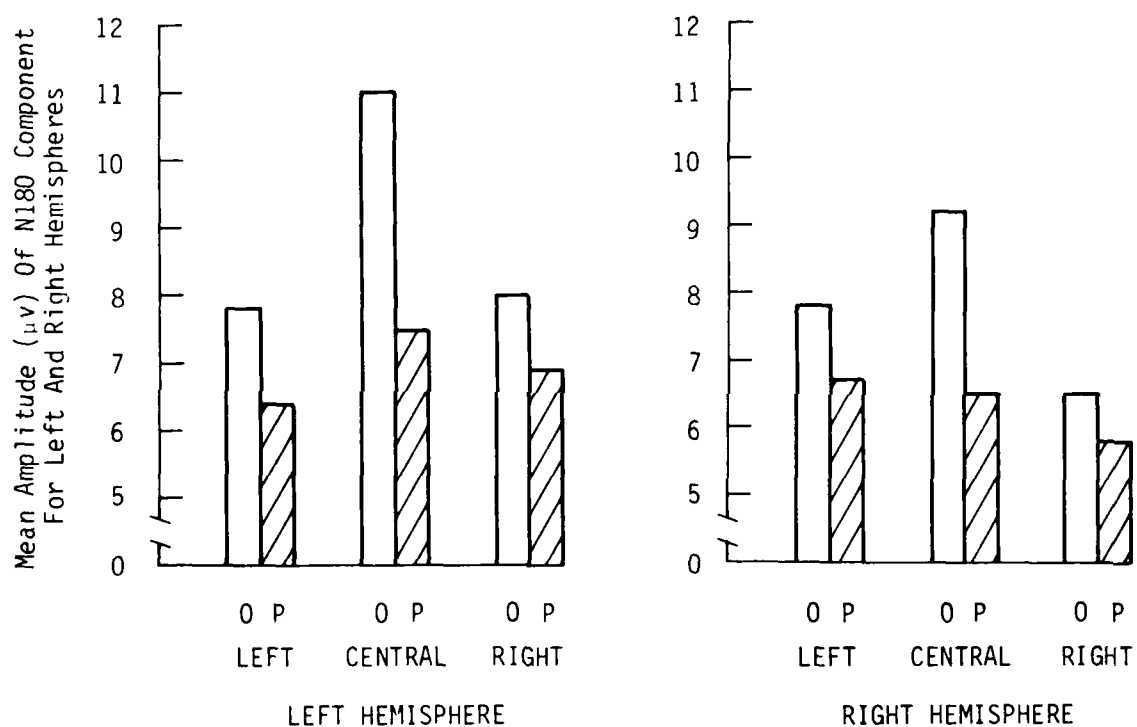for six right-up subjects

FIGURE 16   Mean amplitudes of N 180 component as a function of hemisphere, visual field and recording site
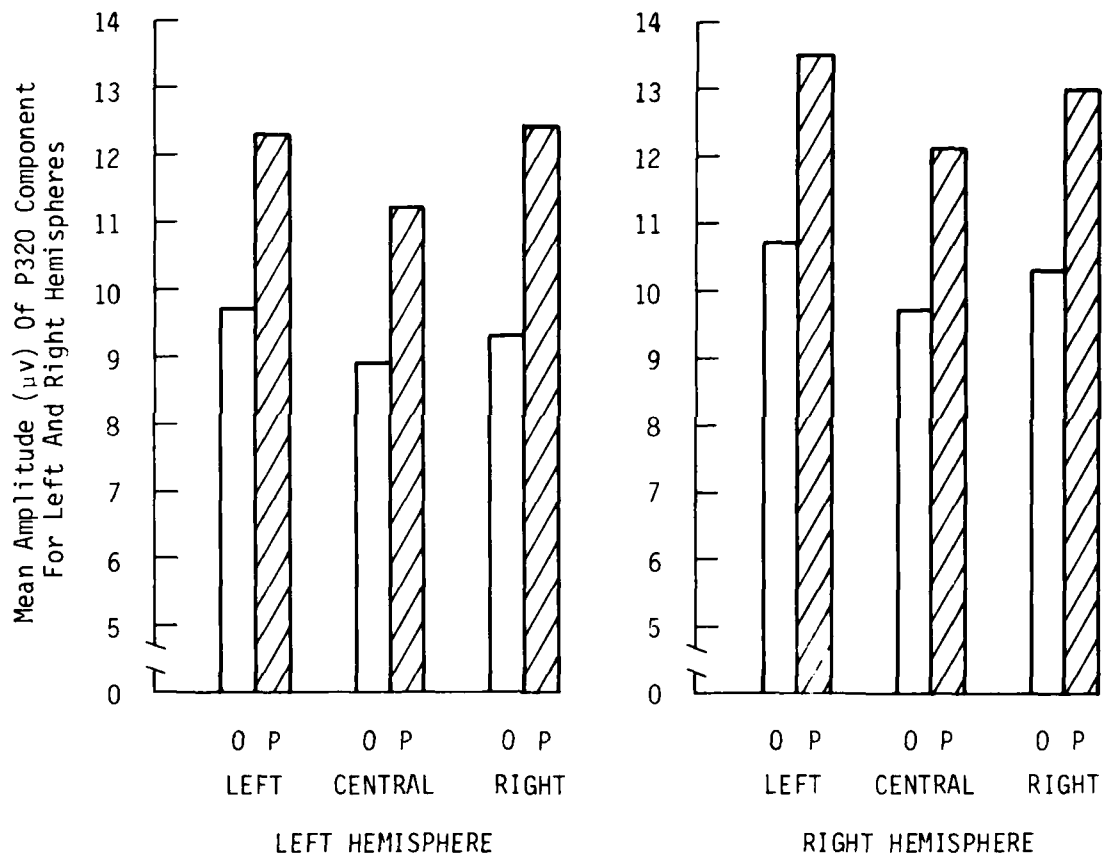
FIGURE 17   Mean amplitudes of P 320 component as a function of
hemisphere, visual field and recording site

