AD-A111 176   BERNARD M BARUCH COLL NEW YORK PSYCHOPHYSIOLOGY LAB   F/G 5/10
BRAIN RESPONSES AND INFORMATION PROCESSING. II. INVESTIGATIONS --ETC(U)
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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
AFOSR-TR- 82 -0051

2. GOVT ACCESSION NO.
AD-A111116

3. RECIPIENT'S CATALOG NUMBER

BRAIN RESPONSES AND INFORMATION PROCESSING II:
INVESTIGATIONS OF HEMISPHERIC ASYMMETRY IN EVENT
RELATED POTENTIALS DURING PERCEPTION OF MOTION
AND LINE LENGTH

5. TYPE OF REPORT & PERIOD COVERED
Annual Report
1 Oct. 1980- 30 Sept. 1981

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
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and
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8. CONTRACT OR GRANT NUMBER(s)
F 49620-80-[illegible]

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Baruch College, City University of New York
School of Liberal Arts and Sciences
New York, N.Y. 10010

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
611 02F
2313/A4

11. CONTROLLING OFFICE NAME AND ADDRESS
Air Force Office of Scientific Research (NL)
Bolling Air Force Base
Washington, D.C.

12. REPORT DATE
30 Nov. 1981

13. NUMBER OF PAGES
80

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 is 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
- P300 Response
- Hemispheric Latency Asymmetries
- Perception of Motion
- Discrimination of Line Length
- Eye Muscle imbalance

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

This is the second annual report to originate from the Psychophysiology Laboratory of the Psychology Department at Baruch College. The research completed over the last 12 months has included a number of studies concerned with evoked cortical potential correlates of visual stimulus processing in humans. Experiment I examines the visual event-related potential (ERP) as a function of moving and stationary stimuli presented in three visual fields. The main finding was that, for female subjects, right hemispheric derived ERPs were larger in amplitude than left hemisphere recordings for moving

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) stimuli presented centrally. Males showed no hemispheric amplitude differences. However, for male subjects the left hemisphere ERP latencies to motion were longer than those recorded from over the right hemisphere with central visual field (CVF) presentations. The sex differences are difficult to explain especially since the literature points to greater right hemisphere specialization for visuospatial stimuli in males than females. It was speculated that different attentional strategies in the two sexes led to the observed result.

Experiment II deals with the problems of undetected strabismic persons in evoked potential research. Approximately 14% of the individuals screened for our research (15 of 109) suffered from strabismus (eye muscle imbalance). These individuals have difficulty in fixating a central point in their visual field with both eyes. A comparison of results for six strabismic and six normal eye balance subjects revealed that strabismics do not show the expected latency and amplitude advantages of contralateral hemispheric stimulation. It was concluded that in studies of hemispheric functional asymmetries, subjects should be carefully screened for strabismus, especially when the research strategy dictates that they fixate centrally while stimuli are presented in different visual fields.

The final study concerns the discrimination of line length in three visual fields and the relation of this process to ERPs. Our performance data included no difference in accuracy of discriminations in left visual field (right hemisphere) and right visual field (left hemisphere). The latency of the P300 component was significantly longer with ambiguous as compared to clear discriminations. It was concluded that ambiguous discriminations require a greater time for stimulus evaluation and this was reflected in delayed P300 latencies.

Included at the outset of this annual report is an introductory section which points out the relevance of evoked potential research for the Air Force. This account also includes examples of how our past and current research findings might be applicable to Air Force or civilian problems.

BRAIN RESPONSES AND INFORMATION PROCESSING II: INVESTIGATIONS OF HEMISPHERIC ASYMMETRY IN EVENT RELATED POTENTIALS DURING PERCEPTION OF MOTION AND LINE LENGTH

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For:

Air Force Office of Scientific Research
Contract F49620-80-C-0013

Second Annual Report

30 November 1981

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Brain Responses and Information Processing II: Investigations of Hemispheric Asymmetries in Event Related Potentials During Perception of Motion and Line Length.

Prepared by: John L. Andreassi, Ph.D.
and
N. Mauro Juszczak, B.A.

Abstract

This is the second annual report to originate from the Psychophysiology Laboratory of the Psychology Department at Baruch College. The research completed over the last 12 months has included a number of studies concerned with evoked cortical potential correlates of visual stimulus processing in humans. Experiment I examines the visual event-related potential (ERP) as a function of moving and stationary stimuli presented in three visual fields. The main finding was that, for female subjects, right hemisphere derived ERPS were larger in amplitude than left hemisphere recordings for moving stimuli presented centrally. Males showed no hemispheric amplitude differences. However, for male subjects the left hemisphere ERP latencies to motion were longer than those recorded from over the right hemisphere with central visual field (CVF) presentations. The sex differences are difficult to explain especially since the literature points to greater right hemisphere specialization for visual spatial stimuli in males than females. It was speculated that different attentional strategies in the two sexes led to the observed result.

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Introduction - Possible Applications of this Research to Air Force Problems.

The question of display-operator compatibility is a pervasive one in both military and nonmilitary man-machine systems. The primary query is, "How can displays be made more efficient in conveying information to the operator of a system?" The "system" can be any equipment complex involving displays and people and can range from panels in aircraft and automobiles to those used in air traffic control centers and automated factories.

Human Factors scientists have made great strides in the improvement of display design to enable more efficient use by the operator. These improvements have now been widely accepted and usually serve as basic design principles in the development of new man-machine systems. Examples of areas touched by human factors design principles include information regarding legibility of numerals and letters, arrangement of displays, use of warning signals, ambient illumination, luminance ratios, aircraft position displays, the use of symbols, color coding, and many others (see for example, Baker and Grether, 1972; McCormick, 1976). While Human Factors Engineer have done an admirable job in the improvement of display design, we believe that the basic researcher can provide information with the potential to further enhance human performance. It is our belief that monitoring brain responses known as event related potentials (ERPs) can assist designers by providing information regarding the relative efficiency and involvement of right and left hemispheres of the brain in various visual perceptual activities. Let us explain this belief in greater detail.

In the past decade evidence has accumulated regarding the role of the right and left hemispheres of the brain in processing different kinds of information. The left hemisphere of most human brains is concerned with linguistic, numerical and analytic functions, while the right hemisphere guides activities controlling spatial relationships, nonverbal thinking and artistic abilities. It is known that stimuli to the left of center project primarily to the right hemisphere and stimuli to the right of center project to the left hemisphere of the brain. Thus, it would appear logical to suggest that when a choice must be made between placing different kinds of displays to the left or right of center, those involving spatial or nonverbal (symbolic) information should be placed in the left visual field and those containing alpha-numeric information should be placed in the right visual field. In this latter example, the alpha-numeric information placed off to the right would reach the analytic and language processing areas (in 96% of the population) earlier, and more efficiently, than they would if they were placed in the left visual field. The opposite would be true for the nonverbal (symbolic) information. These are only two of many possible examples that could be given since the relative sensitivity of the two hemispheres in processing motion, shape, line orientation, and color are also variables of interest.

In our first annual report (November, 1980) we reported that reaction times to critical signals slowed over the course of a vigilance session, and this slowing was accompanied by a delay in the brain response to visual targets. While our results did not support a suggestion in the literature (Dimond, 1977) that the left hemisphere would be superior to the right in vigilance performance over the short run, we did obtain a finding of possible importance for display designers. Namely, when a symbolic target was presented to the right hemisphere, the response controlled by that hemisphere (left hand) was faster than when an alphabetic target was presented. Further, when the alphabetic and symbolic targets were presented to the left hemisphere, responses with the right hand were faster to the alphabetic target. Thus, the suggestion here is that when symbolic stimuli are used and responses are required, it would be better to have the stimuli on the left (right hemisphere presentation) and to require a left hand response (right hemisphere control). The opposite would be suggested for alphabetic information.

In the first study covered in the current annual report we found that females showed a greater right hemisphere response to moving stimuli as compared to the left hemisphere response. The males showed no differential hemispheric response to motion. The literature had reported greater right hemispheric specialization for visuospatial tasks in males. Hence, the finding that females appear more sensitive to a visuospatial (motion) stimulus leads us to question whether they would also show a high degree of proficiency in a manual task involving moving stimuli, or whether the sensitivity is limited to merely observing and detecting motion. The answer to this question is of practical significance since it could help in the assignment of female personnel to jobs requiring various visuospatial abilities in either military or civilian occupations.

A number of potential subjects were visually screened during the study on motion. The screening involved tests of acuity, depth perception and eye muscle balance, (strabismus). We found that approximately 14% of our sample had eye muscle imbalance. The strabismus portion of the testing, which was accomplished with our Bausch and Lomb Orthorator, refers to the ability of a person to use the two eyes together in fixating on some object. Persons who have exophoria (the tendency of one or both eyes to move outward) or esophoria (tendency to move inward) have difficulty in fixating. This is important for us to know since presentations of stimuli differentially to the two hemispheres depends strongly on the ability of our subject to fixate on a point which is straight ahead. We decided to examine these individuals in an experimental situation which required them to fixate centrally while stimuli were present in left, right and central visual fields. The six strabismic individuals gave results that differed from a group of six normal controls. Namely, they did not show the usual ERP latency and amplitude advantages observed at the hemisphere contralateral to the presented stimuli. The normal controls did show the expected results. The muscular strains and stresses experienced in trying to overcome the muscular imbalance in attempting to fixate centrally led to complaints of headaches and eye fatigue in strabismic subjects. We have two points to make. The first concerns methodology and suggests that researchers who require central fixation on the part of their subjects in order to accomplish differential hemispheric presentations should screen for strabismus. The second is that persons required to perform long term monitoring tasks, such as monitoring radar screens or other information-giving CRT screens or terminals, should be screened for strabismus. They may have to overcome undetected eye muscle imbalance at the cost of eye fatique or headache, two factors that could lead to performance decrement over time, especially in situations where the workload is high.

In our final experiment we found that latency of the P300 component of the ERP was delayed when subjects were required to make a discrimination in an ambiquous situation. The latency of P300 appears to index stimulus evaluation time (see review by Pritchard, 1981). Therefore, its delayed latency is probably related to the longer time to cognitively evaluate the ambiquous stimuli. To the extent that it does this, it is suggested that P300 latencies be used, along with performance, as an objective indicator of display ambiguity. What we are suggesting here is that equipment designers test the clarity of their displays with P300s, i.e., the shortest latency P300s may reflect the clearest, most unambiqous, display configuration and be related to efficient visual discrimination.

Experiment I: Hemispheric Differences in Visual Evoked Potentials During Perception of Moving and Stationary Stimuli in Three Visual Fields

This research was designed in an attempt to determine whether evoked potentials recorded from over the two hemispheres would indicate differential processing of moving and stationary stimuli. The literature suggests that the right hemisphere is lateralized with respect to visual-spatial abilities especially for males. This right hemisphere specialization has been found in studies using strictly perceptual measures (DeRenzi, 1978; Koss, 1981) and those using both behavioral and electrophysiological responses (Furst, 1976; Rebert and Low, 1978; Robertshaw and Sheldon, 1976).

The perception of motion is dependent upon the timing and spatial aspects of stimuli presented, and thus may be considered to be a visuo-spatial-temporal phenomenon. There are studies which indicate that males show a greater degree of right hemisphere specialization for visuo-spatial functions than females (Harris, 1978; McGlone and Davidson, 1973; Tucker, 1976; Witelson, 1976). For this reason we decided to make a male-female comparison part of our experimental design.

Studies of brain response and motion are not numerous. An early investigation (Barlow, 1964) showed that evoked potentials could be produced by sudden changes in the vertical position of a spot on an oscilloscope. Clarke (1974) produced VEPs through reversals in the horizontal motion of a visual noise pattern. The velocity of motion was

10 degrees of visual angle per second. Clarke suggested that motion-reversal VEPs were produced largely by direction-sensitive mechanisms within the human brain. Coffin (1977) presented subjects with different velocities of apparent motion while EEG was measured. He found higher frequency alpha-range EEG, at a midline occipital placement, with the higher velocity "strong motion" conditions. There was a non-significant trend toward greater right occipital EEG frequencies, but not left, with higher velocities. The greater (non-significant) right hemisphere effect was attributed to the spatiotemporal nature of the task which allowed for some differential processing by the right ("spatial") hemisphere. Andreassi et al. (1979) reported a study in which two types of apparent motion and one stationary condition were presented while EPs were measured from midline, occipital, and central areas. The motion conditions were each presented at three different velocities. The continuous apparent motion condition resulted in greater VEP amplitudes and longer latencies than discrete apparent motion at the two higher velocities (19.18 deg/sec and 13.08 deg/sec). These differences were observed at the occipital but not at the central recording site. The results suggested that the human visual system processes these two types of motion differently.

Based on information contained in the literature we hypothesize that: 1) Visual event related potentials (ERPs) to apparently moving stimuli will produce larger right hemisphere responses as compared to the left hemisphere; 2) Visual ERP latencies will be longer from right hemisphere derivations with motion conditions since that hemisphere will be more involved (engaged) in processing visuo-spatial stimuli; 3) right hemisphere responses of male subjects will be larger and latencies longer to moving stimuli than the corresponding responses of females; 4) Visual ERPs to stationary stimuli will show no hemispheric differential for males or females.

Method

Subjects: The subjects were nine male and nine female right-handed students associated with the City University of New York. They ranged in age from 18-45 years. All subjects were screened for right-handedness by a questionnaire (Annett, 1971). The questionnaire asked subjects to report the preferred hand used in a number of different tasks (see Appendix I). Subjects were tested for vertical and lateral phoria (at distance and at near) and visual acuity with a Bausch and Lomb Orthorator. The phoria test measured eye muscle balance and estimated the subjects ability to fixate. Only subjects showing normal eye muscle balance (Orthophoria) as determined by the Bausch and Lomb Occupational Vision Standards were accepted for further testing. The visual acuity test results of all subjects showed that vision was 20/25 or better (with or without glasses).

Apparatus and Procedure: Subjects were seated in an electrically shielded, sound attenuated IAC chamber. All experimental sessions were conducted with the lights dimmed.

The visual event related potential (ERP) was obtained from O_1 and

O_2 (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to a silver clip electrode on the subject's left ear lobe. A Beckman Type RM Dynograph recorder was used to record the EEG and a Mnemotron Computer of Averaged Transients (CAT 1000) averaged the responses to stimuli. The 9806A coupler of the Dynograph was used to condition the EEG signal (bandpass set at 0.5 to 32.0 Hz). The filtered and amplified signal was then fed into the CAT. A "start" signal from a PDP-8/E digital computer triggered the CAT to take EEG samples of 500 msec duration following the presentation of each stimulus to the subject. After 100 stimulus presentations, the summated ERPs were plotted from CAT memory on a Hewlett-Packard X-Y plotter.

Ongoing EOG was monitored on two separate channels and stored on a Tektronix oscilloscope to observe possible artifacts produced by eye blinks and/or movements. Such artifacts appeared as sudden deviations in the oscilloscope trace. If a given trial showed these contaminations, it was terminated and the subject was reminded to minimize the eye blinks and eye or head movements. The trial was then repeated. Most subjects were trained, having participated in past ERP studies, and EOG artifact was minimal. Subjects were instructed to blink during the two-second interval separating the stimulus presentations.

The stimuli were displayed on a Digital Equipment Corporation VR-14 display which was mounted at the subject's eye level outside the chamber at a distance of 114.3 cm (45 in.). The VR-14 CRT display was controlled by the computer to deliver the stimuli at specific times and locations on the CRT.

There were six experimental conditions consisting of "continuous apparent motion" (CAM) and "stationary" (STAT) stimuli presented in the right, left, and central visual fields. In the CAM conditions, a single vertical line appeared on the screen for 5 msec followed by 9 successive lines each on for 3 msec. The last line was 2.8 cm to the right of the first line. This produced the perception of a single line moving smoothly across the screen from left to right. The stationary conditions consisted of a single line on the screen for 5 msec followed 1 msec later by a second line 2.8 cm to the right of the first line. All subjects reported seeing two simultaneous lines in this STAT condition. The vertical lines were all .5 cm in length. The luminance level for the combined stimuli in the CAM and STAT conditions was 6.68 millilamberts (mL) as measured by a Tektronix J-16 Digital Photometer. The 2.8 cm horizontal separation between the first and last line for CAM and STAT produced a visual angle of 1°24' of arc. Thus, luminance and spatial characteristics were equated for all conditions. The six conditions were as follows:

Condition A - CAM (R) - Right visual field - First line 1°24' of arc to the right of the fixation point. Last line 2°48' of arc to the right of the fixation point.

Condition B - CAM (L) - Left visual field - First line 2°48' to the left of the fixation point. Last line 1°24' to the left of the fixation point.

Condition C - CAM (C) - Central visual field - First line directly under the fixation point. Last line 1°24' to the right of the fixation point.

Condition D - STAT (R) - Right visual field - First line 1°24' to the right the fixation point. Second line 2°48' to the right of the fixation point.

Condition E - STAT (L) - Left visual field - First line 2°48' to the left of the fixation point. The second line was 1°24' to the left of fixation point.

Condition F - STAT (C) - Central visual field - First line directly under the fixation point. The second was line 1°24' to the right of the fixation point.

In both CAM and STAT conditions the first vertical line was of the same luminance and display time. Thus, the stimulus which triggered the ERP in both situations was identical. Any differences in the ERPs between the CAM and STAT conditions would be due to the stimuli following these initial ones and the subject's perception of these stimuli. Eccentricity of the initial vertical line was greater in the LVF than the RVF. This was done to keep direction and extent of motion constant in each visual field, i.e., from left to right with an extent of 1° 24'. The initial locations used were previously found equally effective in producing contralateral hemisphere latency and amplitude advantages in the visual ERP (see Andreassi et al., 1975).

In every instance 2000 msec intervened between each stimulus presentation. For example, in Condition F the stimulus was presented followed by a blank screen for 2000 msec before the next stimulus appeared. The disappearance of the stimulus was virtually immediate (50 usec) with the brief persistence P24 phosphor specially installed in the VR-14.

The instructions asked subjects to focus directly on a small fixation point at all times and to restrict any eye blinks and eye or head movements. In all conditions stimuli were presented 6mm below central fixation. The fixation point was a dim (.001 mL) red neon light source. A Bausch and Lomb head and chin rest was used to keep the subject's head in a fixed position. Subjects were asked to silently count the stimulus presentations. This counting procedure was used to help insure subject concentration in the task.

In pilot trials subjects were asked to draw diagrams of what they saw under the six conditions. All drawings indicated that in conditions A, B, and C, motion was perceived as intended, i.e., a vertical line moving from left to right. Conditions D, E, and F produced the effect of two stationary lines appearing simultaneously on the screen. The six conditions were counterbalanced across the eighteen subjects over a period of three days for a total of 18 visual ERP traces from O_1 and O_2 for each subject.

