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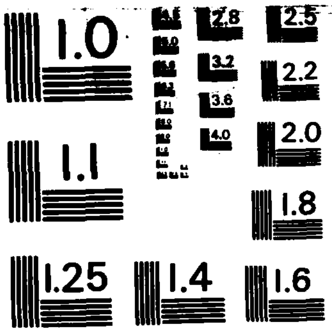

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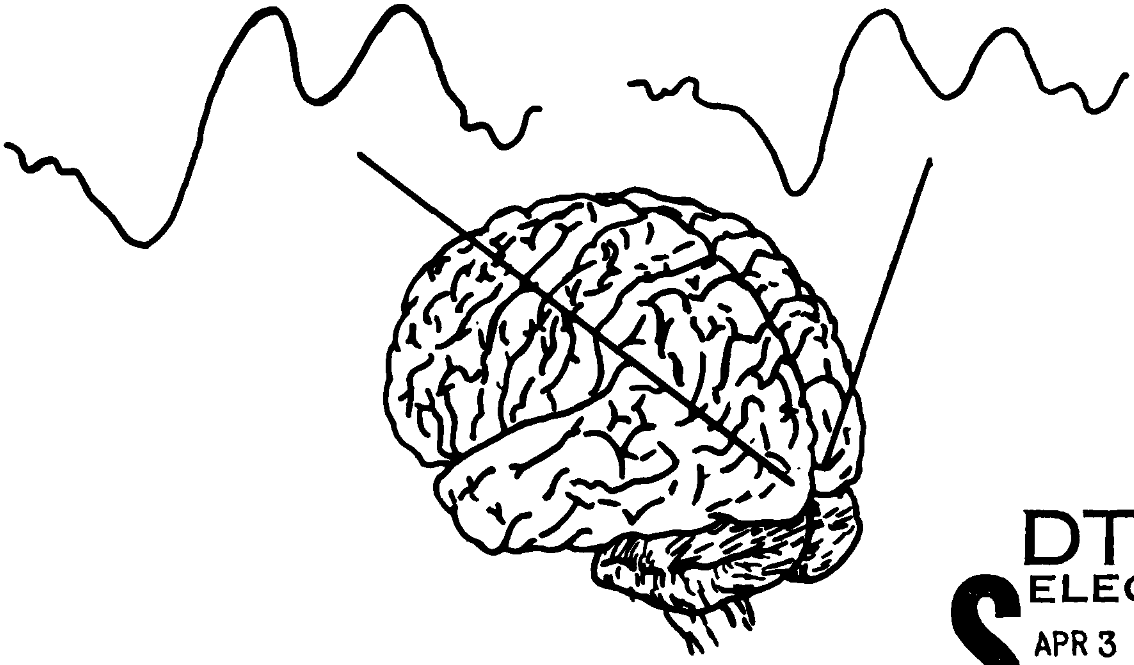

Brain Responses and Information Processing

Psychophysiology Laboratory
Department of Psychology
Baruch College
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Shape Discrimination

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

This is the final annual report to originate from the Psychophysiology Laboratory at Baruch College. The research completed over the last twelve months has included a number of studies concerned with evoked cortical potential correlates of visual stimulus processing in humans. The first experiment was conducted in order to replicate an earlier finding in which the amplitude of a relatively late positive component of the event related potential (ERP), known as the P3, was larger to a line orientation that

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required a "yes" response than one that required a "no." The angular difference between the two lines was only 5°. Another purpose was to assess the reliability of the better right hemisphere performance found with male subjects in the line orientation discrimination task used.

The hypothesis that the P3 amplitude advantage previously associated with a 55° line orientation would switch to the 50° line in the present study because of the positive label "yes" associated with 50° was not supported. The remaining ERP data also revealed no hemispheric differences when other components (N2 and P2) were analyzed for both latency and amplitude of response. Analysis of the performance data did not support a preliminary finding of right hemisphere advantage for male subjects in spatial discrimination. The twelve males and twelve females performed equally well with left and right hemipshere discriminations.