component showed a first-second half change of 335 to 342 msec, F (1, 10) = 18.37, while the P320 parietal component showed a 326 to 335 msec difference, F (1, 10) = 22.05 (p < .01, for both). Thus, significant time effects were obtained for the first and second halves. The only amplitude change observed was for the P320 component at the parietal area. This was a decrease of from 12.3uV to 11.5uV for the first to second half, F (1, 10) = 9.66, p < .05. There were no significant latency or amplitude differences observed for the Right-up verus the Left-up group.

Reaction Time Data - The RT data are plotted in Figure 18 and show speed of response as a function of visual field and hand of response. The figure suggests an interaction between hand of response and field of presentation. The RT data entered into the ANOVA were log-transformed to ensure that they would meet the assumptions of normality of distribution and homogeneity of variance required by ANOVA. This was done because the RT data were skewed.

The ANOVA for RT data show a significant effect for Time, F (1, 10) = 5.36, p < .05; Field, F (2, 20) = 21.95, p < .01; and Hand X Field, F (2, 20) = 3.67, p < .05. The Time effect was due to a longer mean RT in the second half of the session as compared to the first half (756 msec vs 779 msec). Separate ANOVAs for the two groups revealed that the time effect was due to a significant slowing in RT for the Right T-up group between the first and second halves, an effect not observed in the Left T-up group. That is, the Right T-up group had a mean RT of 724 msec for the first half and 759 for the second half, F (1, 10) = 8.83, p < .05; the Left T-up group had a mean RT of 788 msec for the first half and 798 msec for the second, F (1, 10) = .19, p < .05. The Field effect is related to a mean RT of 774 msec for the LVF, 742 msec for the CVF and 785 msec for the RVF. The N-K comparisons indicated that RTs for CVF presentations were faster than for either LVF or RVF (p < .01), and the RVF did not differ from LVF. The plot of the Hand X Field
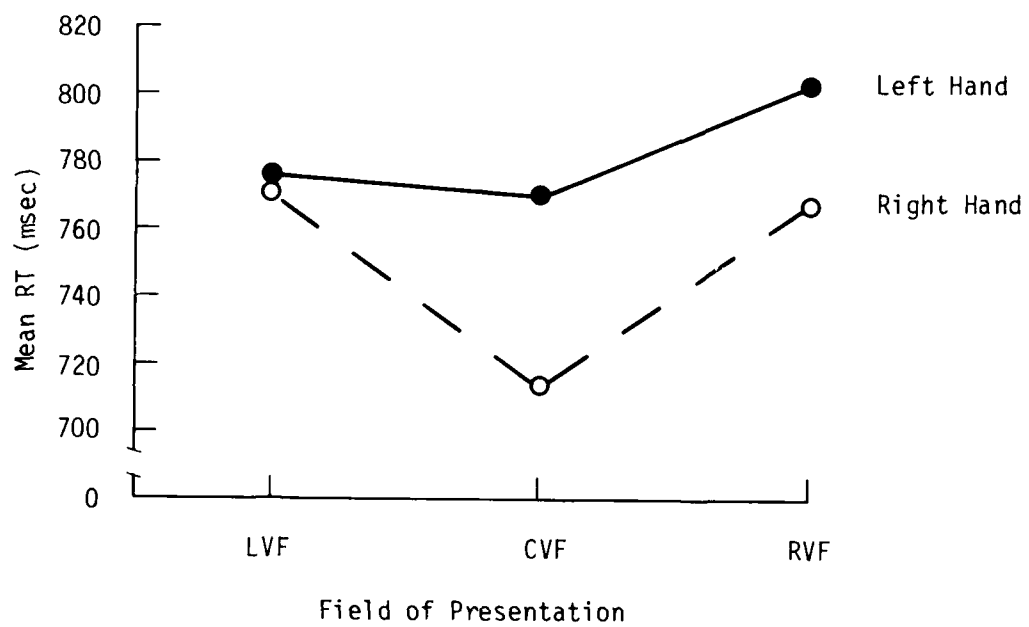
FIGURE 18   Mean RT (12 subjects) as a function of visual
field and responding hand