Results

The mean latencies (msec) and amplitudes (uV) were computed from the X-Y plotter tracings. A negative peak in the ERP trace which occurred between 135 and 170 msec after stimulus presentation, was termed the N2 component. A positive peak in the trace, immediately following N2, and occurring between 190 and 220 msec, was termed P2. The amplitude component N2-P2 was measured in microvolts from the peak of N2 to the peak of P2. Averaged ERP traces are shown in Figures 1 and 2 for several individuals.

The perceptual reports and diagrams produced after each condition indicated that in conditions A, B, and C (continuous apparent motion) all subjects reported seeing lines or dots moving from left to right. In conditions D, E, and F, all subjects reported seeing stationary lines or dots flashing on and off.

Figures 1 and 2 compare the ERPs recorded from O_1 and O_2 for several female and male subjects under the CAM central visual field condition. The figures show a larger right hemisphere N2-P2 amplitude response, relative to the left, for the females but not for the males. In Figures 3 and 4 right and left hemisphere ERPs to CAM and STAT central visual field stimulation are compared for females and males. The females had larger N2-P2 amplitudes at O_2 for CAM than they did for STAT, while the male responses were essentially the same.

The mean latency data for the visual ERP component N2 and P2 are depicted in Table 1 for all subjects, conditions, and scalp locations.

This information is graphically depicted in Figures 5 and 6, respectively.

Table 1
Mean Latency (msec) for the Visual ERP Components N2 and P2 for All Subjects, Conditions, and Placements
(N=18)

Conditions	Scalp Locations Visual ERP Components			
	O_1		O_2	
	N2	P2	N2	P2
CAM (R)	150	213	162	219
CAM (L)	156	216	148	207
CAM (C)	143	212	137	209
STAT (R)	148	205	160	218
STAT (L)	153	213	143	210
STAT (C)	142	201	137	202

Table 2 shows the mean amplitude of component N2-P2 for all subjects, conditions, and scalp locations. The data in Table 2 are depicted in Figure 7. Figures 5 through 7 show the latency and amplitude advantages of stimulating the visual field corresponding to the contralateral hemisphere.

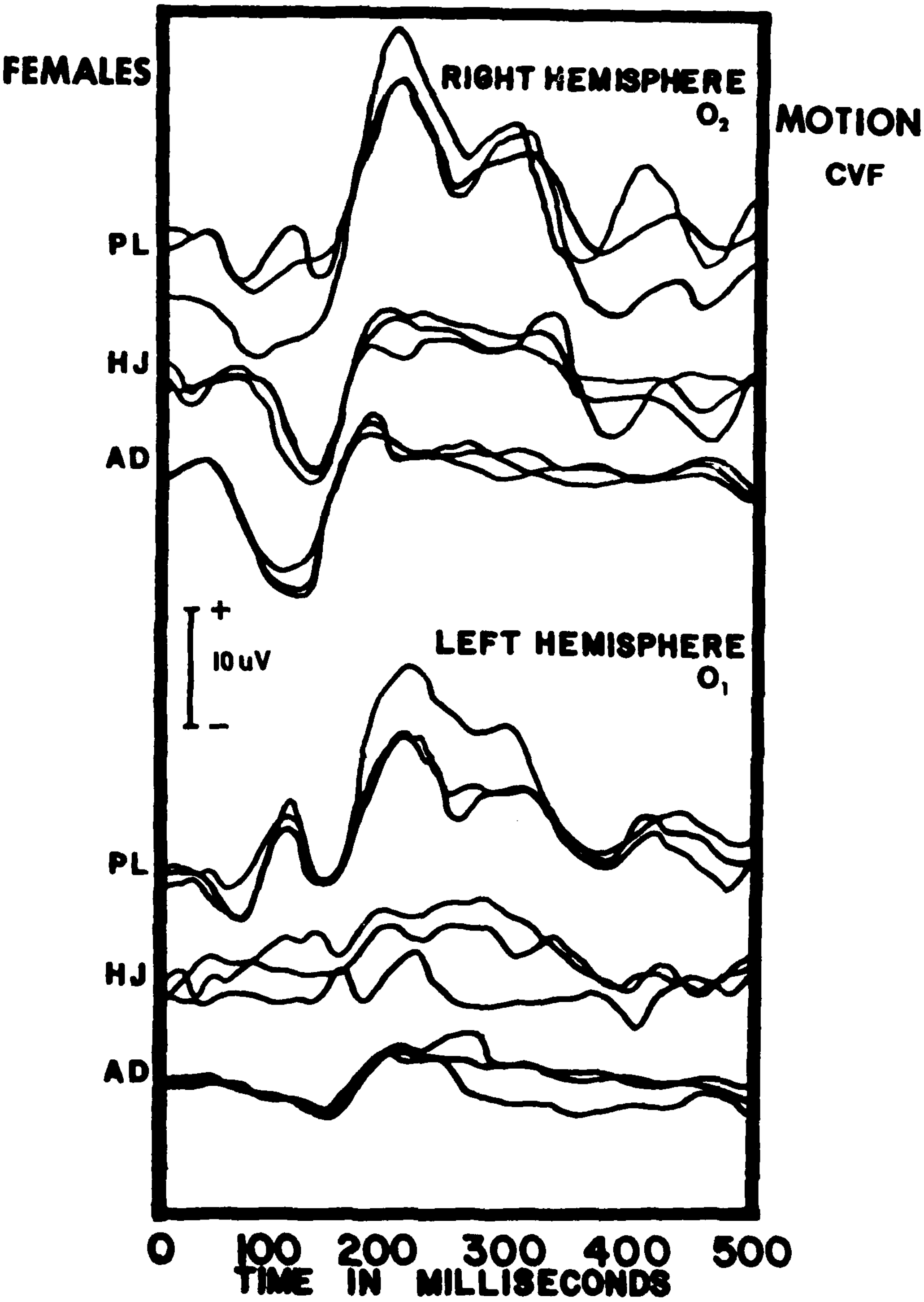

Figure 1 - Visual ERPs of three females recorded from O_1 and O_2. Each trace was recorded on a separate day.

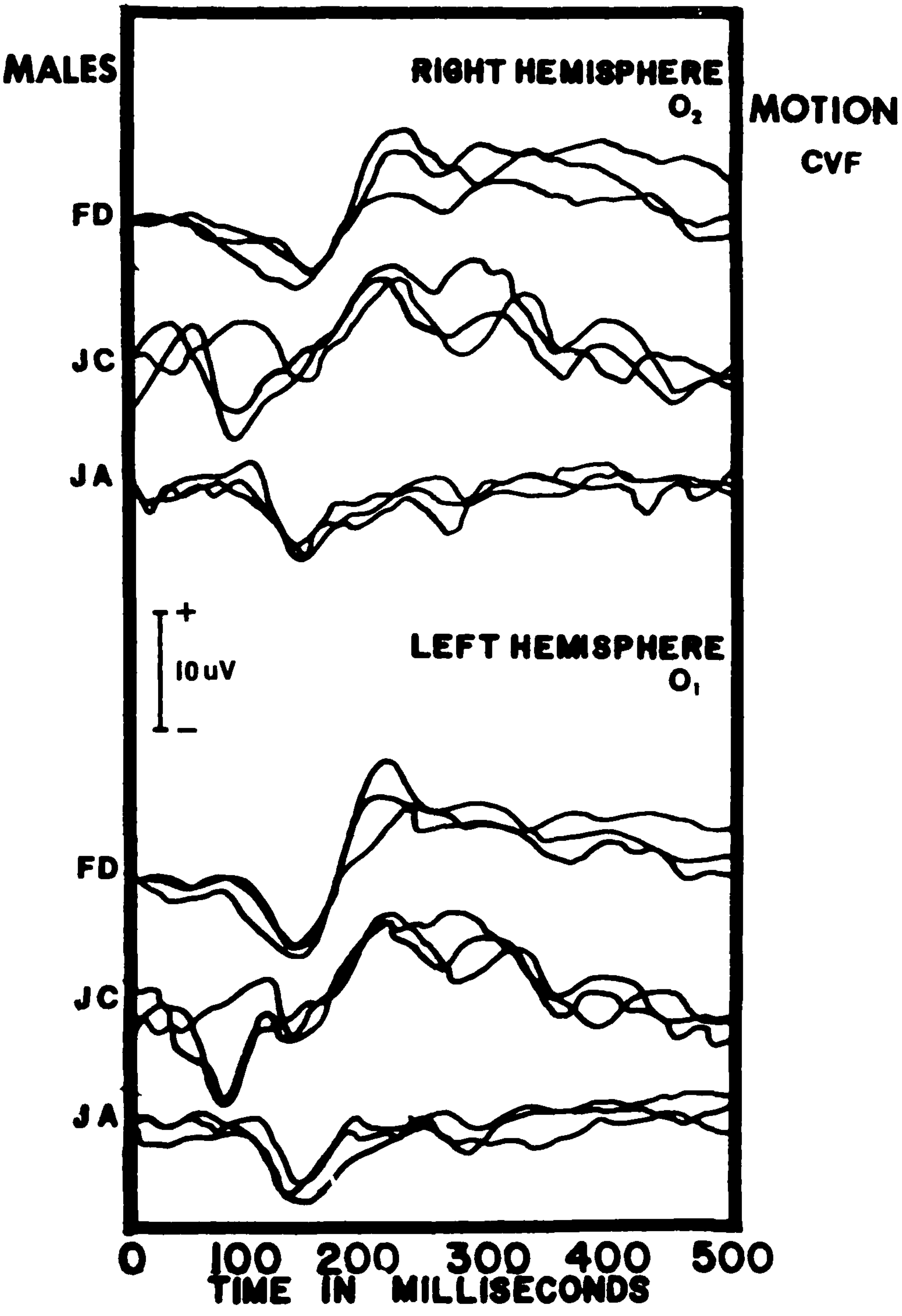

Figure 2 - Visual ERPs of three males recorded from O_1 and O_2. Each trace was recorded on a separate day.

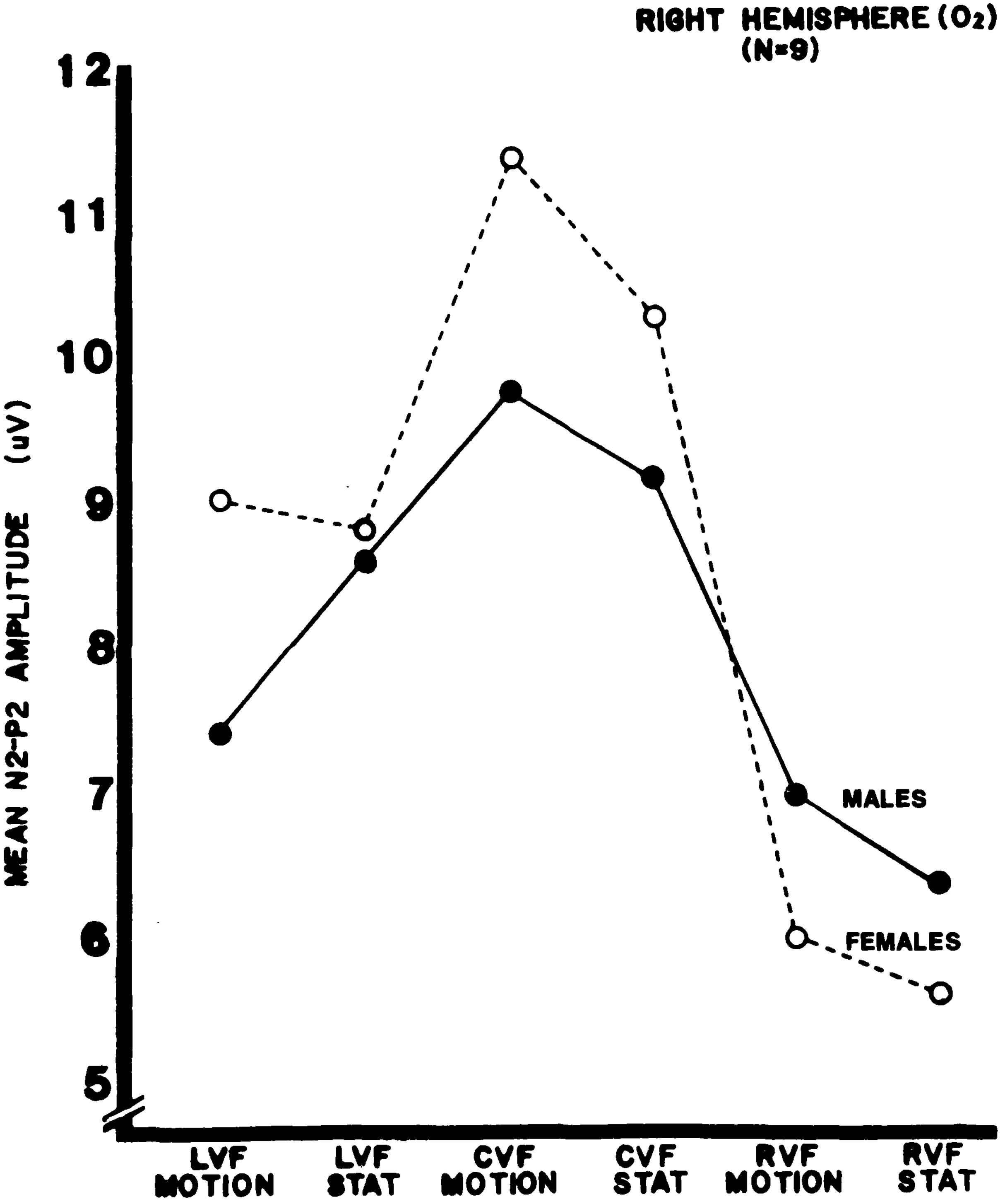

Figure 3 - Mean amplitude of N2-P2 component of the Visual ERP as recorded from O_2 for nine males and nine females.

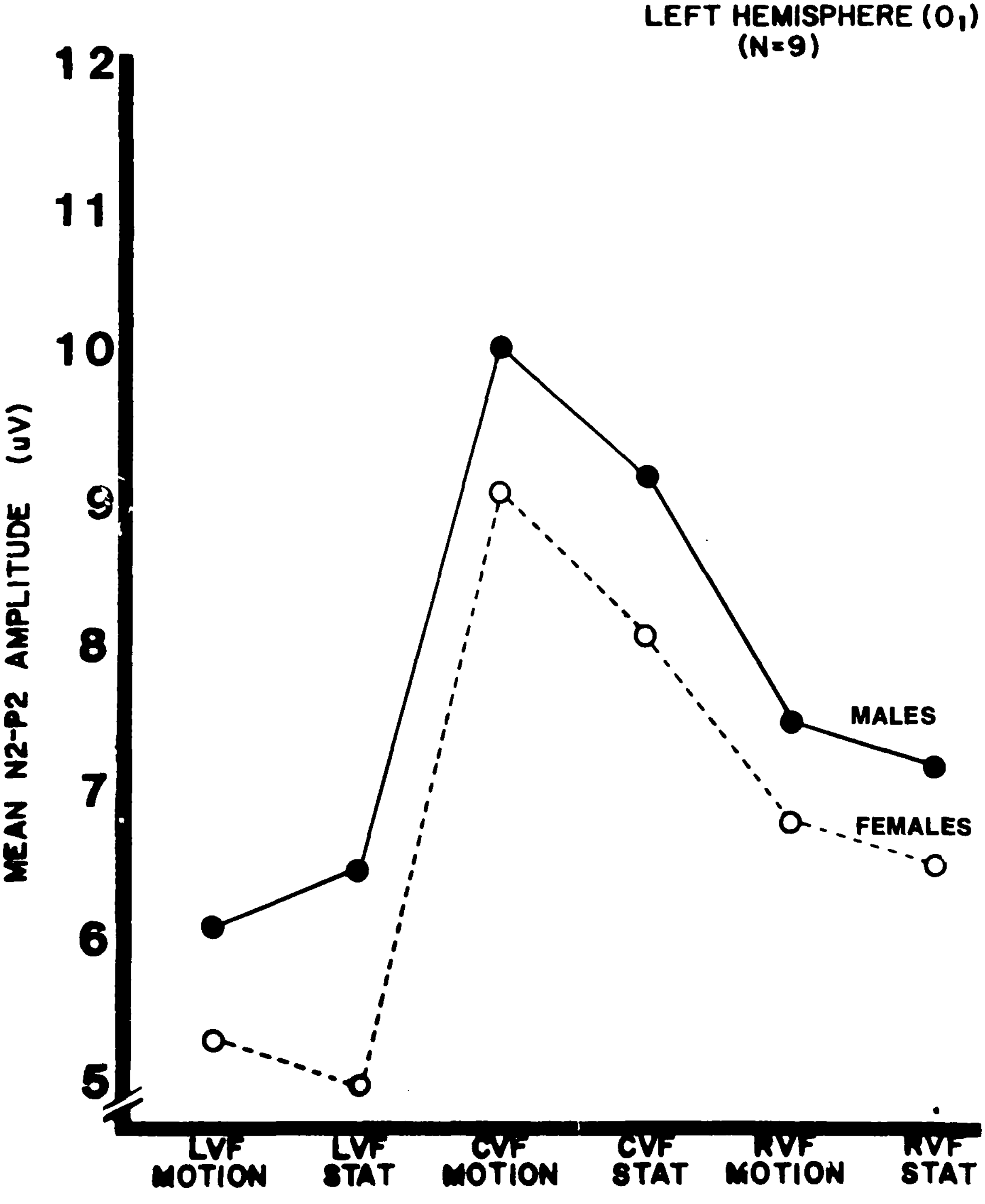

Figure 4 - Mean amplitude of N2-P2 component of the Visual ERP as recorded from O_1 for nine males and nine females.