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A ~~The~~ fourth experiment was performed to determine the relative responsivity of the two hemispheres to verbal (letter) and spatial (geometric form) stimuli. Letter (B and E) and geometric (square and triangle) stimuli were presented in three visual fields. Both performance and ERP data indicated no laterality in response to the two types of stimuli. Several past studies had indicated hemispheric differences with these two types of stimuli. Perhaps the simplicity of our task (identifying the letters and forms) was not demanding enough to engage the two hemispheres differentially.

The foregoing account has summarized the work of our final annual report. The focus of our experimental work in the first annual report was upon hemispheric asymmetries of performance and ERPs in a signal detection task. In the second annual report, we studied possible hemispheric asymmetries in the perception of motion and line length. Investigations of hemispheric asymmetries during discriminations of line orientation and velocity of motion were conducted and reported on in the third annual report.

BRAIN RESPONSES AND INFORMATION PROCESSING IV: INVESTIGATIONS OF HEMISPHERIC ASYMMETRY IN EVENT RELATED POTENTIALS AND PERFORMANCE DURING DISCRIMINATION OF LINE ORIENTATION, COLOR, SHAPE AND UNDER VISUAL MASKING

Prepared By: John L. Andreassi and N. Mauro Juszczak

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City University of New York

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The hypothesis that the P3 amplitude advantage previously associated with a 55° line orientation would switch to the 50° line in the present study because of the positive label "yes" associated with 50° was not supported. The remaining ERP data also revealed no hemispheric differences when other components (N2 and P2) were analyzed for both latency and amplitude of response. Analysis of the performance data did not support a preliminary finding of right hemisphere advantage for male subjects in spatial discrimination. The twelve males and twelve females performed equally well with left and right hemisphere discriminations.

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The fourth experiment was performed to determine the relative responsivity of the two hemispheres to verbal (letter) and spatial (geometric form) stimuli. Letter (B and E) and geometric (square and triangle) stimuli were presented in three visual fields. Both performance and ERP data indicated no laterality in response to the two types of stimuli. Several past studies had indicated hemispheric differences with these two types of stimuli. Perhaps the simplicity of our task (identifying the letters and forms) was not demanding enough to engage the two hemispheres differentially.

Annual Reports 1, 2, and 3

The foregoing account has summarized the work of our final report. The focus of our experimental work in the first annual report was upon hemispheric asymmetries of performance and event related brain potentials in a signal detection task. Error analyses showed that the two hemispheres were equal in accuracy of processing signals. A slowing of brain potential responses from the first to second half of the experiment was accompanied by a slowing of response time to signals.

In the second annual report we studied possible hemispheric asymmetries in the perception of motion and line length. It was found that brain potentials from the right hemisphere were larger than left hemisphere responses to moving stimuli for female subjects, but not for males. With regard to line length, left and right hemisphere discrimnation was comparable. The interesting finding was that the latency of the P300 component was significantly longer with ambiguous as compared to clear discriminations. A final study in the second year pointed to the importance of screening potential subjects for strabismus (eye muscle balance). Comparisons reveal that strabismic individuals do not show the expected latency and amplitude advantages of contralateral hemispheric stimulation.

Studies of hemispheric asymmetries during discrimination of line orientation and velocity of motion were undertaken in the third year. Preliminary results suggested a right hemipsheric advantage in judging line orientation. This was not confirmed in a follow-up study. Performance data for velocity of motion discrimination indicated better left hemisphere performance compared to that of the right hemisphere. It was suggested that the sequential-temporal nature of the motion situation might make it a left hemisphere task.