interaction for the 12 subjects is presented in Figure 18. The plot shows a decided right hand superiority in RT with CVF presentations. A N-K comparison indicates that this difference is significant at $p < .01$. The other significant comparisons involve the right hand; i.e., when the right hand is used there is a significant slowing of RT with LVF and RVF presentations vs CVF presentations. When separate ANOVAs were calculated for the Right T-up subjects and the Left T-up subjects, significant Hand X Field interactions were observed (see Figures 19 and 20). When these significant effects were examined by N-K comparisons for the Right T-up group it was found that RTs were faster with the right hand than the left with both CVF and RVF presentations (N-K, $p < .01$). However, for the Left T-up group the only significant difference was a faster right hand response with CVF presentations.

Error Analyses - There were a total of 439 errors made by all subjects in the two sessions. The breakdown over time is 223 errors for the first half and 216 for the second. A t-test for correlated data indicated that this difference was not significant. With respect to visual field, 159 errors were made with LVF presentations, 162 with RVF and 118 with CVF. The t-values for CVF vs RVF and LVF were 2.29 and 2.31, respectively ($p < .05$). Errors did not differ for RVF and LVF. A significantly greater number of errors were made with the non-preferred hand (left) compared to the preferred hand. The mean difference was 249 vs 190 errors, with a t-ratio of 3.20 ($p < .05$).

Another aspect of this experiment which must be considered as part of the Results section is the subject's reaction. Subjects in the Left-up group complained that to respond with their left hand to the T in the rightside up orientation and with the preferred (right) hand to the upside down T seemed "unnatural", "strange" or "awkward". There we no such complaints from the Right-up group.
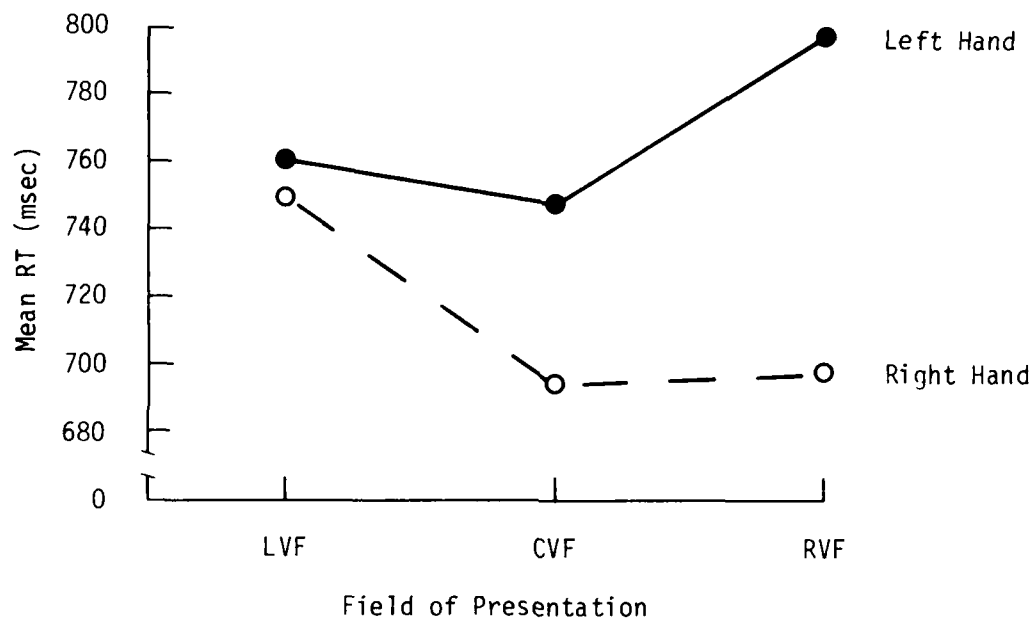
FIGURE 19   Mean RT (6 right-up subjects) as a function of
visual field and responding hand
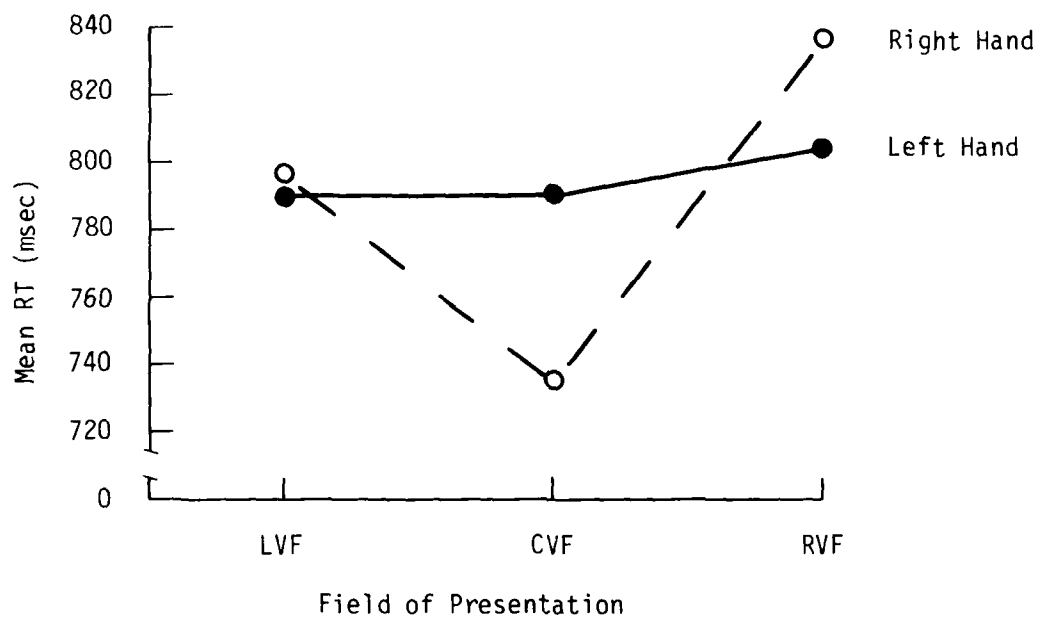
FIGURE 20   Mean RT (6 left-up subjects) as a function of
visual field and responding hand