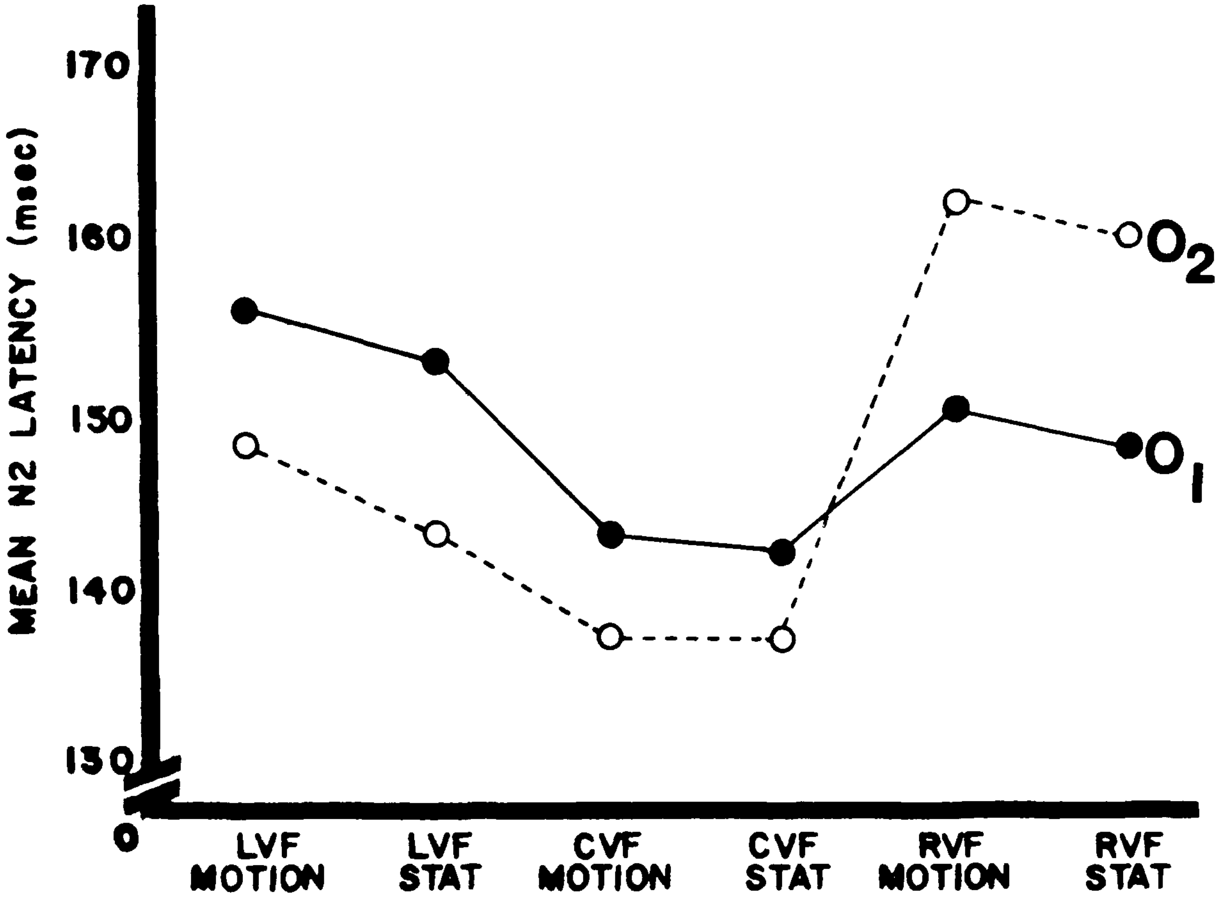

Figure 5 - Mean latency of N2 component of the Visual ERP as recorded from O_1 and O_2 for males and females combined.

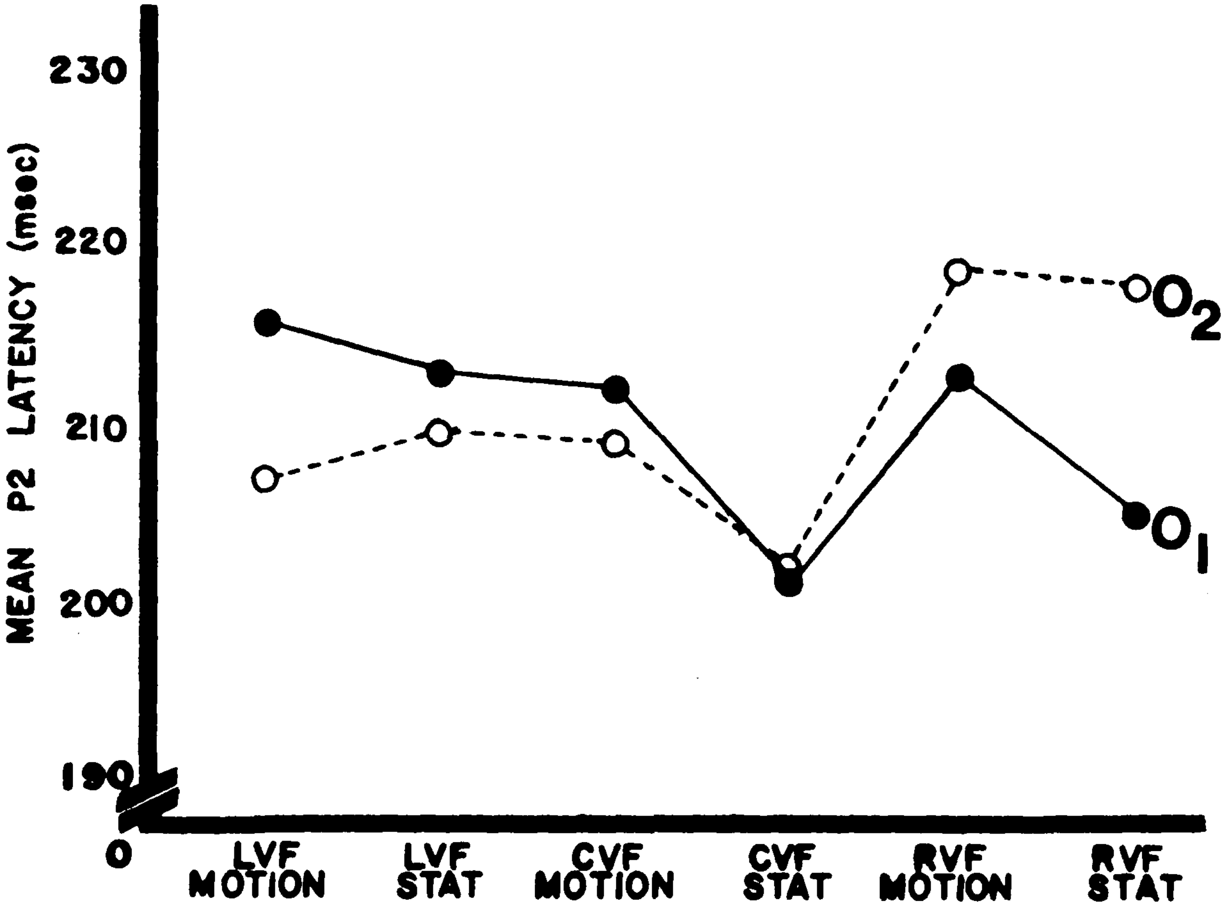

Figure 6 - Mean latency of P2 component of the Visual ERP as recorded from O_1 and O_2 for males and females combined.

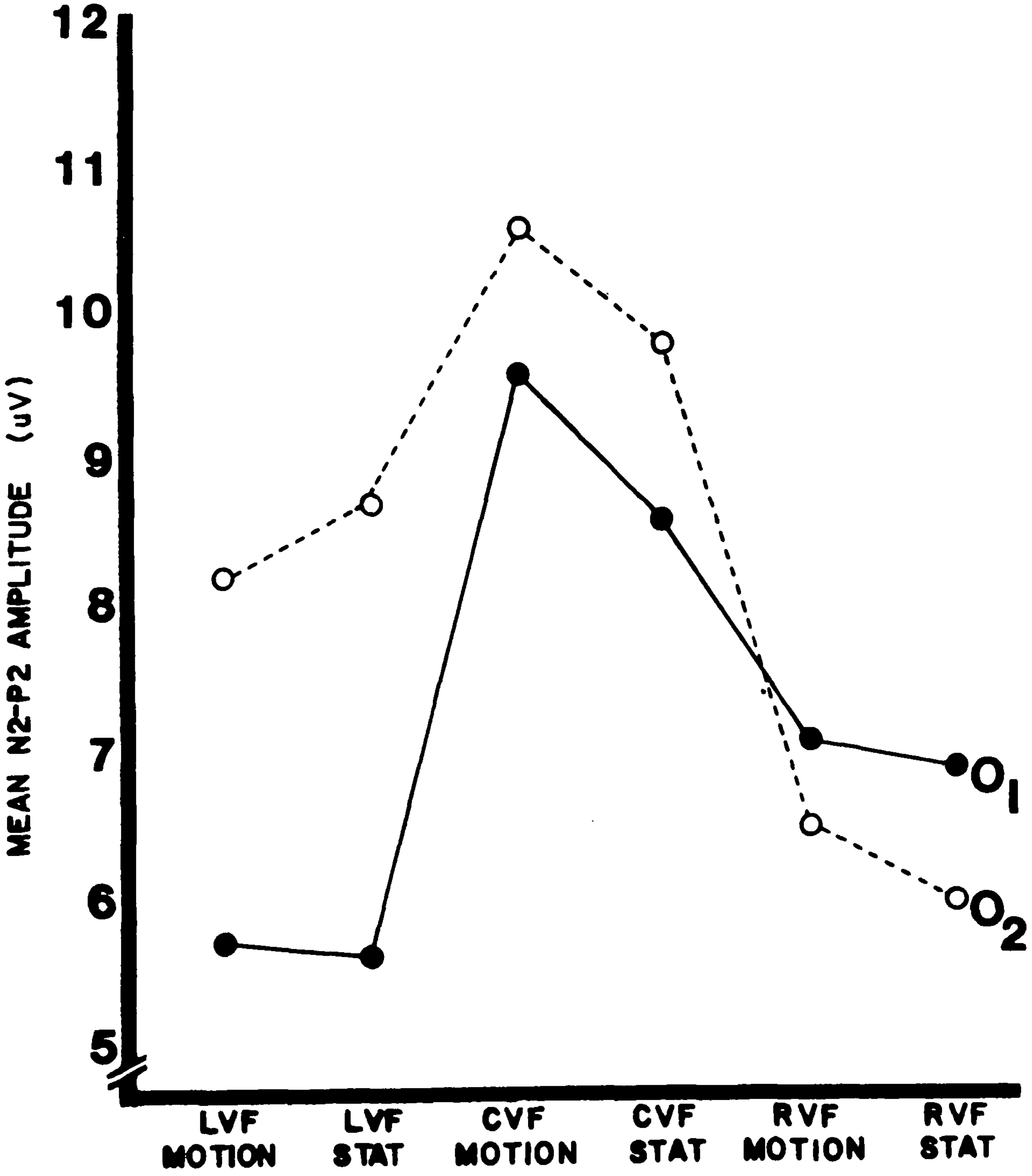

Figure 7 - Mean amplitude of N2-P2 component of the Visual ERP as recorded from O_1 and O_2 for males and females combined.

Table 2
Mean Amplitude (uV) for the Visual ERP
Components N2 - P2 for All Subjects,
Conditions, and Placements
(N=18)

Conditions	Scalp Locations	
	O_1	O_2
CAM (R)	7.1	6.5
CAM (L)	5.7	8.2
CAM (C)	9.6	10.6
STAI (R)	6.9	6.0
STAI (L)	5.6	8.7
STAI (C)	8.6	9.8

The data for the 9 males and females were separated to investigate the possibility of gender differences. Table 3 shows the mean latency components N2 and P2 for males and females as a function of condition and recording hemisphere. Figures 8 and 9 graphically depict some information from the table.

Table 3
Mean Latency (msec) for the Visual ERP
Components N2 and P2 for Males,
and Females, Conditions, and Placements
(N=18)

Conditions	Scalp Locations							
	Visual ERP Components							
	O_1				O_2			
	Males		Females		Males		Females	
	N2	P2	N2	P2	N2	P2	N2	P2
CAM (R)	154	220	146	205	167	229	156	208
CAM (L)	163	222	150	210	154	214	143	199
CAM (C)	145	223	140	201	139	222	134	196
STAI (R)	152	214	144	197	164	227	156	208
STAI (L)	154	223	153	202	143	218	144	201
STAI (C)	146	208	137	194	143	208	132	196

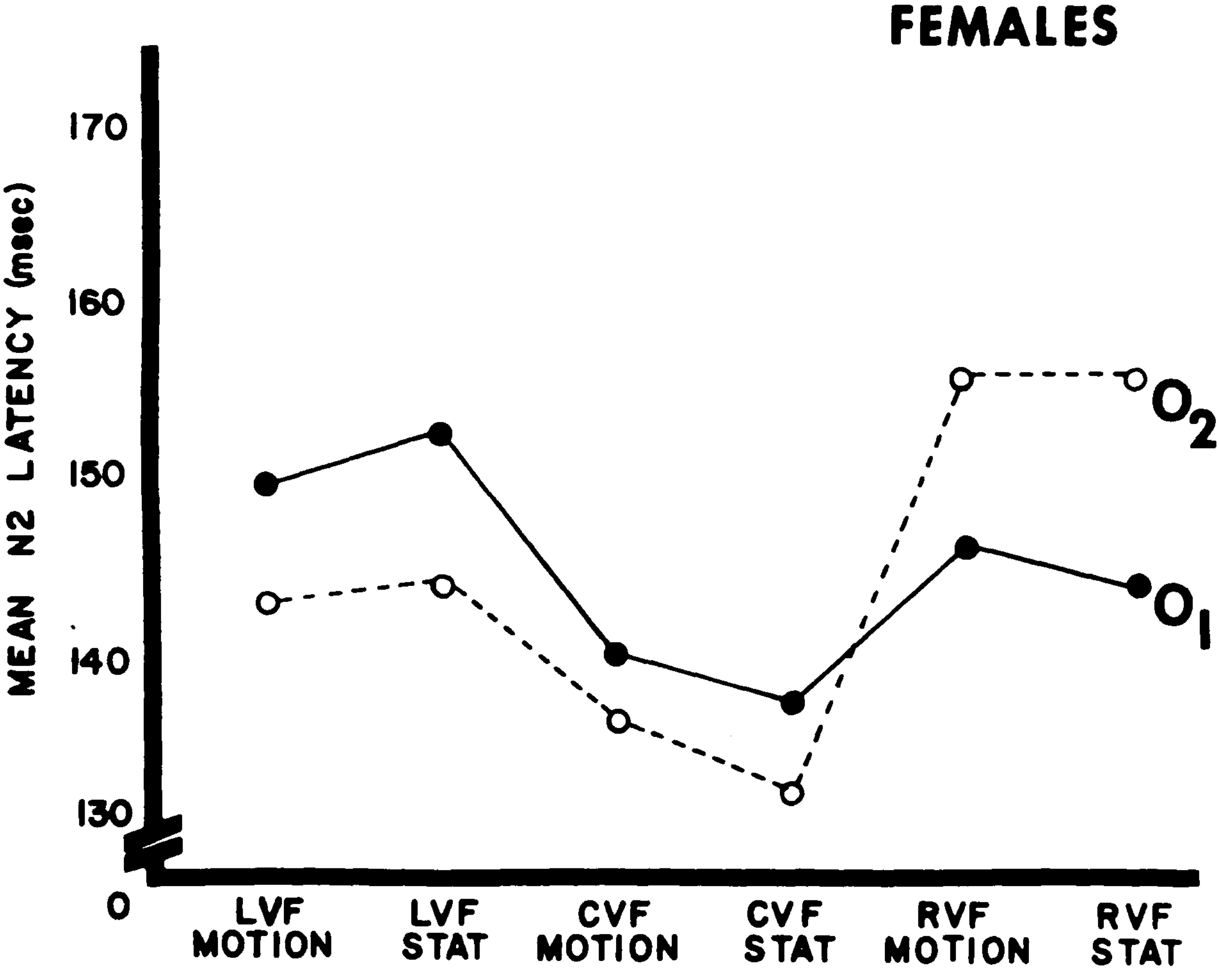

Figure 8 - Mean latency of N2 component of the Visual ERP as recorded from O_1 and O_2 for nine females.

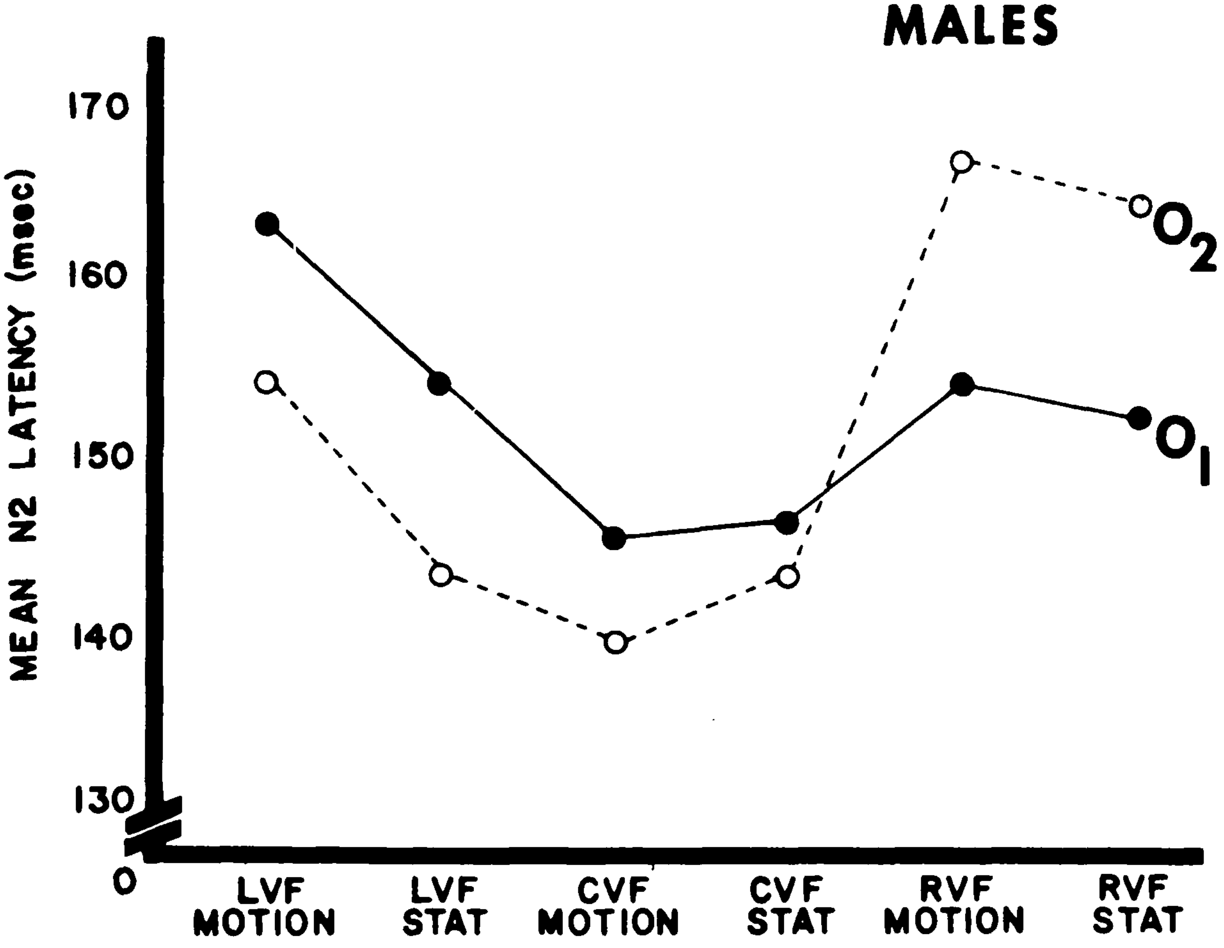

Figure 9 - Mean latency of N2 component of the Visual ERP as recorded from O_1 and O_2 for nine males.