POSSIBLE APPLICATIONS OF THIS RESEARCH TO AIR FORCE PROBLEMS

In past annual reports, we have considered the question of application of our research to practical Air Force problems. One area that seemed potentially fruitful was that of display-operator compatibility. This seemed to be a natural sequence to published literature which has reported functional differences between the left and right brain hemispheres. It is generally acknowledged that verbal analyses are performed primarily by the left hemisphere of most right-handed individuals, and that the right hemisphere is concerned with nonverbal tasks and those of a spatial nature. It seemed logical to us to propose that displays containing verbal information might best be presented so that the primary projection of this material would be to the left hemisphere of the brain, i.e., with a person looking straight ahead this would be accomplished by displaying the information to the right of center or in the right visual field. Conversely, displays containing spatial information might best be projected to the right hemisphere for most efficient processing (left of center). While this seemed logical, it was still necessary to demonstrate actual performance and electrophysiological differences before suggesting further testing of this possibility in a quasi-operational situation. We, therefore, undertook to present individuals with a variety of different tasks while visual event related potentials (ERPs) were recorded from over both left and right hemispheres. The results to date have been somewhat disappointing with regard to laterality. In nine studies completed to date, there were only two instances in which ERPs indicated hemispheric differences. Both of these instances of ERP laterality involved situations in which subjects were required to observe and describe differences between apparently moving and stationary stimuli. In a variety of other studies involving discriminations of line length, line orientation judgments, backward visual masking in peripheral vision, discriminations of motion velocity, detection and identification of signals over a 78 minute time period, color discriminations in three visual fields, shape and letter discriminations in peripheral vision, there was no evidence for ERP differences recorded from over the right and left hemispheres (Andreassi, Rebert and Larsen, 1980; Andreassi and Juszczak, 1981; Andreassi and Juszczak, 1982; Andreassi and Juszczak, this report). There were a number of interesting ERP results, but these primarily involved the P3 response and most did not relate to laterality. For example, in the study of line length discriminations, it was found that the P3 response was significantly delayed with the most difficult (ambiguous) judgment (Andreassi and Juszczak, 1981). In the velocity of motion discrimination study, the right hemisphere derived P3 response was greater in amplitude with the higher velocity condition (Andreassi and Juszczak, 1982). The P3 component, related to making decisions about signals, was found to be significantly larger at parietal scalp derivations as compared to occipitally derived responses (Andreassi, Rebert and Larsen, 1980). Visual ERPs were of greater amplitude to the color blue than to red (Andreassi and Juszczak, this report).

The performance data obtained in seven of the studies indicate that hemisphericity is not supported in the majority of instances. Laterality was not observed in the discrimination of line length, nor in the replication of the line orientation study. In the first line orientation discrimination study, males showed a right hemisphere superiority, but females did not. The velocity discrimination experiment revealed a female left hemisphere superiority. There was some evidence for laterality in processing of compatible stimuli, e.g., left hemisphere processes T better than ⊥, presumably because the T is verbal and the ⊥ is nonverbal. On the other hand, performance laterality was not in evidence for either males or females in peripheral masking, peripheral shape or letter discriminations, or in color discriminations. Thus, when the results of our experimental series are examined, considering both the ERP and performance data, the bulk of the findings do not lend support to the usual notion of laterality.

Despite the fact that our series of studies did not indicate strong support for hemispheric electrophysiological or performance differences in the processing of various kinds of stimuli, there did emerge some findings which could have potential application to Air Force problems. Among these are the following:

1) In the vigilance study, time effects were observed in that significant slowing of ERP components from the first halves to second halves of the experimental sessions were accompanied by a slowing of reaction time to signals. Monitoring of the ERP may be justified in situations which demand detection of subtle changes in ability to perform a vigilance task as time progresses (Annual Report #1).

2) When a symbolic target was presented to the right hemisphere, the reponse controlled by that hemisphere (left hand) was faster than when an aplhabetic target was presented. The converse happened when the alphabetic target was presented to the left hemisphere. It is suggested that when symbolic materials are used and manual responses are required, it might be better to have such stimuli located on the left (right hemisphere processing) and to require a left hand response (right hemisphere control). The opposite would be suggested for alphabetic information (Annual Report #1).