The behavior of three subjects must be noted. One of these had strong visual hallucinations, especially during the first session. For example, he reported seeing "one of my professor standing in a field of snow" and other visual hallucinations. He also reported hearing his name being called. A second subject fell asleep during one of the sessions. The sleep period resulted in slow wave activity being observed in the EEG record. After the subject missed three consecutive signals the experimenter called his name once and he immediately awoke saying, "oops, I fell asleep", and continued the rest of the session without lapsing into sleep again. This same subject remarked upon leaving the IAC chamber after the first session that, " I could smell the rubber". He explained that he had once spent two years aboard a Navy destroyer taking 4 hour watches in a rubber gun-mount. His task was to watch the shore line through a telescope and warn gunners of possible civilian targets during gunnery practice.

A third subject found the experimental situation so confining that he was reluctant to return for a second session. He had to be replaced by another individual.

Discussion

The data analyses indicated the emergence of two major ERP components at all recording sites. There was a negative peak occurring at about 180 msec post-stimulus and a positive peak at about 320 msec after the stimulus. The N180 peak represents the cortical response to visual stimulation and corresponds to visual ERP latencies obtained under a wide variety of stimulating conditons (Andreassi, 1976; Regan, 1972; Vaughan, 1969). Recordings made from the cortical surface of humans indicate that most sensory ERP components (e.g., aduitory, visual, somatosensory) seem to originate in or near the primary cortical sensory areas (Goff et al., 1978).

The positive peak is the well-documented P300 response which a variety of investigators have related to cognitive activites (Donchin et al., 1973, 1975; Hillyard et al., 1973; Ritter and Vaughan, 1969; Sutton et al., 1965; and also see a review by Donchin, Ritter, and McCallum, 1978). In the present study the P300 wave developed because of the requirement to discriminate between a T-up and T-down and to decide whether to respond with the left or right hand on each trial.

The data analyses indicated that visual field of stimulation influenced the latencies and amplitudes of these ERP components. We will examine these effects more closely, first for the occipital responses, then for the parietal responses. The N180 occipital responses indicated strong contralateral latency effects. More specifically, when the stimulus was in the RVF, latencies were shorter at the left hemisphere as compared to the right. These latency effects are similar to those observed by Andreassi et al. (1975) and Ledlow et al. (1978). The opposite happened with RVF stimulation. These differences are due to the organization of the visual system in which each

visual field projects to the contralateral hemisphere. The contralateral latency advantage was not demonstrated for the P320 occipital latencies. This N180 effect was more pronounced for the Right-up group than the Left-up group since the Right-up group showed a contralateral latency advantage for the LVF and RVF, while the Left-up group showed it only for the RVF. This between-group difference is puzzling. Closer inspection revealed that this between group difference was caused mainly by reversal of the contralateral advantage trend in two of the Left-up subjects, and perhaps may be related to undetected lapses in focusing on the fixation point.