The amplitude of component N2-P2 for males and females is shown in Table 4. This information is graphically depicted in Figures 10 and 11 as a function of gender, condition and hemisphere.

Table 4
Mean Amplitude (uV) for the Visual ERP
Component N2-P2 for Males and Females,
Conditions, and Placements
(N=18)

Conditions	Scalp Locations Gender			
	O_1		O_2	
	Males	Females	Males	Females
CAM (R)	7.5	6.8	7.0	6.0
CAM (L)	6.1	5.3	7.4	9.0
CAM (C)	10.1	9.1	9.8	11.4
STAT (R)	7.2	6.5	6.4	5.6
STAT (L)	6.5	4.8	8.6	8.8
STAT (C)	9.2	8.1	9.2	10.3

The latency and amplitude data were subjected to Analysis of Variance (ANOVA). A three way fixed model was used (Winer, 1971). Log transformations of all the raw data were performed to assure that the data would conform to the assumptions of ANOVA. The results for the latency component N2 show significant effects for Gender $F(1/192)=15.05$, $p < .01$, Conditions, $F(5/192)=9.14$, $p < .01$, and the Placement X Condition interaction, $F(5/192)=4.37$, $p < .01$. Significant Gender and Condition effects were also obtained for the latency component P2 ($F(1/192)=64.54$, $p < .01$, $F(5/192)=4.93$, $p < .05$). No significant effects were obtained for the Placement X Condition interaction for this

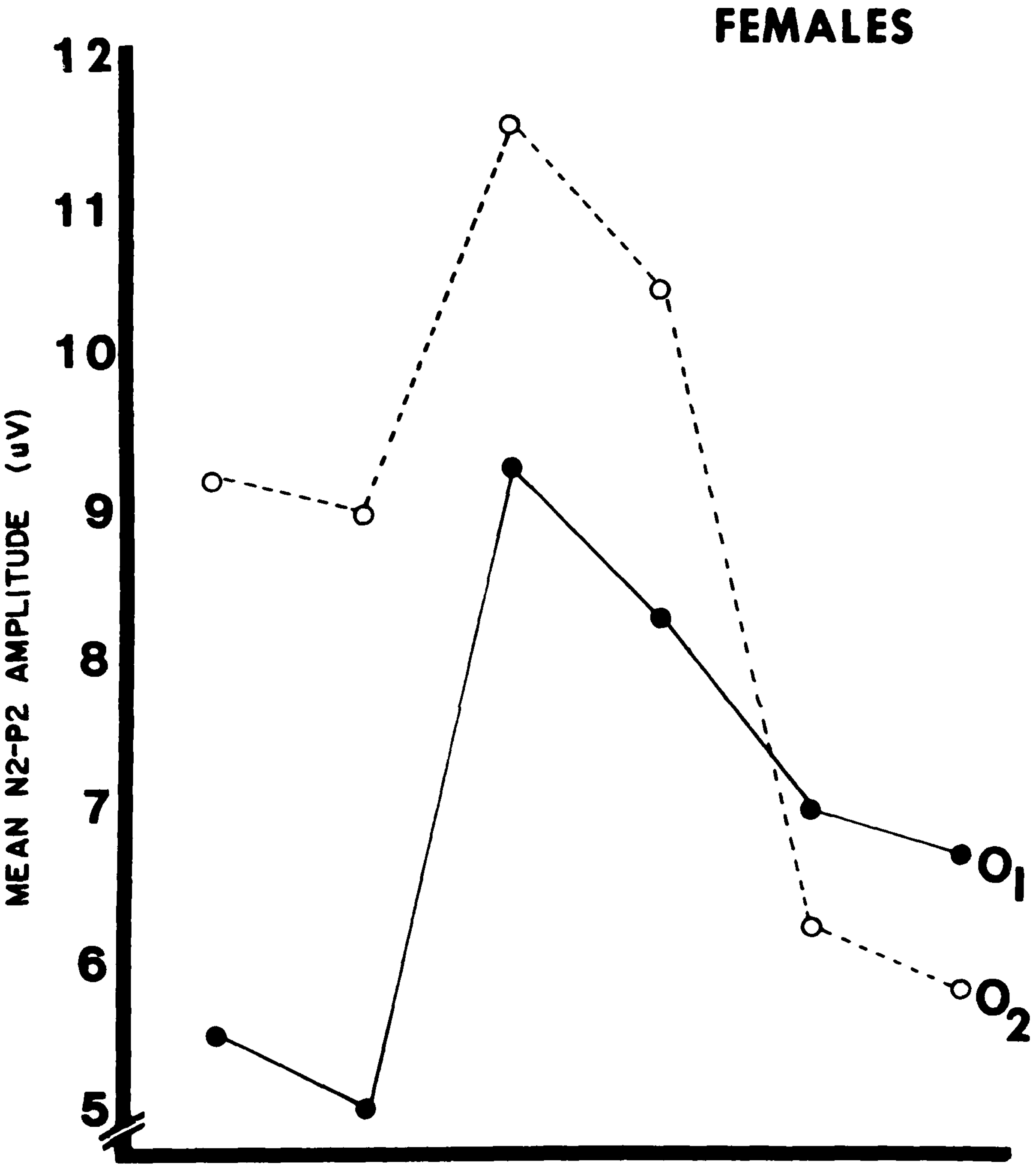

Figure 10 - Mean amplitude of N2-P2 component of the Visual ERP as recorded from O_1 and O_2 for nine females.

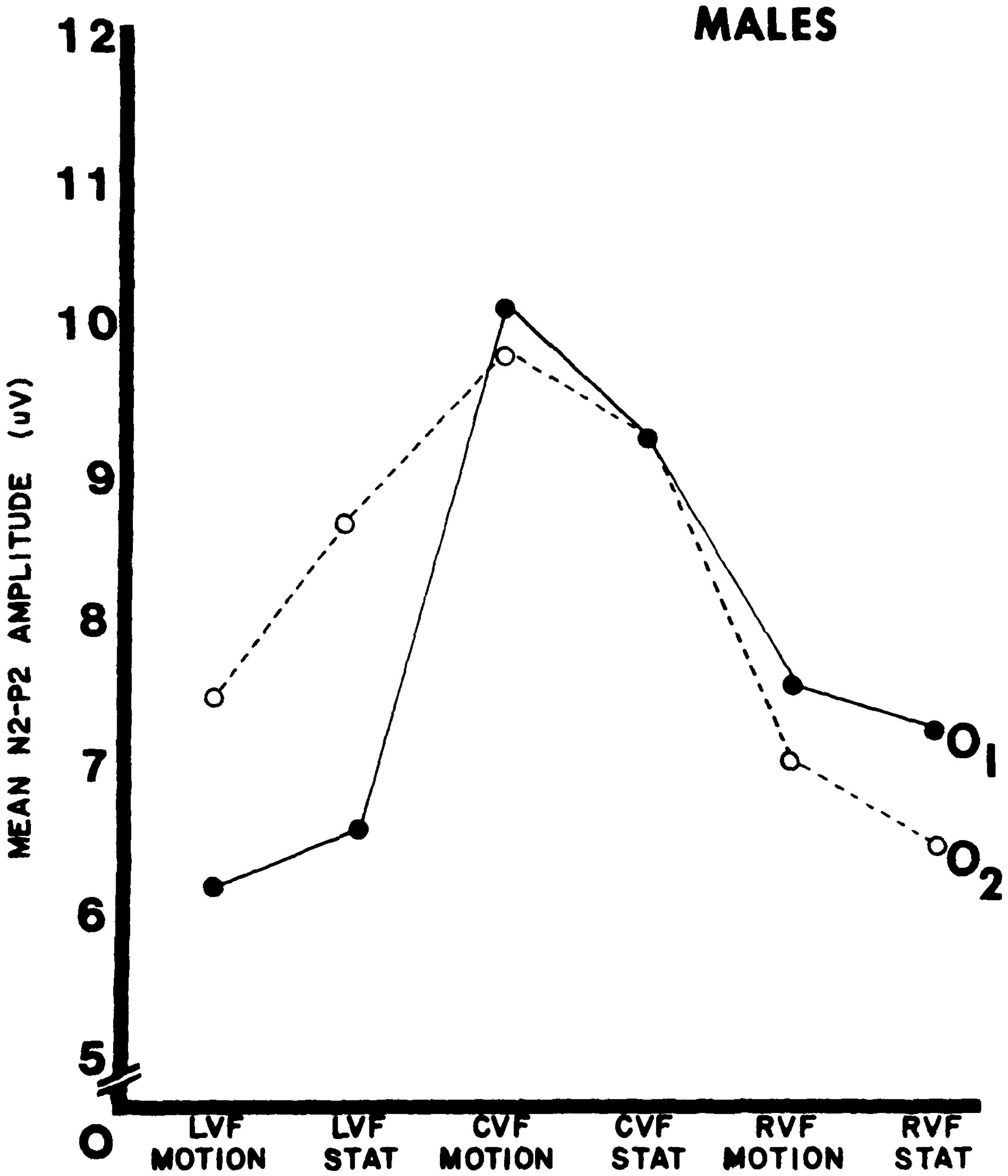

Figure 11 - Mean amplitude of N2-P2 component of the Visual ERP as recorded from O_1 and O_2 for nine males.

component. The ANOVA for the amplitude component N2-P2 shows significant effects for Gender, F(1/192)=4.93, $p < .05$, Conditions, F(5/192)=9.66, $p < .01$, and Placement X Condition interaction, F(5/192)=3.39, $p < .01$. The significant Gender effects obtained for the latency components reflect the fact that females had shorter VEP latencies than males for both 0_1 and 0_2 (see Table 3). The condition effects for both the latency and amplitude components demonstrate the central visual field superiority in producing shorter latency and larger amplitude responses at both scalp locations. This can be observed in Tables 1 and 2. The expected effects were obtained for the Condition x Placement interaction and revealed a latency and amplitude advantage (i.e., shorter latencies and larger amplitudes) contralateral to the field of presentation. Tables 1 and 2 also depict these differences.

A Newman-Keuls multiple comparison test (Winer, 1971) was used to further examine the observed differences within scalp locations. The condition comparisons for the latency component N2 at the 0_1 scalp location show that condition C (CAM CVF) and F (STAT CVF) resulted in significantly shorter latencies than condition B (CAM LVF) and E (STAT LVF), $p < .01$ and that condition F produced shorter latencies than D (STAT RVF), $p < 01$. The only other significant difference was a shorter latency for D than B, $p < .05$. At the 0_2 scalp location, Condition C and F produced shorter latencies than all other conditions, $p < .01$. In addition, significant differences were obtained for left and right visual field comparisons (e.g., E vs A, $p < .01$, E vs D, $p < .01$, B vs

A, $p < .01$, and B vs D, $p < .01$). Thus, the tests for the N2 component show that the central visual field conditions produced the shortest latency responses at both scalp locations. The left and right visual field comparisons clearly reflect the shorter latency response at the scalp location contralateral to the visual field of presentation. However, only one visual field comparison was significant at the left hemisphere (O_1) site, while all comparisons were significant at the right hemisphere (O_2). These findings were supported by the latency results for the P2 component as well. For example, Condition F produced significantly shorter latencies than all other conditions except D, $p < .01$, while condition D produced a significantly shorter latency than B, $p < .01$. At O_2, the CVF conditions (C and F) produced significantly shorter latencies than A and D, $p < .01$, while all the visual field comparison showed significant differences, (e.g., E vs A, E vs D, B vs A, B vs D; $p < .01$ for all).

An examination of N2 latency differences with central visual field stimulation for O_1 versus O_2 was conducted with t-tests for correlated data for males and females. The left hemisphere response was significantly longer for male subjects under the motion condition, $t=3.20$, $p < .01$, 8 df, while there was no O_1-O_2 difference with stationary stimuli. There were no latency differences for O_1 versus O_2 for females as a function of motion and stationary stimuli. The P2 latencies showed no left-right hemisphere differences for males or females with CAM or STAT conditions.

The Newman-Keuls multiple comparison tests for the amplitude component N2-P2 support the results for latencies. For both 0_1 and 0_2, the CVF conditions produced significantly larger amplitude responses than the left and right visual field conditions (C vs A, B, D, and E, $p < .01$, and F vs D, $p < .05$, B, and E $p < .01$.) Again, left and right visual field comparisons showed significant differences only at the 0_2 scalp location. That is, the amplitude response at 0_2 was significantly larger than the response at the ipsilateral location when the stimulus was presented in the left visual field (E vs A, D, $p < .01$, B vs D, $p < .05$).

The N2-P2 amplitude differences between 0_1 and 0_2 were also analyzed separately for males and females using correlated t-tests. The results show that females produced larger ERP amplitudes at the right hemisphere site for <u>both</u> moving and stationary conditions with CVF stimulation ($t=2.00$, $p < .05$, 8 df and $t=3.79$, $p < .01$, 8 df respectively). Moreover, further t-test analysis reveal that when N2-P2 amplitudes to CAM and STAT stimuli are compared separately for 0_1 and 0_2, the females produce larger responses at 0_2 for CAM ($t=2.19$, $p < .05$, 8 df) with no hemisphere difference at 0_1 ($p > .05$). Male subjects did not show hemispheric differences with respect to the amplitude measure. The males did show significantly longer than right hemisphere responses with CAM, but not under the STAT condition, for CVF stimulation. Thus, longer latency left hemisphere responses were obtained for male subjects under conditions of apparent motion with CVF stimulation.

Figures 5 through 7 show the latency and amplitude advantages which occur when stimulating the visual field of the contralateral hemispheres. Thus, for example, stimuli presented in the left visual field as subjects fixate straight ahead produce shorter latency and larger amplitude ERPs at the right hemisphere recording site. In order to control for this contralateral advantage in an attempt to assess hemisphere differences in processing moving and stationary stimuli we devised a difference score computational technique. This procedure is described in Appendix II.

The sex differences are clearly illustrated in Figures 8 through 11. A significant effect for males was a longer latency N2 component (135-170 msec post-stimulus) recorded at the left hemisphere site with CVF stimulation (Figure 9). The fact that CVF stimulation produced larger right hemisphere responses with apparent motion for females is depicted in Figure 10. In contrast, the male subjects in this experiment produced slightly larger (non-significant) left hemisphere ERPs to moving stimuli with CVF stimulation (Figure 11).

Discussion

Central visual field stimulation produced a larger amplitude right hemisphere response compared to the left with apparent motion, but only for the female subjects. Hence, the females seemed to show greater right hemisphere sensitivity or responsivity to moving versus stationary stimuli. The male subjects showed no hemispheric amplitude differences with moving stimuli. If males are as right hemisphere specialized for visuo-spatial stimuli as the literature suggests then we may have expected a larger amplitude ERP from the right hemisphere with the motion stimulus. Also, if the females are less specialized with respect to hemispheric activity for visuo-spatial stimuli then we might have expected to see little or no ERP difference to moving vs. stationary stimuli. If males are right hemisphere specialized for visuo-spatial tasks, this characteristic is not related to the apparent motion generated ERPs of the present study with CVF stimulation. Perhaps the word "tasks" is a key here. That is, the subjects in this experiment were not required to complete a task as such, but rather they were instructed to merely observe and then to diagram the observed stimuli <u>after</u> they were presented. Studies which previously reported differential right hemisphere engagement, and concomitant performance superiority, for male subjects as compared to females, involved actual performance in a motor-visuo-spatial task such as T.V. tennis (eg., see Rebert & Low, 1978).

The amplitude results for the females suggest that it is possible for them to show a greater right versus left hemisphere response, compared to males, with at least one type of visuo-spatial stimulus (apparent motion). It remains to be determined whether females have a corresponding facility in detecting or responding to apparently moving stimuli.

The hypothesis that ERP latencies would be longer from right hemisphere derivations with motion conditions was not supported. In fact, the males had significantly longer <u>left</u> hemisphere responses to moving stimuli with CVF stimulation. Perhaps some attentional mechanism related to analyzing the apparently moving condition more intently affected the left hemisphere activity of males. In contrast, a different attentional strategy for females might evidence itself in a greater right hemisphere response to moving stimuli. These suggestions are merely speculations regarding the gender differences observed in this experiment. The speculations would also be based on an assumption that the moving and stationary stimuli would produce differential attentional strategies in the sexes. Any bias produced would have to operate relatively early in stimulus processing since the N2 latencies occurred within a range of 135 - 170 msec and P2 from 200 - 230 msec. However, the strategy could be adopted early in the stimulus sequence once the individuals came to know the two basic kinds of stimuli used (moving or stationary).

Eccentric stimulation produced latency differences that reflected visual field effects rather than stimulus type, regardless of gender. Thus, the usual latency advantages were observed for central stimuli and with contralateral stimulation, i.e., RVF stimulation produced a mean 12 msec latency advantage at the left hemisphere, while LVF presentations resulted in a mean 9 msec difference in favor of the right hemisphere. Central stimulation resulted in essentially equal left and right hemisphere latencies and produced the shortest latencies of all.

The visual ERP latencies of males tended to be longer than those of the females for stationary as well as moving stimuli. Thus, there seemed to be a gender effect with regard to response latencies in this experiment. The reason for the shorter latencies in female ERPs observed here is not known, but could possibly be related to the fact that female brains are smaller and, therefore, transmission time of impulses through the visual system may be shorter. There were no significant hemispheric differences in response to stationary stimuli for males or females.