Thus far, over 200 potential subjects have been visually screened in connection with our series of experiments. The screening involved tests of acuity, depth perception and eye muscle balance (strabismus). We found that approximately 14% of our young adult sample had eye muscle imbalance. The strabismus portion of the testing, which was accomplished with a Bausch and Lomb Orthorater, refers to the ability of a person to use the two eyes together in fixating on some object. The muscular strain and stress experienced in trying to overcome the muscular imbalance in attempting to fixate objects (such as words on a page or signals on a screen) often leads to complaints of headache and eye fatigue in strabismic persons. A point to be made here is that persons required to perform long term vigilance tasks, such as monitoring radar screens or other information-giving displays, screens, or terminals, be screened for strabismus. These individuals may have to covercome undetected eye muscle imbalance at the cost of eye fatigue or headache, two factors that could lead to performance decrement over time, especially where the workload is high (Annual Report #3).

4) One of our findings was that the latency of the P3 component of the ERP was delayed in both hemispheres when subjects were required to make a discrimination in an ambiguous situation. The latency of P3 appears to index stimulus evaluation time, i.e., the longer the time to evaluate a stimulus in an ambiguous or difficult discrimination, the longer is P3 latency. It is suggested that the P3 may be used, along with performance, as an objective indicator of display difficulty or ambiguity. Further, we suggest that equipment designers test the clarity with which their displays present information with P3s, i.e., the shortest latency P3s may reflect the clearest, most unambiguous, display configuration and be related to efficient visual discrimination.

5) The very robust and consistent finding of contralateral ERP latency and amplitude advantages noted throughout this entire series of studies would suggest that in situations where it is not possible to

present verbal information centrally it should be presented in the right visual field since this would result in its earlier arrival at the hemisphere primarily responsible for processing that type of information (the left) than if it were presented in the left visual field. The latency difference between cortical responses to contralateral and ipsilateral stimulation (averaging about 10 msec) represents, at least in part, the time it takes for neuronal impulses to cross from the visual area of one hemisphere to the other (Annual Reports # 1,2,3, and 4).

6) The finding that the color blue resulted in greater amplitude visual ERPs than the color red suggests a possible application for display design. If we can assume that greater sensory impact is indicated by larger amplitude ERPs (and there is good reason to indicate that we can, since, for example, higher intensity stimulation generally produces larger amplitude ERPs), then it would be worth investigating the use of the color blue, or other shorter wavelength colors, in the display of important information. We intend to replicate and expand this study by testing the effects of a wider range of colors on the visual ERP (Annual Report #4).

EXPERIMENT I -- A Follow-up of Line Orientation Discrimination in Three Visual Fields and Associated Event Related Potentials

INTRODUCTION

Cerebral hemispheric asymmetry has been extensively studied under many different experimental situations over the last decade. Examples of some studies are those dealing with unilateral brain lesioned and commissurotomized patients (Sperry, 1974, 1982; Kinsbourne, 1978) and those using visual discrimination paradigms with normal subjects, e.g., Umilta et al., 1973, 1974, 1978; Sasanuma and Kobayashi, 1978; Koss, 1981. The concept of hemispheric asymmetry that has been developed attributes analytic, mathematical, and language related functions to the left hemisphere, and synthetic, nonverbal, and visuo-spatial functions to the right (Gazzaniga and Le Doux, 1978).

There has also been work on the question of sex differences in hemispheric asymmetry. Harris (1978) suggests that the male brain is lateralized with respect to linguistic-visuo-spatial functions (i.e., left hemisphere, language; right hemisphere, visuo-spatial), while in females, both hemispheres equally participate in these same activities. This notion received support from several studies, some of which addressed developmental aspects of male-female cerebral lateralization (Molfese, 1973; Rudel et al., 1974; Wittelson, 1975) and others on adults using electrophysiological and and perceptual measures (e.g., Rebert and Low, 1978; Sasanuma and Kobayashi, 1978). In the Sasanuma and Kobayashi study, it was found that males showed a significant left visual field (LVF) superiority (right hemisphere) in a line orientation discrimination task, while females did not. Similarly, Koss (1981) had six male subjects discriminate two lines oriented 95° and 100° from horizontal, projected in left and right visual fields, and reported a LVF superiority.