A striking latency effect is the consistently shorter latencies observed with CVF presentations. This is due to foveal stimulation produced by centrally located stimuli. The dense concentration of cone cells in the fovea is partly responsible for the high degree of visual acuity in this area. Foveal cone cells are served by a greater number of retinal ganglion cells than the rod cells of the peripheral retina. The ganglion cells form the optic nerve. Thus, foveal cells have richer representations in the pathways traversing to cortical visual areas than do extra-foveal cells. The 2.5 deg lateral presentation in both visual fields was just outside the 2.0 deg estimated as foveal extent (Ruch et al., 1965). This effect of CVF in producing the shortest latency ERPs was also obtained with occipital P320 latencies.

The N180 amplitudes were largest with CVF stimulation, for reasons similar to those which make CVF generated ERPs the shortest in latency, i.e., the predominance of foveal projections in the visual system. However, there was no significant contralateral amplitude advantage for the N180 component as previously reported by Andreassi et al. (1975), Eason and Dudley (1971), and Eason and White (1967).

The parietal area responses showed N180 latencies which indicated a contralateral advantage when examined for the 12 subjects as a whole, i.e., a significant RVF effect for hemispheric latency asymmetries, with a trend in the same direction for the LVF. However, as with the occipital advantage for both RVF and LVF. Both the N180 and P320 parietal latencies showed a strong CVF effect, i.e., shortest latencies of response. Parietal amplitudes were not significantly influenced by any of the conditions.

When there is a contralateral latency effect at a given hemisphere, one notes that a response also takes place at the opposite hemisphere. It has been proposed that this opposite hemisphere response is most likely due to transmission of impulses via neuronal fibers of the corpus callosum, from one visual area to another (Andreassi et al., 1975; Ledlow et al., 1978). In primates (rhesus monkeys) transcallosal fibers of the visual system terminate in a strip of cortex between striate and prestriate and other areas of visual cortex, including the parieto-occipital sulcus (Van Essen and Zeki, 1978).

When overall latency effects are considered, it is clearly evident that there are no hemispheric asymmetries with CVF stimulation. However, with respect to occipital N180 amplitude there was a left hemisphere advantage. Perhaps the verbal aspect of the task, i.e., responding to a letter T, caused the larger left hemispheric response. In general, the similarity of hemispheric response with CVF stimulation indicates that the stimuli had approximately equivalent effects on the two hemispheres under this condition.

There were larger amplitude P320 components at parietal areas than occipital sites. This suggests that the brain processes generating this cognition-related response are operating more strongly at parietal areas than at occipital. The parietal sites selected (approximately over the angular gyri of left and right hemispheres) are known to be associated with cognitive

activities. In this present case we believe the cognitive activity which
generated the P300 response was the decision to respond with either the right
or the left hand. A number of studies have shown parietal maxima for the P300
response (Donchin et al., 1978). The N180 component, related to the visual
response, was greater in amplitude at both occipital sites compared to the
parietal locations. These findings underscore the greater role of occipital
brain areas in processing visual stimuli and the involvement of parietal
cortex in cognitive activities. A study by Ritter et al. (1979) produced
results similar to ours since they found that the P300 response was maximal at
parietal areas while the visual ERPs were greatest in amplitude at occipital
sites. These investigators also reported that the P300 response showed
similar response patterning at the scalp recording sites for both auditory and
visual stimuli. On the other hand, auditory and visual ERPs showed different
patterns of response, i.e., the auditory responses were maximal at central
areas and visual responses were greatest at occipital sites. Thus, the P300
response was not as affected by stimulus modality as were the sensory ERPs.
This result demonstrates once again that the P300 response is more dependent
on internal (endogenous) factors than are the sensory ERPs.

Reaction times were fastest with CVF presentations. Further, right hand
responses were faster than left hand RTs with CVF stimulation, indicating a
superiority with the preferred hand. This RT result appears to have some
relation to ERP latencies sinces CVF generated ERPs were consistently shorter
in latency than peripherally evoked ERPs. However, this does not mean that
the shorter ERPs caused the shorter RTs. The relationship could represent the
relation of both to some third factor, i.e., centrality of stimulation. In
other words, the CVF stimulation causes both shorter latency ERPs and RTs, but
the shorter latency ERPs do not necessarily cause the shorter RTs. If short

ERP and RT latencies covary in a given stimulus condition, the ERP latencies
might be predictive of RT latencies in that situation.

The relatively long mean RTs obtained in this study (700-800 msec)
contrast with those found in experiments where there is one stimulus and one
response (simple RT). In the simple RT situation responses typically average
between 200 and 300 msec. The RT paradigm used in this study is choice RT, in
which the subject has more than one stimulus and more than one response.
Thus, the RT was more than doubled compared to simple RT, reflecting the extra
time required to decide about the response to be made on each trial.