The observation that males produced longer latency left hemisphere ERPs with moving stimuli and females produced greater amplitude right hemisphere ERPs with motion as compared to stationary stimuli were the main findings of this study. We already questioned whether the perceptual task required right hemisphere involvement on the part of male subjects. One might also question whether the physical arrangement of the stimuli used made the "stationary" condition any less visuo-spatial than the "continuous apparent motion" stimuli. The question arises since both were visual stimuli occupying separate points in space. The assumption was that the "moving" stimuli would certainly provide a more dramatic type of visuo-spatial experience than the "static" stimuli. The fact is that subjects did experience vastly different perceptual effects with the two stimulus conditions: one condition in which they saw a vertical line moving from left to right and the other where two stationary lines were perceived. Males and females perceived the stimuli in exactly the same way, so perceptual differences could not explain the ERP differences. A possible explanation in the form of hemispheric attentional strategies for males and females was advanced earlier. Whatever the reason for the effects observed here, there is a body of literature which supports the notion of hemispheric differences in brain function for males and females. The support comes from diverse areas such as clinical studies, experimental (purely behavioral) studies and electrophysiological investigations (Springer & Deutsch, 1981 McGlone, 1980). The evidence suggests a trend toward lateralization of both verbal (left hemisphere) and spatial (right hemisphere) abilities in men and greater bilateral (less specialized) representations for both types of functions in women. Levy (1978) suggests an evolutionary basis for hemispheric differences in males and females. Namely, visual spatial abilities favored survival of males as hunters, thereby giving a selective advantage to those with better developed skills of this type. However, skills of females in the use of language and non-verbal communications aided selectively in their child-rearing activities. Perhaps, greater specialization has assisted males in their activities throughout evolutionary history while bilateralization has helped with the skills required for survival by females. One certain type of follow-up to the present study would be to have males and females actually engage in different tasks involving moving and stationary stimuli. Then it would be possible to determine whether the right hemisphere amplitude advantage observed for females is related to an actual superiority in detecting and working with moving stimuli as compared to stationary ones. Perhaps, also, we will have to reformulate our notions for hemispheric specialization based on gender to include the possibility that the type of visuo-spatial task might produce evidence for specialization in females and males not observed before.

Experiment II: The Problem of Undetected Strabismic Subjects in Visual Evoked Potential Research

A common strategy in neuropsychological research involves the presentation of stimuli in left or right visual fields in order to study possible processing differences by the right and left hemispheres of the brain. Examples of strictly behavioral studies are those of Dimond and Beaumont (1973) in which vigilance performance of the two hemispheres was compared and that of Pennal (1977) which examined hemispheric asymmetries in color processing. Visual event related potential (ERP) researchers have used a similar strategy to investigate effects of visual field location on ERPs recorded from over both hemispheres (eg., Andreassi, Stern & Okamura, 1975, Ledlow, Swanson & Kinsbourne, 1978). In the Andreassi et al. study the results showed that stimuli presented in the left visual field (LVF) resulted in shorter visual ERP latencies at the right occipital area than the left, while for stimuli presented in the right visual field (RVF) the opposite occurred. These field effects on visual ERP latencies have also been found by Ledlow et al. (1978) and by Andreassi, Rebert and Larsen, (1980).

Whether a study is strictly a behavioral one or involves the measurement of ERPs it is critical that the subject fixate at the center of the visual field if the two hemispheres are to receive differential stimulation. We became concerned about the ability of subjects to fixate when in one study (Andreassi et al., 1980) two of 12 subjects did not show the expected contralateral hemisphere latency advantage for eccentric stimuli. This occurred even though eye movement (vertical & horizontal) were monitored by electrooculography and stored on tape for later analysis.

In our laboratory we now screen [1] all potential subjects for visual acuity, strabismus [2] and depth acuity prior to their participation in visual ERP studies. Persons with eye muscle imbalance are not always detectable by casual observation and they may readily pass a binocular visual acuity test since they tend to regularly use one eye in viewing. It was reasoned that individuals with strabismus would have difficulty maintaining their line of sight on some central fixation point. Thus, even though EOG is measured these individuals may take up some different fixation point and deviations from center would not be detected, and the usual contralateral effect might not be observed. We believed that the absence of the contralateral hemisphere effect indicates that one or the other hemisphere is not being differentially stimulated.

The depth acuity test was initiated as an additional check since individuals with eye muscle imbalance have extremely poor binocular depth acuity. Our screening of 109 potential subjects to date has revealed that 15 of these (approximately 14%) suffered eye muscle

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[1] Visual screening is done with a Bausch and Lomb Orthorater.

[2] Strabismus is a condition due to unequal ocular muscle tone. The type we are dealing with is the nonparalytic (concomitant) variety which does not involve nerve lesions. It involves the deviation of one eye from parallelism with the other (Berkow, 1977).

imbalance. Some of these individuals were screened before the depth acuity test was added to the battery. We now have complete screening data on seven persons who were tested as strabismic and six of them had zero binocular depth acuity while all had satisfactory binocular visual acuity (corrected or uncorrected to at least 20/25). All of the normal eye balance individuals had good depth and visual acuity.

We tested these six strabismic individuals and compare their visual ERPs with those of six normals in a situation which required central fixation while stimuli were presented in left, right and central visual fields. The aim of this procedure was to determine whether these strabismic subjects would produce the expected contralateral hemisphere latency advantages observed in previous studies. Our hypothesis was that they would not.

METHOD

Subjects: The subjects were 12 individuals associated with the City University of New York. Some of these were students and some staff. Three of the strabismic and three normals were males.

Procedure: Visual ERPs were obtained from O_1 and O_2. Horizontal eye movements were monitored by placing electrodes at the outer canthi of the two eyes. A one cm square grid was presented in three visual fields at a distance of 114cm. The location and timing was as follows:

A) Grid in RVF - 1 deg 24 min to right of central fixation, for 40 msec

B) Grid in LVF - 1 deg 24 min to left of central fixation, for 40 msec

C) Grid presented centrally, for 40 msec.

The luminance level of the grid was 4.9 mL and produced a visual angle of 38 min of arc. The three conditions were presented twice in each session. There were three sessions on three separate days.

Results and Discussion

The latencies of two major components of the visual ERP were measured from time of stimulus presentation. For the strabismic subjects a negative components occurring between 126 and 169 msec after stimulus presentation was referred to as N2. The second was a positive component occurring between between 183 and 228 msec and labelled P2.

The Mean N2 Latencies for the Strabismic Subjects were:

Left Hemisphere	Right Hemisphere
LVF=147 msec	LVF=142 msec
RVF=144 msec	RVF=144 msec
CVF=143 msec	CVF=137 msec

For P2:

LVF=210 msec	LVF=208 msec
RVF=205 msec	RVF=208 msec
CVF=207 msec	CVF=204 msec

The N2 latency data for the strabismic subjects were evaluated by ANOVA, after they were log transformed. A two-way fixed model was used (Winer, 1971) in which hemisphere, visual field, and hemisphere X field interaction effects were examined. None of the F-Values were significant, indicating little or no latency differences at the two hemispheres as a function of presentation field. This result confirmed our hypothesis that strabismics would not show contralateral latency advantages (See Figure 1).

The results for strabismic subjects differed markedly from the normals.

For the Normal Eye Balance Individuals:

Left Hemisphere	Right Hemsphere
LVF=157 msec	LVF=132 msec
RVF=147 msec	RVF=163 msec
CVF=143 msec	CVF=136 msec

The Mean P2 latences were:

Left Hemisphere	Right Hemisphere
LVF=205 msec	LVF=197 msec
RVF=202 msec	RVF=212 msec
CVF=203 msec	CVF=202 msec

The ANOVA for N2 latencies of the normal group indicated significant condition, F (2/30) = 4.03, $p < .05$, and hemisphere X condition, F (2/30) = 6.88, $p < .01$, effects. (See Figure 1.)

The Newman-Keuls multiple comparison test (Winer, 1971) was used to examined latency differences more closely for the normal group. These individuals showed significantly shorter N2 latencies with RVF stimulation, at the left hemisphere ($p < .01$). Latencies recorded at the right hemisphere were significantly shorter with LVF presentations as compared to RVF ($p < .01$). Thus, the normal subjects showed a latency advantage for the contralateral hemisphere, a finding consistent with past results for similar subjects. No significant effects were observed in the ANOVAs of P2 latency for either group.

The amplitude of the ERP was measured from the peak of N2 to the peak of P2. These N2-P2 amplitudes in microvolts for the strabismic group were as follows:

Left Hemisphere	Right Hemisphere
LVF = 5.9	LVF = 7.5
RVF = 7.8	RVF = 8.0
CVF = 8.2	CVF = 9.4

While for the normals:

Left Hemisphere	Right Hemisphere
LVF = 5.1	LVF = 8.0
RVF = 6.8	RVF = 5.9
CVF = 10.1	CVF = 12.3

Separate ANOVAs for the two groups revealed no significant effects for the strabismic subjects, but significant condition effects for the normals, $F(92/30) = 9.89$, $p < .01$. The Newman-Keuls test was used for specific amplitude comparisons. The normal showed a larger amplitude response at the hemisphere contralateral to field of presentation (O_1 - RVF LVF, $p < .05$; O_2 - LVF RVF, $p < .05$). In addition, CVF presentations resulted in larger amplitude ERPs than either LVF or RVF presentations ($p < .01$). (See Figure 1.)

The visual ERP traces for one normal and one strabismic subject are shown in Figures 2 and 3. Note that the normal traces show ERP

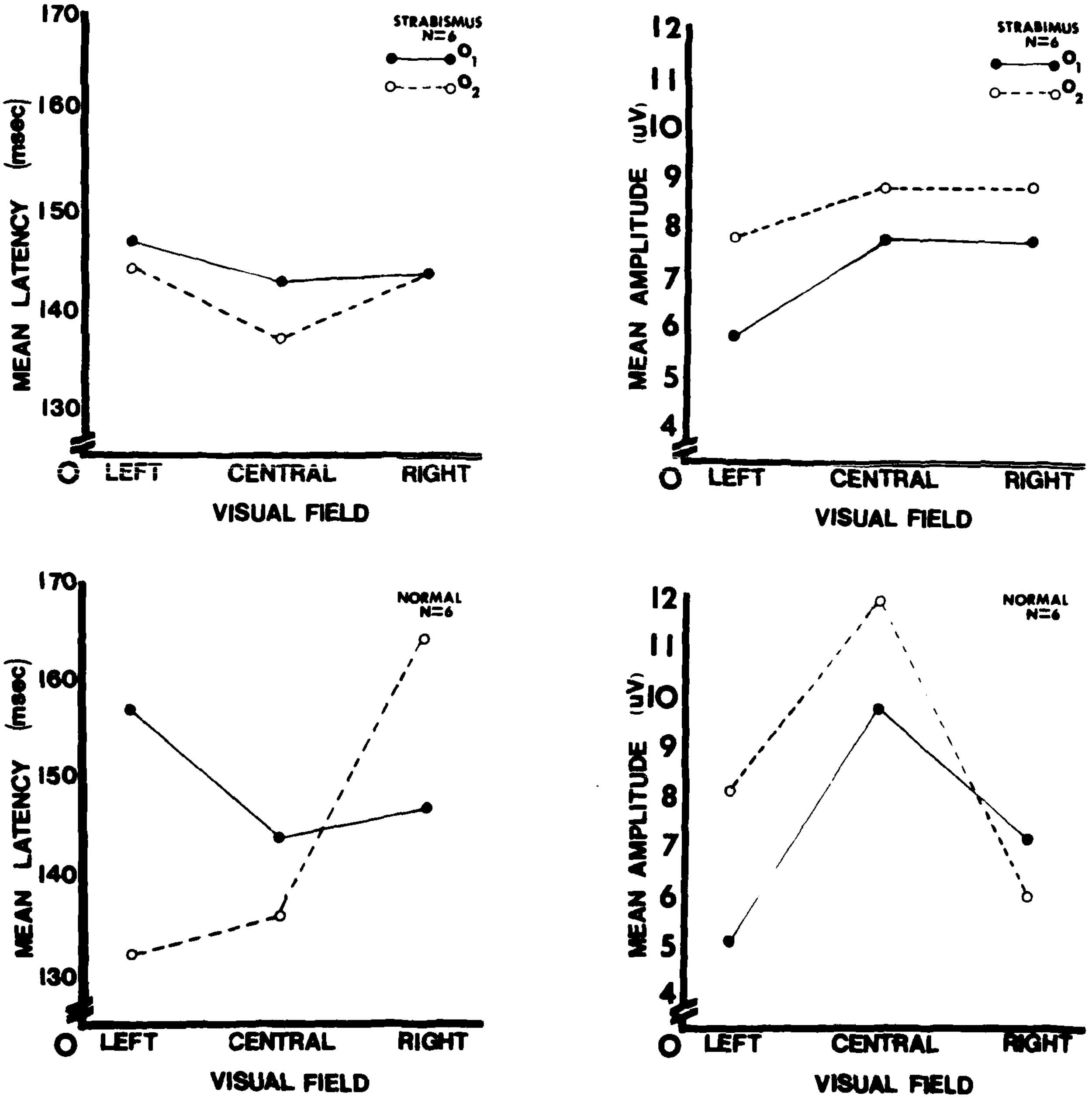

Figure 1 - Mean latency and amplitude of N2 and N2-P2 component of the Visual ERP as recorded from O_1 and O_2 for normal and strabismic subjects.

latency and amplitude advantages at the contralateral hemisphere, while the strabismic subject does not. Central stimulation yielded larger ERPs than eccentric stimuli for the normal, but not the strabismic individual.

In conclusion, strabismic subjects do not show the expected latency advantages at the hemisphere contralateral to stimulation, as did the normals. In addition, the amplitude of the ERP was greater for the normal subjects, with contralateral stimulation, an effect not observed with strabismics. These results indicate that eccentric stimuli may not arrive at the contralateral hemisphere as expected with strabismic individuals.

Therefore, in studies of hemispheric functional asymmetries, whether strictly behavioral or including visual ERP measures, subjects should be carefully screened for strabismus especially when the research strategy dictates that they fixate some central location while stimuli are presented in different visual fields.

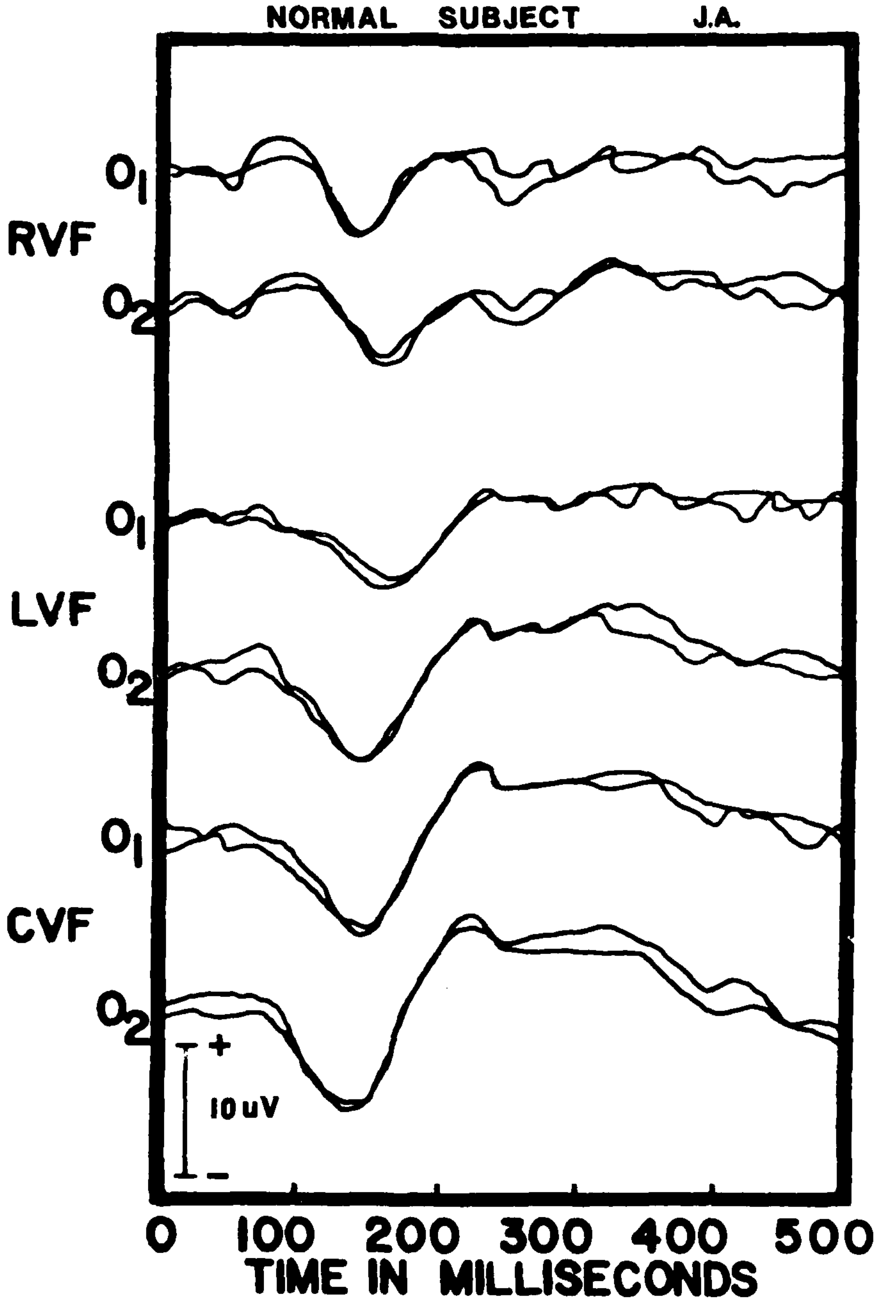

Figure 2 - Visual ERP of a normal subject recorded from O_1 and O_2. Each trace was recorded on a separate day.