A contrasting position on this question has been taken by Buffery and Grey (1972) who proposed that females are more lateralized along the linguistic-visuo-spatial dimension while males are more bilateralized. These authors cite anatomical (e.g., Geshwind and Levitzky, 1968) and psychological studies (Buffery, 1971) as supporting their hypothesis. Andreassi and Juszczak (1982a) obtained visual ERPs while male and female subjects observed apparently moving stimuli (a visuo-spatial-temporal phenomenon) displayed in left, central, and right visual fields. Under conditions of central visual field stimulation, females showed asymmetric brain responses to apparently moving stimuli while males did not. That is, event-related potentials (ERPs) for females were larger in amplitude for right hemisphere derivations than for left hemisphere responses. It was speculated that the findings might reflect a right hemisphere sensitivity in females for apparently moving (visuo-spatial) stimuli. These findings support the possibility of greater right hemisphere sensitivity in females for at least one kind of visuo-spatial stimulus. Most research findings, however, support the notion of greater lateralization with males and bilateralization with females (McGlone, 1980).

A recent study origination in this laboratory (Andreassi and Juszczak, 1982b: Experiment I) suggested a relationship between P3 amplitude, and the yes-no decision that subjects were required to make in a line orientation discrimination task. Specifically, it was reported that larger P3 amplitudes occurred to the stimulus (i.e., 55° line orientation) which required a "yes" response, compared to the stimulus (50°) which required a "no." It was proposed that P3 amplitude might reflect some implicit cognitive process which attributes greater relevance or importance to a stimulus which requires a positive response. One purpose of the present investigation was to ascertain whether the P3 amplitude advantage initially associated with the

55° line might switch to the 50° line as a result of a reversal in the instructions, i.e., by instructing subjects to say "yes" to the 50° and "no" to the 55° line in this study. Another purpose was to address the reliability of the better LVF (right hemisphere) performance found with the male subjects in the line orientation discrimination task used in the Andreassi and Juszczak (1982b: Experiment I) study. These previous findings have been supported by those of Koss (1981) and Sasanuma and Kobayashi (1978) in which the superior LVF discrimination of line orientation for male subjects was proposed as representing a greater efficiency of the right hemisphere in the processing of visuo-spatial information. A final consideration, which is related to the notion of lateralized visuo-spatial abilities in the right hemisphere of the male brain, concerned a test of the hypothesis that females are bilateralized with respect to these same visuo-spatial abilities (McGlone, 1980).

We hypothesize that:

1) The P3 amplitude component of the visual ERP will be larger to the 50° line orientation than amplitudes to the 55° line when a "yes" response is required to the 50° line.

2) Males will show a LVF superiority in the line orientation discrimination task while females will not.

3) Females will show neither a LVF or RVF superiority in the line orientation task, i.e., bilateralization of function will be evidenced.

METHOD

Subjects: The subjects were twelve male and twelve female right-handed students associated with the City University of New York. They ranged in age from 17-35 years. Each subject was administered a vision test battery with a Bausch and Lomb Orthorator, and a handedness questionnaire (Annett, 1970). The vision test battery screened subjects for vertical and lateral phoria, and binocular visual acuity (both at near and at a distance). The handedness questionnaire asked subjects to report the preferred hand used in a variety of tasks and to indicate any familial history of left-handedness. All subjects met the criteria of normal visual acuity (corrected to at least 20/25 with glasses) and eye muscle balance (Orthophoria) as established by the Bausch and Lomb Occupational Vision Standards. None reported any personal or familial history of left-handedness.

Apparatus and Procedure: Subjects were seated in an electrically shielded, sound attenuated Industrial Acoustics Corporation (IAC) chamber while EEG was recorded from O_1 and O_2 (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to silver clip electrodes on both ear lobes (linked ears). 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 PDP8/E computer, obtained EEG samples of 500 msec duration following presentations of the stimulus to the subject. The resultant summated ERP trace was plotted on a Hewlett Packard X-Y plotter.