The mean RT over the 12 subjects was 778 msec for the ipsilateral hand
responses and 791 msec for the hand contralateral to the stimulus. This
significant 13 msec difference is greater than that obtained by Berlucchi et
al., 1971, 1977 and Poffenberger, 1912, but, as has been mentioned previously,
larger ipsilateral-contralateral differences occur when stimulus location is
not known (Ledlow et al., 1978). The 13 msec difference was significant, but
separate analyses showed that it was due mainly to the Right-up group's
responses. That is, they had faster RTs with the right hand than the left
with RVF stimulation. Thus, the ipsilateral-contralateral RT difference
previously reported was observed only partially in one sub-group of subjects.
This partial effect occurred in the sub-group which showed the stronger
contralateral ERP latency effects and who did not complain about the relation
between the hand of response and stimulus orientation. One might be tempted
to conclude that the ipsilateral RT effect may be shown to a greater degree
with persons who show clear contralateral latency advantages for ERPs.
However, this still would not rule out the role played by stimulus-response
compatibility in producing the ipsilateral-contrlateral hand RT differences,
as suggested by Broadbent (1974). The role of S-R compatibility is further

reinforced by the fact that for RVF stimulation the Left-up group showed faster contralateral RTs, a reversal of the proposed ipsilateral advantage. Hence, the model of IHTT based on RT differnces is given support only by the results for the group for whom there was stimulus-response compatibility.

The question regarding RT as an estimate of IHTT still does not seem to be resolved. In some studies (e.g., Berlucchi et al., 1971, 1977; Harvey, 1978; Poffenberger, 1912) it would appear that the RT advantage observed for the hand ipsilateral to the stimulus can be explained by primary projections to the hemispheres in control of the reponding hand. Others, such as Broadbent (1974), Simon et al. (1970), and Wallace (1970), have argued for the role of S-R compatibility in producing the faster ipsilateral hand responses, i.e., it is easier for subjects to respond faster when the stimulus is on the same side as the responding hand. A study by Anzola et al. (1977) sheds some light on this controversy. In their first experiment, employing a simple RT paradigm, responses by the ipsilateral hand were faster regardless of whether hands were crossed or uncrossed. They concluded, therefore, that in the simple RT situation the directness of the anatomical connections between the receiving hemiretinae and the responding hand was the critical determining factor, not the spatial contiguity of the hand with respect to the stimulus. In a second experiment a choice RT paradigm was used. This time the ipsilateral hand was faster in the uncrossed hand trials, but the opposite occurred when hands were crossed. Thus, with choice RT spatial contiguity of responding hand and stimulus was important, i.e., spatial compatibility, and not the directness of the anatomical connections. The anatomical factor, therefore, was overshadowed by the compatibility and hand position factors in the choice RT situation. Anzola and colleagues conclude that when the task does not require decisions the directness of anatomical connectivity prevails

and no spatial compatibility effect is present. However, compatibility
between stimulus and response become important when the task involves a choice
between different responses.

Many variables seem to affect the model of IHTT based on RT differences.
For example, the factors of spatial compatibility, hand position, knowledge of
stimulus location and use of preferred versus nonpreferred hand. These
complications attenuate the usefulness of RT measures as estimates of IHTT.
Therefore, it is suggested that contralateral-ipsilateral ERP latencies
(visual, somatosensory) may provide more reliable and valid estimates of IHTT
than RT.

Is one hemisphere superior to the other with respect to vigilance
performance? The results of this experiment do not seem to support such a
notion nor do they support the concept advanced by Dimond and Beaumont (1973)
and Dimond (1977). The reason for this conclusion is based on the RT and
error analyses for LVF vs RVF presentations. As noted in the introduction,
RVF presentations are processed primarily by the left hemisphere and LVF
presentations by the right hemisphere. The RT analyses indicated that
response time was not significantly different for stimuli projected to left
and right hemispheres, 785 and 774 msec, respectively. In addition, the error
analysis showed 162 and 159 errors for left and right hemispheres. Therefore,
no left-right hemisphere difference was found in the vigilance task used in
this study when response time and errors were used as criteria.

Further error analyses indicated that the fewest errors were made with
CVF presentations, once again emphasizing the superiority of central
stimulation in this vigilance task. A significantly greater number of errors
were made with the left hand than the right, a result which indicates the
importance of responding hand in a situation such as the one devised in our
study.

Conclusions

1. The N180 component observed in this study represents a cortical response to visual stimulation. This component was significantly larger at occipital (visual) areas than at parietal areas. The P320 component occurred consistently in all subjects and is associated with discriminations of stimulus orientation and decisions about the responding hand. This component, commonly attributed to cognitive activities, was larger at parietal than occipital areas suggesting that the brain processes generating this response operate more strongly at parietal areas than at occipital.

2. Analyses of reaction time measures and error scores indicate that the left and right hemispheres did not differ with regard to detection performance.

3. Latencies of N180 components were shorter when the field of stimulation was contralateral to the hemisphere from which the recording was made. The latency difference between cortical responses to contralateral and ipsilateral stimulation represents, at least in part, time for neuronal impulses to cross the corpus callosum.