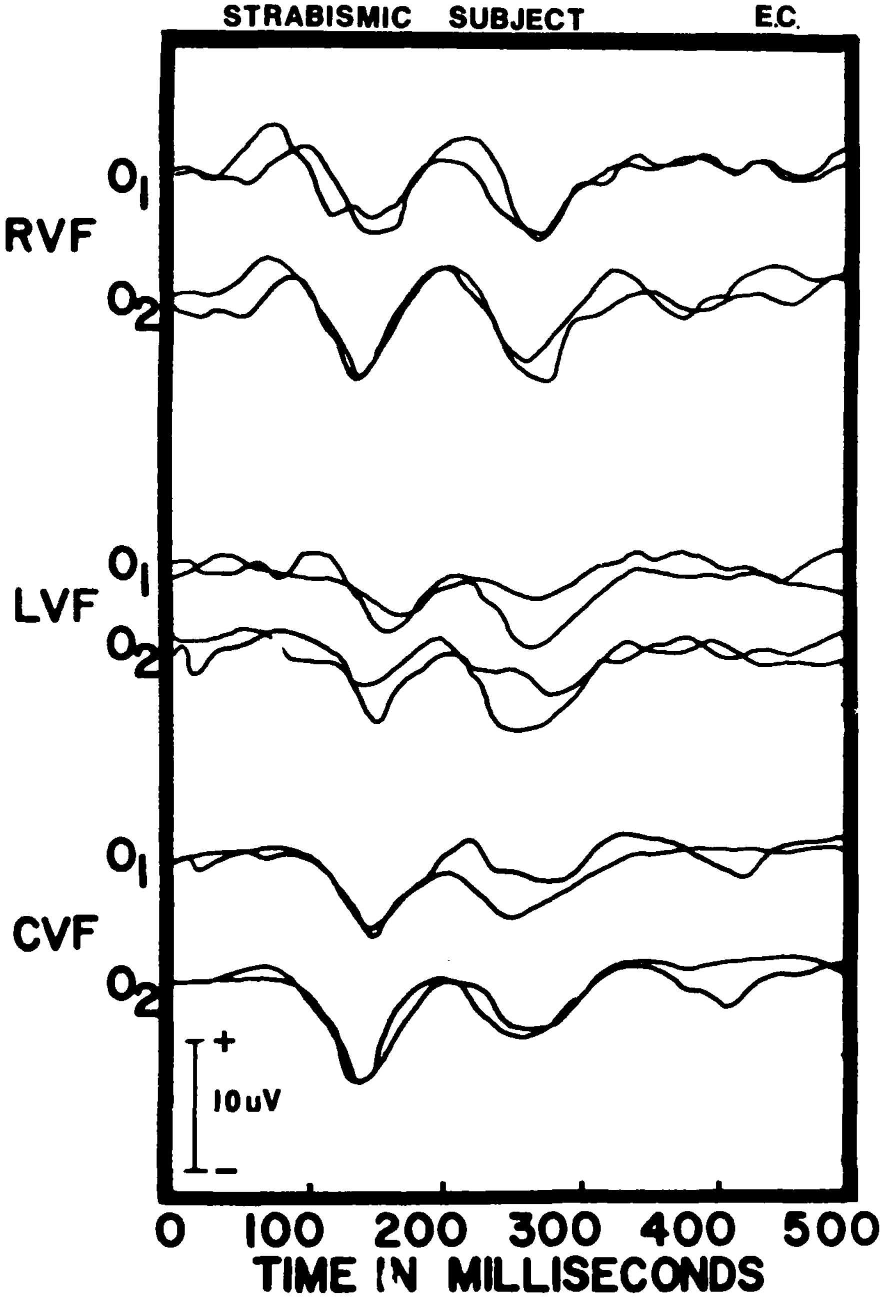

Figure 3 - Visual ERP of a strabismic subject recorded from O_1 and O_2. Each trace was recorded on a separate day.

Experiment III: Discriminations of Line Length and Event-Related Potentials

The notion that the two hemispheres of the brain are functionally asymmetric received much support from research findings on unilateral brain lesioned and commissurotimized patients (Sperry, 1974; Kinsbourne, 1978). A summary of these findings attributes verbal and analytic processing to the left hemisphere and visuospatial and wholistic processing to the right. Consequently, many researchers have used visual discrimination paradigms to study differential hemispheric processing in normal subjects (e.g., Umilta et al., 1973, 1974, 1978; Koss, 1981). Such tasks required that one detect differences in geometric shapes or lines of varying orientations, with the assumption being that the visuospatial nature of the task would preferentially engage the right hemisphere.

Generally, findings confirmed the expectations, i.e., superior right hemisphere performance with visuospatial tasks. These investigators, however, used perceptual measures only. Other investigators have related the P300, a well known endogenous response, to visual discrimination (Ford et al, 1973), and discrimination difficulty (Poon et al, 1976). It will be the purpose of the present research to examine the nature of the ERP obtained during a visual discrimination task. The strategy used will be to present a standard-comparison line discrimination in such a manner as to compare perceptual performance and visual ERPs from the left and right hemispheres of the brain.

An ERP component that has received much attention is the so called "P300" response. First discovered by Sutton et al. (1965), this relatively late, positive component, appearing between 250 and 600 msec after stimulus presentation, was found to be associated with a variety of cognitive activities such as decision making, stimulus probability, and discrimination of stimuli (for a review, see Pritchard, 1981). As previously mentioned, the Ford et al. (1973) study showed that P300 was related to visual discrimination. Subjects were required to make discriminations in the same sensory modality (e.g. flashes of light) and between modalities (clicks and flashes). The stimuli were made relevant or irrevelant through instructions. These investigators found that the P300 was of high amplitude to relevant stimuli, medium size if the stimulus was relevant but in the irrelevant modality, and non-existent in the irrelevant modality. Thus, P300 reflects discriminations between and within modalities. Poon et. al., (1976) measured ERPs during a visual discrimination task at two levels of difficulty. In the simple task subjects pressed a key as soon as they saw a pair of letters on a screen. For the difficult one, subjects were required to press one key to indicate that two letters were both consonants or vowels and another key to indicate that the pair consisted of a vowel and a consonant. They found that an enlarged P300 correlated with difficult discriminations and longer reaction time (mean RT 1,128 vs 728 msec for difficult and simple discrimination). Hillyard et al. (1971) reported that confidence in decisions regarding detection was related to P300 amplitude, i. ., higher amplitudes were associated with greater degrees of confidence. This finding was confirmed by Squires et al, (1973, 1975). They found that when decision making was difficult, the amplitude of the P300 varied as a function of decision confidence. Thus, some studies seem to contradict the Poon et al. findings. If larger P300s are associated with more confident decisions as, several studies suggest, easier discrimination should have resulted in greater decision confidence and a larger P300.

Another dependent variable of interest with respect to discrimination performance is that of P300 latency (late positive components appearing between 250 and 600 msec after stimulus presentation, depending on the experimental paradigm). Donchin (1979) suggested that P300 latency is dependent upon the time it takes a person to complete an evaluation of a stimulus. A number of studies support the stimulus evaluation time hypothesis. For example, N. Squires et al. (1977) found that P300 latency varied with discriminability of the relevant stimuli in a counting task. It was found that P300 latency to an 1100 Hz tone was 60 msec longer when paired with a 1060 Hz tone than when paired with a 1000 Hz tone, i.e., longer latency P300s were observed with the more difficult discrimination. Differences in choice reaction time to the same pairs of stimuli averaged 95 msec. Further evidence is derived from work by Gomer et al. (1976) who reported that P300 latency increased as the number of items in a memory set (Sternberg paradigm) increased. K. Squires et al. (1973) found P300 latency delays with higher levels of task difficulty in a discrimination task.

Donchin et al. (1978) have pointed out that the relation of P300 latency to reaction time depends on the extent to which the subject's response depends on stimulus evaluation. For example, Kutas et al. (1977) found that when subjects were instructed to respond as quickly as possible, the correlation between P300 latency and RT was +.26. In this case response selection and execution were the main factors indexed by the overt response. However, when subjects were told to respond as quickly as possible, while avoiding errors, the P300-RT correlation increased to .62. Donchin and colleagues proposed that under accuracy instructions the response selection is contingent on stimulus evaluation and therefore P300 and RT are closely related, with RT frequently longer than P300 latency. On the other hand, speed instructions lead to a looser coupling between stimulus evaluation and response selection, and responses may be made before full evaluation of the stimulus. Donchin et al. (1978) stress that processes reflected by P300 do not imply stimulus evaluation, but they do suggest that stimulus evaluation must be completed before P300 occurs.

The research literature generally suggests that the right hemisphere is superior to the left in visual discriminations. There are exceptions to this suggested right hemispheric superiority. For example, White (1971) found better left hemisphere performance in the recognition of vertical, horizontal and 45 deg. oblique lines. Only 47% of the stimulus orientations were correctly identified in the left visual field (LVF) while 84% were identified in the right visual field (RVF). White concluded that the RVF superiority was due to the fact that these orientations were easily categorized in verbal terms. Geffen et al. (1972) reviewed White's findings and proposed that the use of vocal responses (left hemisphere function) may have masked a right hemisphere superiority. Umilta et al. (1974) obtained results similar to White's in certain respects. Their subjects were required to make discriminations of line orientations flashed in LVF and RVF. There were three experimental groups, with each group presented with line orientations that varied in discrimination difficulty. Group one discriminated among vertical, horizontal, right and left oblique (45 deg.) lines. Group two was presented with vertical, horizontal, 30 deg. and 45 deg. lines, while the third groups discriminated among lines that differed by 15 deg. increments from one another (i.e., 15, 30, 45 and 60 deg. from vertical). The results were interesting. For group one, White's results were replicated. That is, this group showed superior discrimination performance with RVF presentations. The second group showed no visual field advantages. However, the third group showed a clear LVF (right hemisphere) superiority. Umilta and colleagues proposed that for the relatively easy task (Group one) the left hemisphere may predominate since these kinds of discriminations can be easily categorized and analyzed in verbal terms. The shift toward right hemisphere superiority for the most difficult discriminations (group three) was attributed to the adoption of a visual matching strategy necessitated by the lack of verbal codes to represent the orientation of these lines.

Koss (1981) used reaction time and accuracy of response as the principal performance measure. She presented six right-handed male subjects with lines positioned in different orientations. There were two stimulus conditions; vertical-oblique and oblique-oblique. For the first condition, black rectangles were oriented either 90 degrees or 95 degrees from horizontal. In the second condition the rectangles were oriented either 95 degrees or 100 degrees from horizontal. The subject's task was to respond to the presentations of the 95 degree stimulus orientation. Koss found an overall right hemisphere superiority, i.e., subjects were significantly more accurate when the stimuli were presented in the left visual field.

The aims of the present experiment were: 1) to determine whether the left or right hemisphere is superior with respect to discriminations of line length; 2) to determine whether the visual ERP is related to performance; 3) to examine the P300 response in the line discrimination task.

Method

Subjects: The subjects were four males and three female right-handed students associated with the City University of New

York. They ranged in age from 18-45 years. Subjects were given a handedness questionnaire (Annett, 1971) and a vision test battery with a Bausch and Lomb Orthorator. The battery included tests for binocular visual acuity and lateral and vertical phoria (at near and at distance). The results showed that none had any visual anomalies other than myopia (corrected to at least 20/25 with glasses), and all subjects showed normal eye muscle balance (orthophoria) as determined by the Bausch and Lomb Occupational Vision Standards.

Apparatus and Procedure: Subjects were seated in an electrically shielded sound attenuated IAC chamber while EEG was recorded from O_1 and O_2 (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to a silver clip electrode on the subjects left ear lobe. A Beckman Type RM Dynograph was used to record the EEG and the 9806 coupler of the Dynograph conditioned the EEG signal (bandpass set at 0.5 to 32.0 Hz). A Mnemotron Computer of Average Transients (CAT 1000), under program control of a PDP 8/E computer, obtained EEG samples of 500 msec duration following presentation of the stimulus to the subject. The resultant summated Visual ERP trace was plotted on a Hewlett Packard X-Y plotter.

Eye blinks and vertical and lateral eye movements were measured using a two channel eye movement monitor.[1] Lateral eye movements were recorded by placing two biominiature electrodes at the external and internal canthi of the left eye. Eye movements were monitored

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[1] Washington University resetting differential amplifiers

on a dual channel Tektronix 502A storage oscilloscope. Such movements appeared as sudden vertical deviations in the oscilloscope trace. Vertical eye movements were measured by placing two electrodes above and below the left eye. The resultant EOG was displayed continuously on a voltmeter in the Washington University Apparatus. Artifacts produced by vertical eye movements appeared as left or right deviations from zero. Any trials suspected of contamination were discarded.

The stimuli were displayed on a Digital Equipment Corporation VR-14 CRT which was mounted at the subject's eye level outside the chamber at a distance of 114.3 cm (45 in.). The VR-14 was controlled by the computer to deliver stimuli at specific times and locations on the CRT. The disappearance of the stimulus was virtually immediate (50 Msec) with the brief persistence P24 phosophor specially installed in the VR-14.

For the experimental conditions, a single vertical 1.0 cm line (standard) was displayed for 40 msec followed two seconds later by either a .9, 1.0, or a 1.1 cm line (comparison) each on for 40 msec and at the same location at the standard. Four seconds intervened before the standard line reappeared followed again by one of the three comparison lines. This order of presentation was continued until each comparision line was displayed nine times resulting in a trial of 27 presentations. The order of presentation of the comparison line was randomized so that subjects could not predict which line size would appear at a given moment within the trial.

The CAI was under the control of the experimenter so that selective EEG samples could be obtained for each comparison line within the trial. This resulted in a Visual ERP trace based on nine samples: one trace for each of the three comparison line sizes. Each line was presented 1°24' of arc to the left and right of the fixation point and directly below (6mm) the fixation point. Thus, there were nine experimental conditions; one for each line size and visual field. They were as follows:

A1 - Left Visual Field, Comparison line .9 cm.
A2 - Left Visual Field, Comparison line 1.0 cm.
A3 - Left Visual Field, Comparison line 1.1 cm.
B1 - Central Visual Field, Comparison line .9 cm.
B2 - Central Visual Field, Comparison line 1.0 cm.
B3 - Central Visual Field, Comparison line 1.1 cm.
C1 - Right Visual Field, Comparison line .9 cm.
C2 - Right Visual Field, Comparison line 1.0 cm.
C3 - Right Visual Field, Comparison line 1.1 cm.

The 1.0 cm line produced a visual angle of 30' of arc while the .9 and 1.1 cm lines produced visual angles of 27' and 33' of arc respectively. The luminance of each line was 3.5 mL as measured by a J-16 photometer. Thus, in all trials and conditions line luminance was equated.

The standard instructions asked subjects to focus directly on the small fixation point directly to the front, and to restrict any eye blinks or eye and head movements at all times. The fixation point was a dim (.001 mL) red neon light located 6mm above the stimulus display. A Bausch and Lomb head and chin rest was used to help keep the subjects head in a fixed position.

All subjects were given practice trials before the beginning of the first session to insure proper performance. The instructions asked subjects to verbally report whether the second of the two lines (comparison) was "longer" or "shorter" than the first line (standard). No equal judgments were permitted. In addition, subjects were periodically reminded to fixate on the red neon light at all times regardless of stimulus location. They were also asked to look and not stare at the fixation point. This additional instruction minimized the problem of stabilized retinal image: an effect often associated with prolonged fixation. It also reduced eye strain. The verbal responses were monitored via an intercom system and recorded by one of the experimenters.

The nine conditions were randomized across subjects over a period of two days for a total of 18 visual ERP traces from O_1 and O_2 for each subject.

Results

Visual ERPs Analysis of the X-Y plotter tracings of all subjects indicated the emergence of several ERP components from which the latency and amplitude measurements were made.

Latencies Four negative and positive peaks, each falling within various time periods of the 500 msec sample, were identified: N2, P2, N3, and P3. For N2 latency, the measurement was taken from the peak of the first major depression which occurred between 145 and 170 msec after stimulus presentation. The P2 component was measured from a positive peak following N2, and appearing between 210 and 230 msec. A second major depression occurring between 260 and 290 msec was considered to be N3. The P3 or P300 component appeared between 320 and 360 msec after stimulus presentation.

Amplitude The N2-P2 component was measured in microvolts as the vertical distance from the peak of N2 to the peak of P2, while for N3-P3, the measurement was made from the peak of N3 to the peak of P3. In approximately 2% of the traces the N3-P3 measurement was taken as the distance from the peak of N2 to the peak of P3 since the N3 component was absent.

Behavioral Data The total number of "longer" judgments for each line size and visual field was computed from the data sheets and was used for statistical analysis. The data were also converted into percentages.

The mean latency data for each visual field across the seven subjects are shown in Table 1 for the two occipital locations while Table 2 depicts the amplitude data. Figures 1 through 4 show these data for latencies (N2, P3) and amplitude components (N2-P2, N3-P3).

Table 1
Mean Latencies (msec) for the Visual
ERP Components N2, P2, N3, P3 for
All Subjects, Placements, and Conditions
(N=7)

Conditions Field and Length of Comparison Line	Scalp Locations Visual ERP Components							
	O_1				O_2			
	N2	P2	N3	P3	N2	P2	N3	P3
LVF .9 cm	160	230	271	327	148	222	266	325
LVF 1.0 cm	154	223	270	350	148	220	271	346
LVF 1.1 cm	158	228	277	340	150	219	275	339
CVF .9 cm	150	221	271	338	152	224	270	331
CVF 1.0 cm	148	216	282	342	148	219	285	339
CVF 1.1 cm	149	220	280	332	149	224	278	332
RVF .9 cm	153	222	273	334	163	229	272	333
RVF 1.0 cm	158	215	274	335	166	220	279	336
RVF 1.1 cm	154	225	277	324	164	228	277	323

Table 2
Mean Amplitude (uV) for the
Visual ERP Components N2-P2 and P3 for
All Subjects, Placements, and Conditions
(N=7)

Conditions Field and Length of Comparison Line	Scalp Locations Visual ERP Components			
	O_1		O_2	
	N2-P2	N3- P3	N2-P2	N3-P3
LVF .9 cm	16.2	10.9	18.6	12.4
LVF 1.0 cm	16.4	12.5	18.9	12.4
LVF 1.1 cm	16.8	9.4	17.1	10.4
CVF .9 cm	18.7	13.7	19.4	13.6
CVF 1.0 cm	19.9	13.0	21.2	12.1
CVF 1.1 cm	19.9	11.8	20.8	14.0
RVF .9 cm	16.6	12.5	14.8	12.5
RVF 1.0 cm	14.2	10.0	15.1	10.1
RVF 1.1 cm	16.1	14.3	14.7	12.0

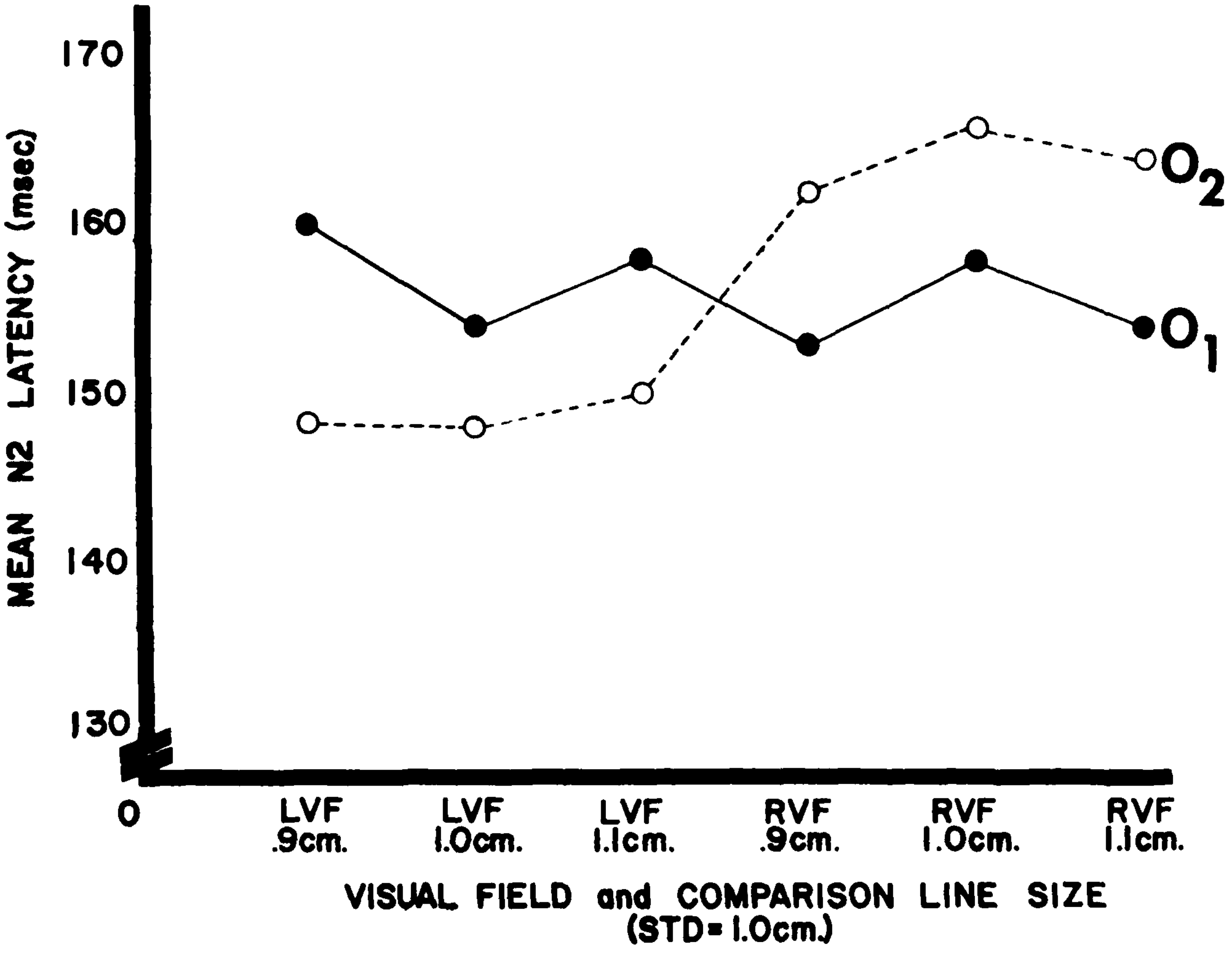

Figure 1 - Mean latency of N2 component of the Visual ERP as recorded from O_1 and O_2 for seven subjects.