Eye blinks and eye movements were recorded with a two-channel eye movement monitor (Washington University resetting differential amplifiers) and were measured by placing two biominiature electrodes above and below the left eye. The resultant electro-oculogram (EOG) was displayed continuously on a voltmeter in the Washington University apparatus and on a Tektronix dual-trace oscilloscope. Artifacts produced by such eye movements appeared as left or right deviations from zero on the EOG device and as abrupt changes from baseline on the storage oscilloscope. 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 PDP8/E to deliver stimuli at specific times and locations on the CRT. The disappearance of the stimuli was virtually immediate (50 usec) with a brief persistence P24 phosphor specially installed in the VR-14.

A 1.0 cm line was displayed on the CRT for 20 msec in either a 50° or 55° orientation (measured from horizontal) in left, central, or right visual fields. The presentation of the lines was randomized[1] so that subjects could not predict the line orientation nor the visual field in which it appeared.

For example, a 50° line might appear in the LVF followed by a 55° line presented in the right visual field (RVF). The time interval between presentations was 4 sec. The probability of a given line (.50) within a visual field (.33) was .17. The CAT was under control of the experimenter so that selected EEG samples could be obtained for each line and visual field within the sequence. Each ERP trace was based on the average of ten samples, i.e., trials containing EOG contamination were repeated until ten samples were obtained. Each line was presented, in the same horizontal plane, $2^{\circ}30'$ of arc to the left and right of fixation and directly below (6 mm) the fixation point (.001 mL red neon light). Hence, there were six experimental conditions: LVF-50° line, LVF-55° line, CVF-50° line, CVF-55° line, RVF-50° line, RVF-55° line. The 1.0 cm line produced a visual angle of 30' of arc at the viewing

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[1] Randomization was restricted in that each line appeared in each visual field an equal number of times.

distance used. The luminance of each line was 2.0 mL as measured by a Tektronix J-16 photometer. Thus, in all conditions the physical parameters of the stimuli were equated.

After subjects were seated in the IAC chamber, they were given the instructions below to read prior to being given practice trials. These instructions are unlike those in the original experiment since, previously, a "yes" response was required for the 55° line and "no"for the 50° line.

> A line will be presented in one of two orientations to the left, right, or just below the small red neon light on the screen. Your task is to identify the less vertical line (50°) by saying YES. When the more vertical line (55°) appears, say NO. Also, you are to rate how sure you are of your judgment. Use the number 4 if you are ABSOLUTELY CERTAIN, the number 3 if you are REASONABLY CERTAIN, the number 2 if you are HALF CERTAIN, and the number 1 if you think you had to GUESS. Give your answer out loud about 1 second after the stimulus appears.

All judgments were absolute, i.e., the two lines never appeared on the screen at the same time. After these instructions, the computer was programmed to display the stimuli for 4000 msec to enable longer duration examination by subjects of both the more vertical (55°) and the less vertical line (50°). Subjects were also advised to avoid anticipating any stimuli within the visual fields, i.e., they were told that the order of presentation was completely randomized so that it would be virtually impossible to predict the line orientation and location. The subjects were given a practice period before the beginning of the experiment to insure proper performance. All reported familiarity with the appropriate response and the certainty of judgment scale at the end of the practice segment. Subjects were reminded to fixate on the red neon light at all times to avoid missing stimuli. They were also asked to look and not stare at the fixation point. This additional instruction minimized the problem of eye strain and tears, a discomfort often associated with prolonged fixation. The verbal responses were monitored via an intercom system and recorded by the experimenter.

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

RESULTS

Performance Data -- As in the previous experiment, the two main variables were: 1) total number of correct discriminations out of 120 stimulus presentations for the two line orientations (i.e., 50° and 55° line separately); and 2) combined correct discriminations, which was derived by combining the accuracy scores from each line (i.e., $50^\circ + 55^\circ$ line accuracy scores out of 240 presentations). Table 1 shows the accuracy data, expressed as percent of correct discriminations, for males, females, and the two groups combined. Figure 1 graphically depicts the same data.