4. Central visual field stimulation (foveal) resulted in shorter RT and ERP latencies. Foveal stimulation results in shorter latencies because of the greater representation of cone cells in the human visual system. While the two may not be causally related ERP latencies may be predictive of RT.

5. The model which uses RT as a measure of interhemispheric transfer time (IHTT) received only partial support in this study. The results from our study and those of others suggest that the model may only hold in simple RT paradigms. More complicated RT paradigms (e.g., choice RT) might be best explained by stimulus-response compatibility factors. Since RT estimates of IHTT are complicated by the paradigm used, then ipsilateral-contralateral ERP

differences may be more reliable and valid estimates of IHTT than RT differences.

6. Time effects were observed in that significant slowing of ERP components from the first half to second halves of the experimental sessions were accompanied by a slowing of time to respond to signals. It was proposed that this slowing may have resulted from a waning of attentiveness over time in the vigilance situation.

References

Andreassi, J.L., Okamura, H., & Stern, M. Hemispheric asymmetries in the
    visual cortical evoked potential as a function of stimulus location.
    Psychophysiology, 1975, 12, 541-546.

Andreassi, J.L., DeSinone, J.J., & Mellers, B.W. Amplitude changes in the
    visual evoked cortical potential with backward masking.
    Electroencephalography & Clinical Neurophysiology, 1976, 41, 387-398.

Anzola, G.P., Bertoloni, G., Buchtel, H.A., & Rizzolatti, G. Spatial
    compatibility and anatomical factors in simple and choice reaction time.
    Neuropsychologia, 1977, 15, 295-302.

Beck, E.C. Electrophysiology and behavior. Annual Review of Psychology,
    1975, 26, 233-262.

Berlucchi, G., Crea, T., Di Stefano, M., & Tassinari, G. Influence of spatial
    stimulus-response compatibility on reaction time of ipsilateral and
    contralateral hand to lateralized light stimuli. Journal of Experimental
    Psychology: Human Perception and Performance, 1977, 3, 505-517.

Berlucchi, G., Heron, W., Hyman, R., Rizzolatti, G., & Umilta, C. Simple
    reaction times of ipsilateral and contralateral hand to lateralized
    visual stimuli. Brain, 1971, 94, 419-430.

Broadbent, D.E. Division of function and integration of behavior. In F.E.
    Schmitt & F.G. Worden (Eds.) The neurosciences: Third study program.
    Cambridge, MIT Press, 1974.

Butler, R.A., Keidel, W.D., & Spreng, M. An investigation of the human
    cortical evoked potential under conditions of monaural and binaural
    stimulation. Acta Otolaryngologica, 1969, 68, 317-326.

Davies, D.R. and Parasuraman, R. Cortical evoked potentials and vigilance: A
    decision theory analysis. In: Mackie, R.R. (Ed.) Vigilance: Theory,
    operational performance, and physiological correlates. New York, Plenum,
    1977.

Dimond, S.J. & Beaumont, J.G. Hemisphere function and vigilance. Quarterly
    Journal of Experimental Psychology, 1971, 23, 433-448.

Dimond, S.J. & Beaumont, J.G. Differences in the vigilance performance of the
    right and left hemispheres. Cortex, 1973, 9, 250-265.

Dimond, S.J. Vigilance and split brain research. In: Mackie, R.R. (Ed.)
    Vigilance: Theory, operational performance and physiological
    correlates. New York: Plenum, 1977.

Donchin, E., Teuting, P., Ritter, W., Kutas, M., & Heffley, E. On the
    independence of the CNV and P300 components of the human averaged evoked
    potential. Electroencephalography & Clinical Neurophysiology, 1975, 38,
    449-461.

Donchin, E., Ritter, W., & McCallum, W.C. Cognitive psychophysiology: The endogenous components of the ERP. In: Callaway, E., Teuting, P., & Koslow, S.H. Event-related potentials in man. New York: Academic Press, 1978, pp. 349-411.

Donchin, E., Kubovy, M., Kutas, M., Johnson, R., & Herning, R.I. Graded changes in evoked response (P300) amplitude as a function of cognitive activity. Perception & Psychophysics, 1973, 14, 319-324.

Eason, R.G., & Dudley, L.M. Effect of stimulus size and retinal locus of stimulation on visually evoked cortical responses and reaction in man. Psychonomic Science, 1971, 23, 345-347.

Eason, R.G., & White, C.T. Averaged occipital responses to stimulation of sites in the nasal and temporal halves of the retina. Psychonomic Science, 1967, 7, 309-310.

Filbey, R.A., & Gazzaniga, M.S. Splitting the normal brain with reaction time. Psychonomic Science, 1969, 17, 335-336.