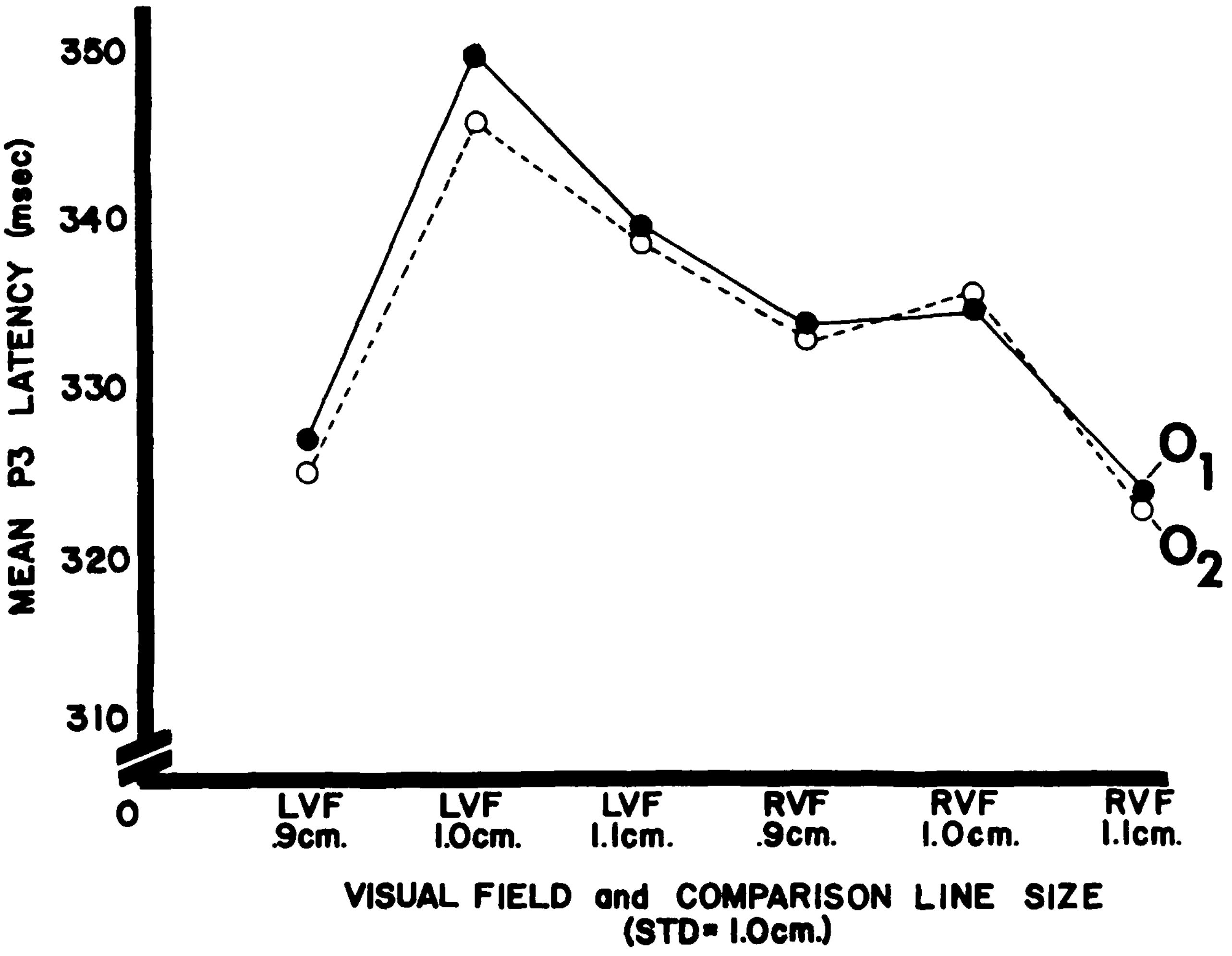

Figure 2 - Mean latency of P3 component of the Visual ERP as recorded O_1 and O_2 for seven subjects.

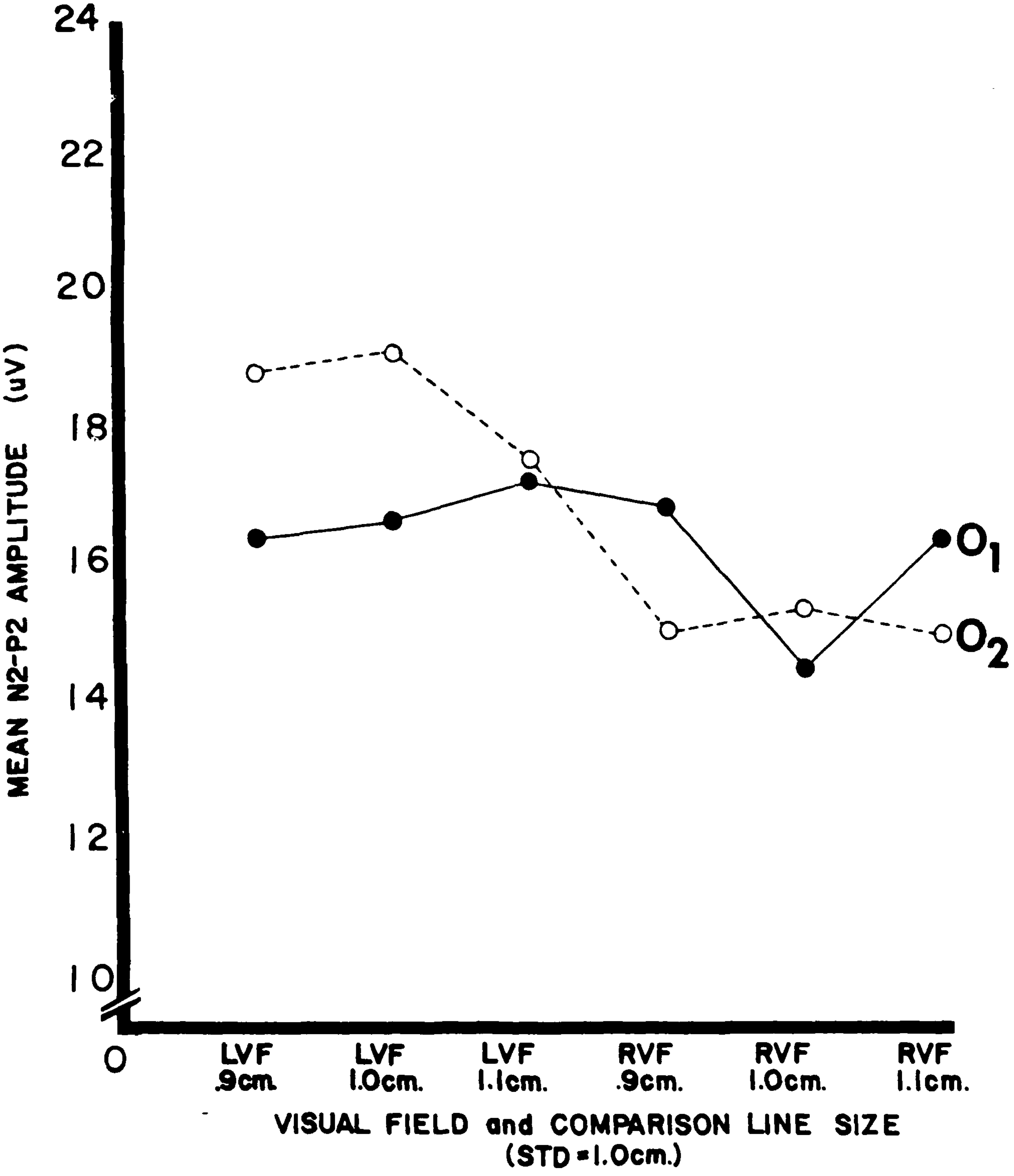

Figure 3 - Mean amplitude of N2-P2 component of the Visual ERP as recorded from O_1 and O_2 for seven subjects.

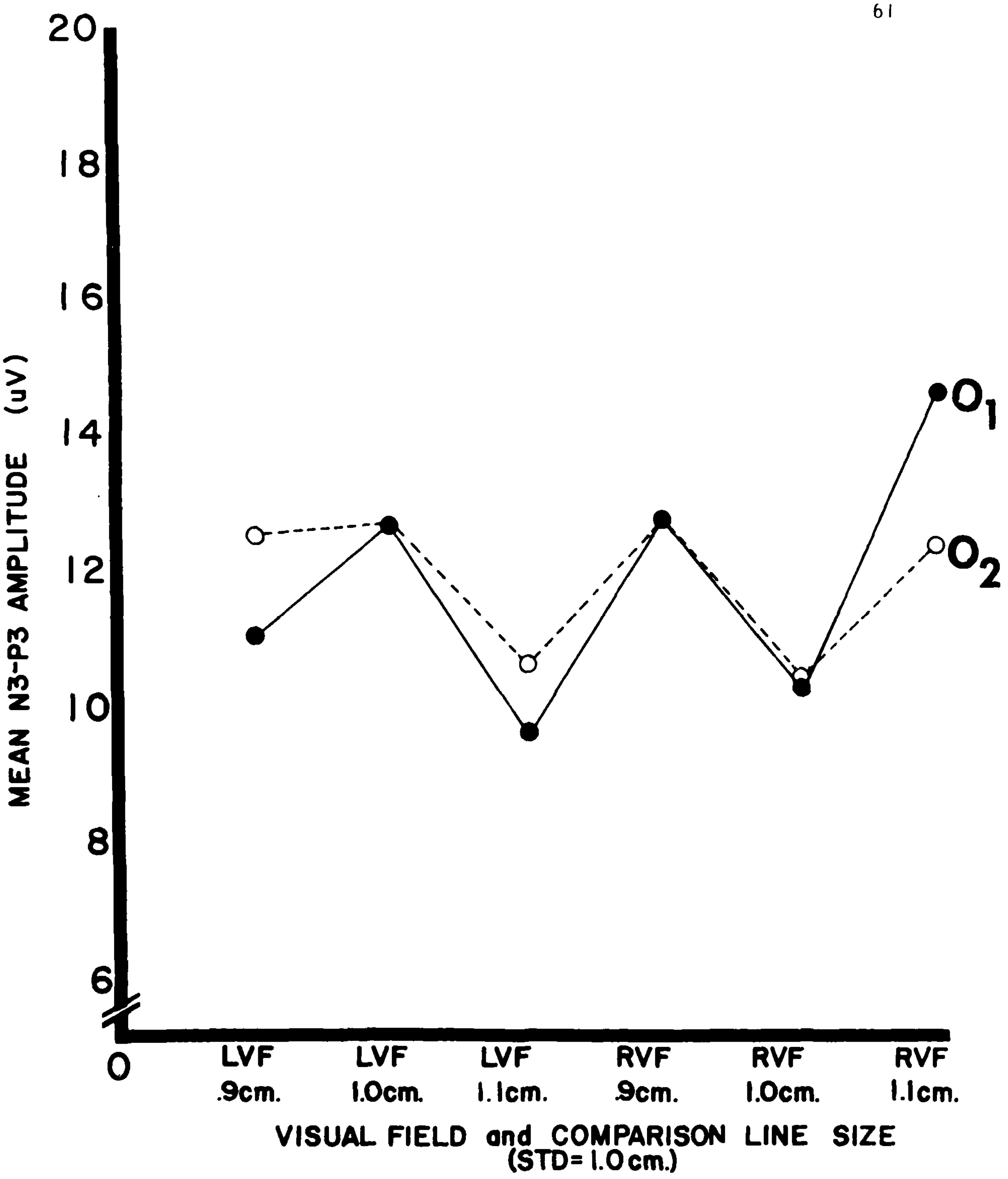

Figure 4 - Mean amplitude of N3-P3 component of the Visual ERP as recorded from O_1 and O_2 for seven subjects.

The percent of longer judgments for each line size and visual field is shown in Table 3.

Table 3
Percent of Longer Judgments
of the Three Line Sizes Within the
Three Visual Fields (Standard Line = 1.0 cm)
(N=7)

Line Size (comparison)	Visual Fields		
	Left	Center	Right
.9 cm	11	7	11
1.0 cm	48	48	48
1.1 cm	85	89	85

The two main variables (visual ERP components and total number of longer judgments) were subjected to separate three-way analysis of variance (ANOVA). For the visual ERP components, subjects (7) conditions (9), placements (2) and their various interactions were examined for significant effects. The data were also analyzed without the CVF conditions (B1, B2 and B3).[2] Only the ANOVA results for the left and right visual fields are reported (For ANOVA on all nine conditions see Appendix). In addition, several empty cells were generated for N3 latency and were filled by computing the mean latency from the remaining cells across the two placements. The ANOVA for the behavioral data (total number of "longer" responses) tested effects for subjects (7), line size (3), visual field (3), and their interactions.

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[2] In this study we found that the CVF conditions made the large latency differences nonsignificant, i.e., the lack of latency asymmetry for CVF conditions nullified the laterality effects found for the LVF, RVF comparisons.

For the latency component N2, significant effects were found for subjects, F(6/84)=24.00, $p < .01$, conditions, F(5/84)=2.67, $p < .05$, and the condition X placement interaction, F(5/84)=4.50, $p < .01$. The most important of these, the C X P interaction, reflects the oft replicated visual field effects, i.e., significantly shorter latencies occur at the scalp location contralateral to the field of presentation. This effect was expected and indicates that the stimuli were appropriately lateralized. The only significant effects for latency components P2 and N3 were found for subjects: N2, F(6/84)=3.00, p .01 and N3, F(6/84)=10.25, $p < .01$. However, significant condition effects were obtained for P3 latency, F(5/84)=6.67, $p < .01$.

For amplitude components N2-P2 and N3-P3 (P300), significant effects were found for subjects N2-P2, F(6/84)=22.06, $p < .01$ and P3, F(6/84)=6.63, $p < .01$), but only P300 showed a significant condition effect, F(5/84)=3.16, $p. < 01$.

The ANOVA for the behavioral data (total number of longer judgments) revealed only one significant main effect; i.e., line size, F(2/62)=233.1, $p < .01$. This indicated that the total number of longer judgments increased as a function of increasing line size. There was no visual field effect, i.e., discrimination in LVF and RVF were as accurate as those in CVF.

The data were subjected to Newman-Keuls multiple comparison tests (Winer, 1971). For N2 latency, no significant differences were found at the O_1 scalp location. On the other hand, significantly shorter latencies at O_2 were obtained for the three left visual field conditions as compared to right visual field conditions (A1, A2, A3 C1, $p < .01$, C2, $p < .01$, and C3, $p < .05$). These differences are easily seen in Figure 1. Note that the latency differences between the two occipital placements within a given condition are about 10 msec: a difference often obtained in our studies on asymmetry in the visual ERP due to lateralization of stimuli.

The P300 latencies also were significantly different. For example, both 0_1 and 0_2 showed significantly longer latencies with condition A2 (LVF, 1.0 cm line) than latencies for A1 (LVF .9) with $p < .01$ for 0_1 and $p < .05$ for 0_2. In addition, latencies were shortest at both scalp locations for C3, (RVF-1.1), $p < .01$ for 0_1 and $p < .05$ for 0_2. Moreover, this component does not show contralateral visual field effects, i.e. both 0_1 and 0_2 covary across conditions. This contrasts with the latency responses at N2 where clear contralateral effects can be observed (see Figure 2).

Although the N2-P2 amplitude responses recorded at 0_1 and 0_2 failed to show significant differences ($p > .05$), visual field effects can be seen. There is a tendency for amplitude responses to be larger at the scalp location contralateral to the field of presentation (see Figure 3). In contrast, N3-P3 amplitude does not show this trend and also appears to covary across conditions (see Figure 4). Significant differences were observed, but only at 0_1 i.e., condition C3 (RVF-1.1) produced significantly larger amplitude responses than C2 (RVF-1.0) and A3 (LVF-1.1), $p < .05$).