Visual Field of Presentation -- A two-way ANOVA (Gender X Field) was performed on the log-transformed combined accuracy scores for all twenty-four subjects and revealed that the two main effects, gender and visual field, were non-significant. The non-significant gender effect reflects the finding that females performed as well as males and contrasts with the results of the earlier study in which males were found to excel in the task. Figure 1 shows that, within the CVF and RVF, female accuracy scores were slightly better than the male scores. These differences were not significant (t-tests for uncorrelated data, two-tailed criterion, $p > .05$ for CVF and RVF). The separate ANOVAs for males and females (Subject X Field), with only LVF and RVF compared, also indicated that the visual field effect was non-significant ($p > .05$ for both females and males). Thus, the previously observed LVF superiority for males was not replicated. An examination of the accuracy scores of each male subject showed that this was due to the fact that five of the twelve subjects had reversals, i.e., better RVF discriminations.

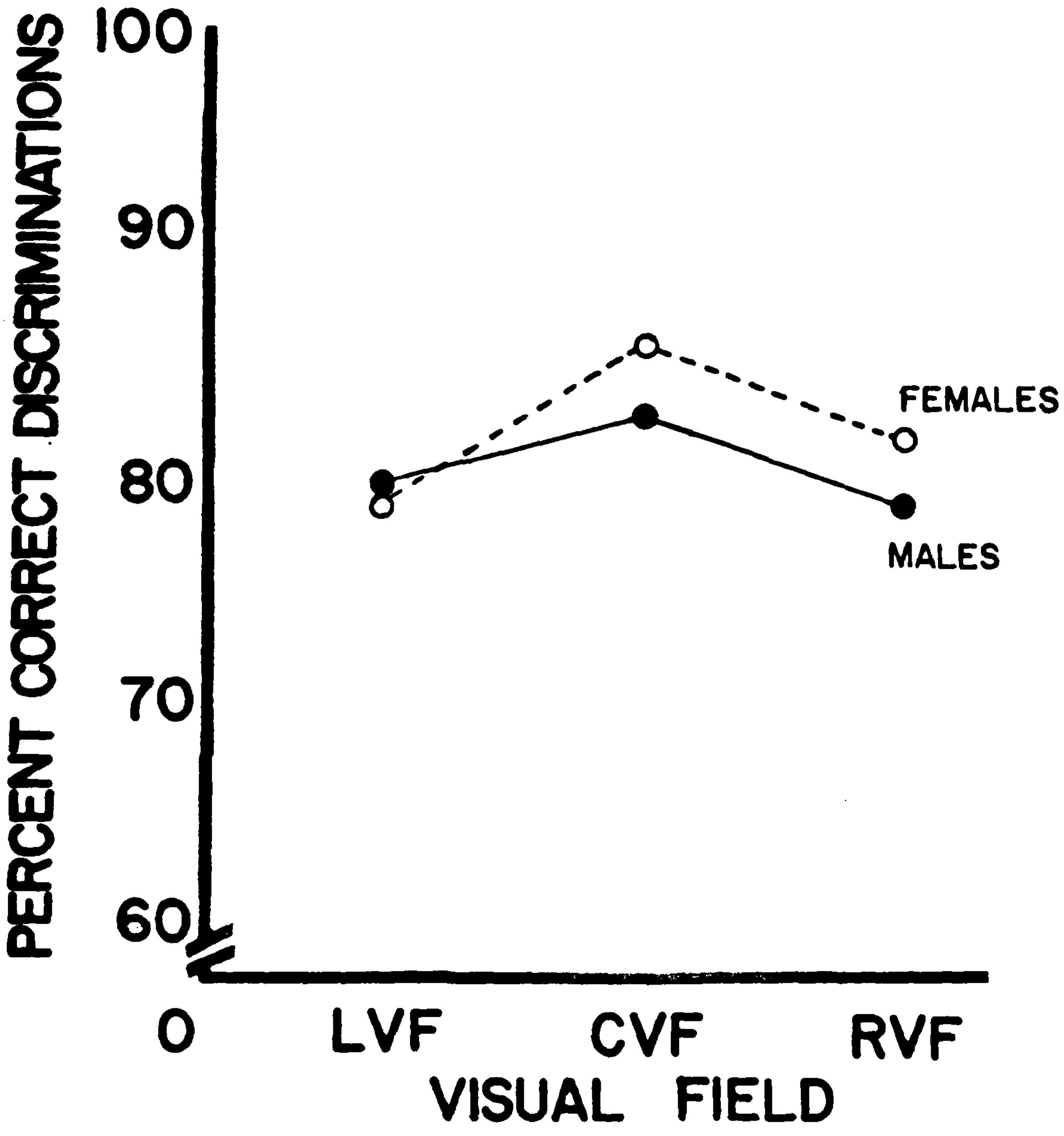

FIGURE 1 Percent correct discriminations of the 12 female and 12 male subjects in this experiment. The slight advantage shown for females with CVF and RVF presentations is not significant.

TABLE 1

Percent Correct Discriminations Within Three Visual Fields for Males, Females, and Males and Females Combined (Combined Accuracy Score)

	LVF	CVF	RVF
Males (N=12)	80	83	79
Females (N=12)	79	86	82
Combined (N=24)	79	85	80

Line Orientation -- A three-way ANOVA (Gender X Field X Line Orientation) was conducted to determine if there was a significant difference in discrimination accuracy with the 50° and 55° line orientations. The line orientation effect was non-significant ($p > .05$). Moreover, separate ANOVAs on males and females (Subject X Field X Line Orientation) also revealed that there was no significant difference in accuracy scores between the two lines ($p > .05$). Females, however, showed higher accuracy scores with the 55° line within the LVF and RVF, and better scores with the 50° line in the CVF (LVF 50°-74% vs LVF 55°-83%; CVF 50°-89% vs CVF 55°-84%; RVF 50°-78% vs RVF 55°-86%). The accuracy data for males, on the other hand, showed that, within LVF and CVF presentations, accuracy scores with the 50° line tended to be