Goff, W.R., Allison, T., & Vaughan, H.G. Jr. The functional neuroanatomy of event-related potentials. In E. Callaway, P. Teuting, & S.H. Koslow (Eds.), Event-related potential in man. New York: Academic Press, 1978, pp. 1-80.

Gomer, F.E., Spicuzza, R.J., & O'Donnell, R.D. Evoked potential correlates of visual item recognition during memory-scanning tasks. Physiological Psychology, 1976, 4, 61-65.

Haider, M., Spong, P., & Lindsley,, D.B. Attention, vigilance, and cortical evoked potentials in humans. Science, 1964, 145, 180-182.

Harvey, L.O., Jr. Single representation of the visual midline in humans. Neuropsychologia, 1978, 16, 601-610.

Hillyard, S.A., Hink, R., Schwent, V., & Picton, T. Electrical signs of selective attention in the human brain. Science, 1973, 182, 177-179.

Hillyard, S.A., Squires, K.C., Bauer, W., & Lindsay, P.J. Evoked potential correlated to auditory signal detection. Science, 1971, 172, 1357-1360.

Jasper, H.H. Report of the committee on methods of examination in electroencephalography. Electroencephalography & Clinical Neurophysiology, 1958, 10, 370-375.

Jeeves, M.A. A comparison of interhemispheric transmission times in acallosals and normals. Psychonomic Science, 1969, 16, 245-246.

Jeeves, M.A. Hemisphere differences in response rates to visual stimuli in children. Psychonomic Science, 1972, 27, 201-203.

Kinsbourne, M., Swanson, J.M., & Ledlow, A. Measuring interhemispheric transfer time in man. Transactions of the American Neurological Association, 1977, 102, 1-4.

Kutas, M., McCarthy, G., & Donchin, E. Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. Science, 1977, 197, 792-795.

Ledlow, A., Swanson, J.M., & Kinsbourne, M. Differences in reaction times and average evoked potentials as function of direct and indirect neural pathways. Annals of Neurology, 1978, 6, 525-530.

Majkowski, J., Bochenek, Z., Bochenek, W., Knapik-Fijalkowska, D., & Kopec, J. Latency of averaged evoked potentials to contralateral and ipsilateral auditory stimulation in normal subjects. Brain Research, 1971, 24, 416-419.

Poffenberger, A.T. Reaction time to retinal stimulation with special reference to the time lost in conduction through nervous centers. Archives of Psychology, 1912, 23, 1-73.

Regan, D. Evoked potentials in psychology, sensory physiology and clinical medicine. New York: Wiley, 1972.

Ritter W., & Vaughan, H.G. Averaged evoked responses in vigilance and discrimination: A reassessment. Science, 1969, 164, 326-328.

Ritter, W., Simson, R., & Vaughan, H.G. Topographic analysis of task-related cerebral potentials. In: Desmedt, J.E. (Ed.) Cognitive components in cerebral event-related potentials and selective attention. Basel: S. Karger, 1979.

Rohrbaugh, J., Donchin, E., & Ericksen, C.W. Decision making and the P300 component of the cortical evoked response. Perception & Psychophysics, 1974, 15, 368-374.

Ruch, T.C., Patton, H.D., Woodbury, J.W., & Towe, D.L. (Eds.) Neurophysiology. Philadelphia: Saunders, 1965.

Ruchkin, D.S., Sutton, S., & Tueting, P. Emitted and evoked P300 potentials and variation in stimulus probability. Psychophysiology, 1975, 12, 591-595.

Salamy, A. Commissional transmission: Maturational changes in humans. Science, 1978, 200, 1409-1411.

Smith, D., Donchin, E., Cohen, L., & Starr, A. Auditory evoked potentials in man during selective binaural listening. Electroencephalography & Clinical Neurophysiology, 1970, 28, 146-152.

Squires, K.C., Hillyard, S.A., & Lindsay, P.H. Vertex potentials evoked during auditory signal detection: Relation to decision criteria. Perception & Psychophysics, 1973, 14, 265-272.

Squires, N.K., Squires, K.C., & Hillyard, S.A. Two varieties of long-latency positive waves evoked by unpredictable auditory stimuli in man. Electroencephalography & Clinical Neurophysiology, 1975, 38, 387-401.

Squires, K.C., Donchin, E., Herning, R.I., & McCarthy, G. On the influence of task relevance and stimulus probability on event related potential components. Electroencephalography & Clinical Neurophysiology, 1977, 42, 1-14.

Sutton, S., Braren, M., Zubin, J., and John, E.R. Evoked potential correlates of stimulus uncertainty. Science, 1965, 150, 1187-1188.

Van Essen, D.C., & Zeki, S.M. The topographic organization of rhesus monkey prestriate cortex. Journal of Psysiology, 1978, 277, 193-226.

Wallace, R.J. S-R compatibility and the idea of a response code. Journal of Experimental Psychology, 1971, 88, 354-360.