The event-related potentials for LVF and RVF presentation are shown

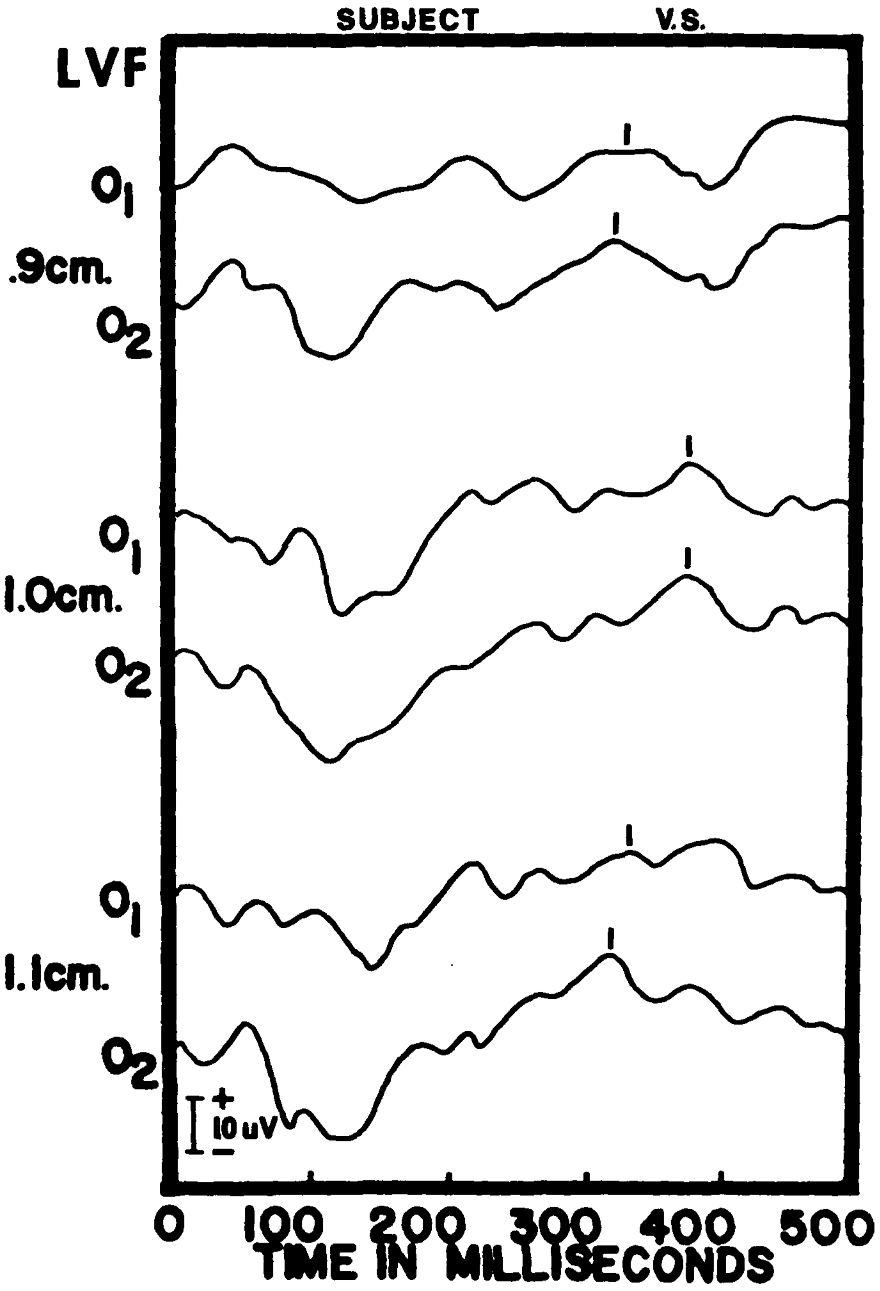

Figure 5 - Visual ERP of one subject (V.S.) with the .9, 1.0, and 1.1 cm comparison lines for left visual field presentations. Each trace is an average based on nine samples. The vertical bars indicate the P300 component.

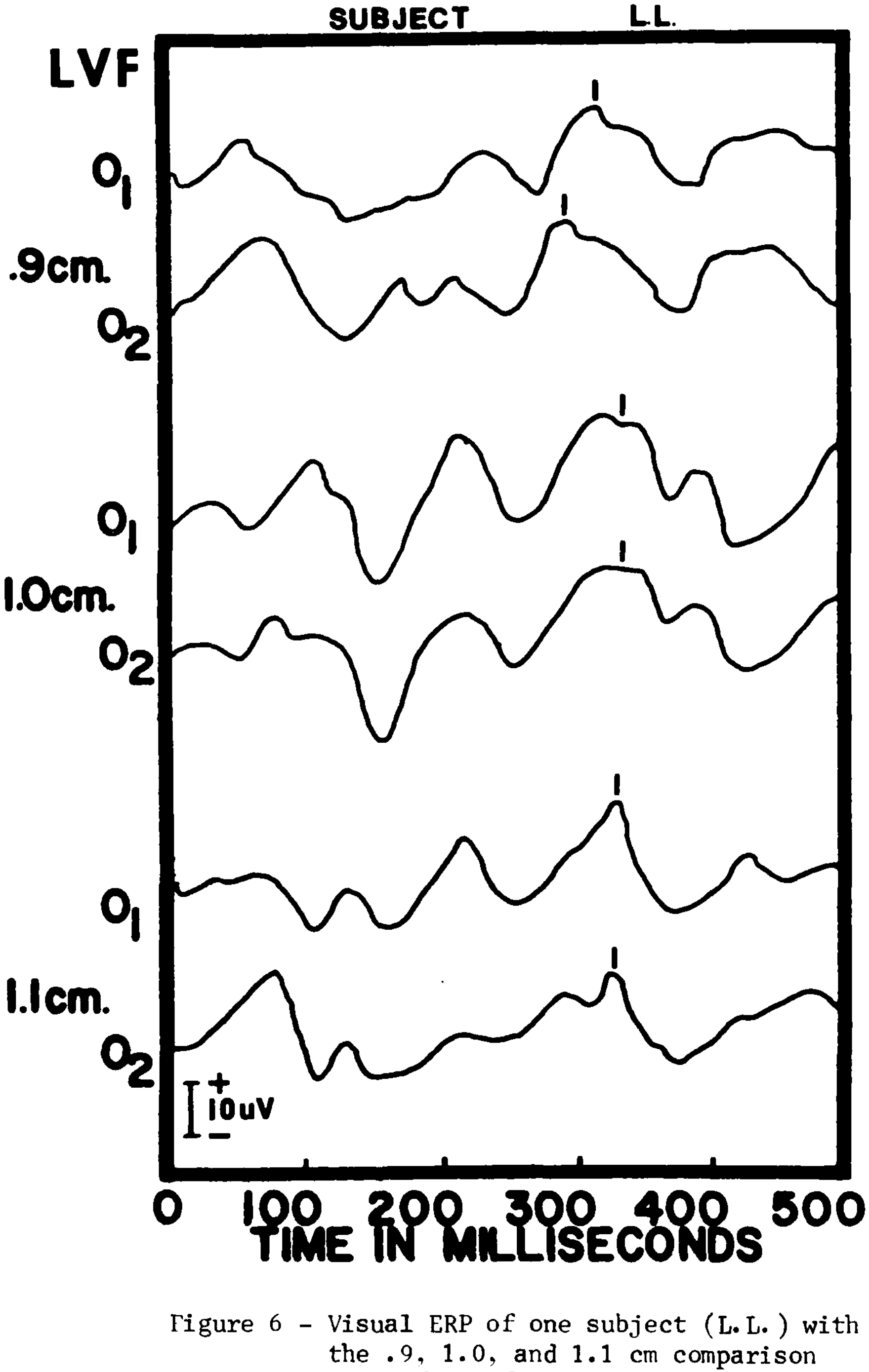

Figure 6 - Visual ERP of one subject (L.L.) with the .9, 1.0, and 1.1 cm comparison lines for left visual field presentations. Each trace is an average based on nine samples. The vertical bars indicate the P300 component.

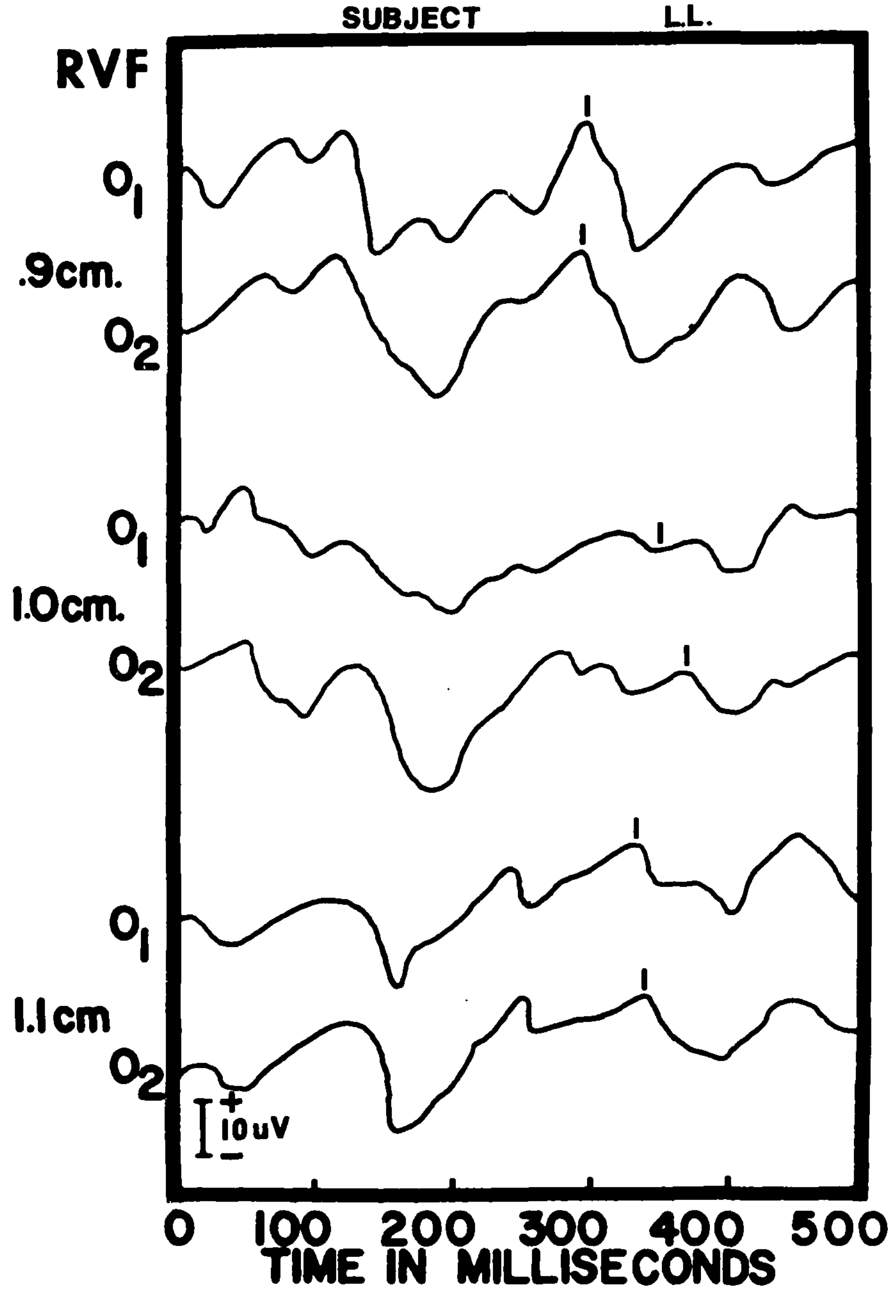

Figure 6 - Visual ERP of one subject (L.L.) with the .9, 1.0, and 1.1 cm comparison lines for right visual field presentations. Each trace is an average based on nine samples. The vertical bars indicate the P300 component.

for two subjects under the various condition in this experiment (see Figures 5 and 6). The individual traces are each based on nine samples.

Discussion

We expected that subjects confronted with making a decision about which of two equally sized stimuli was "longer" would experience difficulty. That they did is shown in the discrimination data indicating that the 1.0 cm comparison line was judged longer then the 1.0 cm standard 48% of the time. This ambiguity was persistent in all three visual fields since the same 48% "longer" judgment was obtained with LVF, CVF, and RVF judgments. In contrast, the subjects experienced little difficulty in deciding that the .9 cm line was shorter (90% correct across three visual fields) and that the 1.1 cm line was longer (87% correct). Judgments of the actually disparate line lengths were slightly, but not significantly, better with CVF presentations.

Our performance data indicate no difference in accuracy for discriminations in LVF (right hemisphere) and RVF (left hemisphere). We might have expected right hemisphere discriminations to be superior to left hemisphere since this is suggested by the literature on visuospatial tasks and by Koss's (1981) recent study concerning discriminations of line orientation. However, one factor must be noted. The error rate for both visual fields was only 11% for the .9 cm comparison line and 15% for the 1.1 comparison. This could mean that the discrimination task was not sufficiently difficult to test the presumably greater spatial abilities of the right hemisphere. It could also mean that discriminations of line length are not as much of a "visuospatial" task as are discriminations of line orientation. We intend to follow up this study with one in which discriminations of line orientation (angle) are required.

The ambiguous discrimination involving the 1.0 cm standard and comparison lines seems to have influenced P300 latency, i.e., it was found to be consistently longer when subjects were required to judge the 1.0 cm comparison line as compared to judgment involving the .9 and 1.1 cm lines. Further, the P300 latencies were longer at both right and left hemispheres with the ambiguous condition indicating that both hemisphere were equally affected and involved in the processing.

This finding further supports the hypothesis of Donchin (1979) and Donchin et al. (1978) that P300 latency seems to reflect stimulus evaluation time, since P300 is not emitted until the stimulus has been evaluated. In our present study, we believe, it was more difficult for subjects to make discriminations when confronted with the ambiguous comparison (i.e., the 1.0 cm standard and comparison lines) than it was to judge the lines which actually differed in length from the standard. How do we interpret our results seeming to show increased P300 latencies related to ambiguity? We propose that the ambiguous discrimination required a greater time for stimulus evaluation and that this was reflected in delayed P300 latencies.

The amplitude results for P300 are not as consistent. We did observe that a higher amplitude response was obtained with the 1.1 line compared to the 1.0 cm line in the RVF, but only for the left hemisphere response. Other investigators have reported that higher P300 amplitudes were related to higher degrees of decision confidence. One might ask, then, which produces large amplitude P300s, uncertainty or confidence? K. Squires et al. (1975) shed some light on this question with results indicating that when a decision is difficult P300 reflects decision confidence, when easy, P300 varies with probability of occurrence of a second stimulus (certainty-uncertainty).

The fact that earlier components of the ERP, e.g., N2, show contralateral latency and amplitude advantages indicate that they are stimulus bound. This is clearly seen in the crossover of plotted lines in Figures 1 and 3, illustrating field effects for latencies and amplitudes of this component. On the other hand, P300 is not affected by field of stimulation, emphasing its endogenous nature. Instead P300 is influenced by the cognitive effort a subject must make in dealing with a discrimination, and appear to index the completion of stimulus evaluation.

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Appendix I

Baruch College - Psychophysiology Laboratory

Handedness Questionnaire

Name________________________________ Age_____ Sex_____

Address______________________________ Telephone___________

Are there any members of your family who are left-handed? If so, please indicate their relationship to you as indicated below:

Mother_____ Sister_____ Father_____ Brother_____ Grandmother_____

Grandfather_____

Please indicate which hand you use to perform the following tasks and the frequency of use for that hand.

	Which Hand?		How Often?		
	Left	Right	Always	Sometimes	Never
1. Draw?					
2. Write?					
3. Throw a ball in order to hit a target?					
4. Use scissors?					
5. Use a toothbrush?					
6. Hold a match when striking it?					
7. Use a tennis racket?					
8. Use an eraser on paper?					
9. Use a hammer?					
10. Use a bottle opener?					
11. Remove the top card of a deck of cards when dealing?					
12. With which foot do you kick a ball?					

Appendix II

This Appendix describes the computation of "delta" scores to control for contralateral latency and amplitude advantages produced by presenting stimuli to left or right of central fixation. Thus, for example, considering LVF presentions the differences between the N2-P2 amplitudes produced with apparently moving and stationary stimuli are obtained as follows:

LVF (CAM) $O_1 = 6.0$ uV
$O_2 = 7.0$ uV

Substracting O_1 from O_2 we get a differential motion (DM) score of 1.0 uV. Then, LVF (STAT) $O_1 = 2.5$ uV
$O_2 = 5.0$ uV; subtracting O_1 from O_2 we get a differential stationary (DS) score of 2.5 uV. Then, subtracting

DM - DS = 1.0 uV - 2.5 uV = -1.5 uV. Therefore,

substracting out the differential between O_1 and O_2 to stationary stimuli from the O_1-O_2 difference to moving stimuli reveals that, relatively speaking, there is actually a larger O_2 response to the stationary stimulus in the left visual field when we might have expected a larger O_2 response to the moving stimulus. Hence, the difference score computation cancels out the visual field effect by subtracting the ERP to the stationary stimulus from the ERP produced by the moving stimlus. Note that moving stimulus at that hemisphere, and a negative score means that a bigger ERP is produced by a stationary stimulus. The same computational procedure can be done for each visual field and the results summarized for individual subjects and for all participants.

The difference, or "delta", scores as we referred to them, were computed for all 18 subjects for the three experimental sessions. The scores indicated no differential effects of apparent motion versus stationary conditions for either amplitude or latency measures when stimuli were in LVF or RVF. Differences did occur when stimuli were presented in CVF as pointed out earlier. The computation of delta scores for one session for an actual subject is shown in Table A. In Table B a summary of three day's scores for the same subject is presented.

Table A

Method for Computing Delta Scores - N2-P2 Amplitude
(Subject #2, H.J., Session 1)

LVF (CAM)	O_1= 6.0 uV O_2=13.0 uV	DM = 7.0 uV
LVF (STAI)	O_1= 3.0 uV O_2= 7.0 uV	DS = 4.0 uV DM - DS = 3.0 uV
RVF (CAM)	O_1= 5.5 uV O_2= 2.5 uV	DM = -3.0 uV
RVF (STAI)	O_1= 7.0 uV O_2= 7.0 uV	DS = 0.0 uV DM - DS = 3.0 uV
CVF (CAM)	O_1= 3.5 uV O_2=10.0 uV	DM = 6.5 uV
CVF (STAT)	O_1= 7.0 uV O_2= 9.5 uV	DS = 2.5 uV DM - DS = 4.0 uV

DM = difference between O_2 and O_1 for a given apparent motion condtion.

DS = difference for stationary conditions. In all cases difference is obtained by subtracting O_1 from O_2.

Table B

Summary of Delta Scores over Three Days
(Subject #2, H.J.)
Female

SESSION	FIELD	DM	DS	DELTA M-S
	LVF	7.0	4.0	3.0
1	RVF	-3.0	0	-3.0
	CVF	6.5	2.5	4.0
	LVF	4.5	7.0	-2.5
2	RVF	1.0	-1.0	2.0
	CVF	6.0	5.0	.5
	LVF	5.5	7.5	-2.0
3	RVF	4.5	0	4.5
	CVF	4.5	5.0	-.5
	LVF	-.50		
*Mean Delta (M-S)	RVF	+1.17		
	CVF	+1.33		

*A positive mean delta score indicates a larger N2-P2 response at the right hemisphere.

END

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DTIC