higher than those with the 55° line (LVF 50°-82% vs LVF 55°-78%; CVF 50°-87% vs CVF 55°-80%) with a reversal for RVF presentations (RVF 50°-76% vs RVF 55°-82%). Our response bias estimates revealed that these differences were due to a greater tendency for females to say NO within LVF and RVF (55% and 53% for LVF and RVF respectively), while the male subjects showed a greater tendency to say YES within LVF and CVF (52% and 54% respectively) and to say NO within RVF (52%). The reason for this slight difference in response bias is unknown and could be due to the operation of chance factors.

Confidence Ratings -- A Mann-Whitney U-test was used to examine the confidence with which the line orientations were judged. Those ratings for the 50° and 55° lines were found to be non-significant ($p > .05$) as were gender effects ($p > .05$). The mean confidence ratings for males and females, across visual fields, were 3.2 and 2.9, respectively, out of a possible 4.0.

Visual ERPs -- All subjects showed major ERP components similar to those obtained from the twelve subjects in the Andreassi and Juszczak (1982) study. Thus, with regard to their measurement, the same criteria were used. Figures 2 and 3 show the ERP traces of one male and one female subject recorded at both scalp locations under the six experimental conditions.

N2-P2 Amplitude -- A three-way ANOVA (Subject X Conditions X Placement) on the data of all twenty-four subjects revealed a significant condition effect (F=3.07, 5/288, $p < .01$). Separate ANOVAs on males and females (Subject X Condition X Placement) showed a significant condition effect for females (F=2.62, 5/144, $p < .05$), and for males as well (F=2.28, 5/144, $p < .05$). Table 2 shows the N2-P2 amplitude and N2 latency data for males, females and the two groups combined.

Newman-Keuls test results showed that this significant N2-P2 amplitude effect was attributable to the largest amplitudes occurring with CVF presentation ($p < .05$ for CVF vs RVF conditions for the combined group). These findings were expected and highlight the fact that foveal stimulation results in greater activity at the occipital cortex than parafoveal stimulation. Another expected finding was that the Condition X Placement interaction effect for the combined group was significant (F=3.06, 5/288, $p < .01$). The figure depicting the data for the combined group (Figure 4) shows a

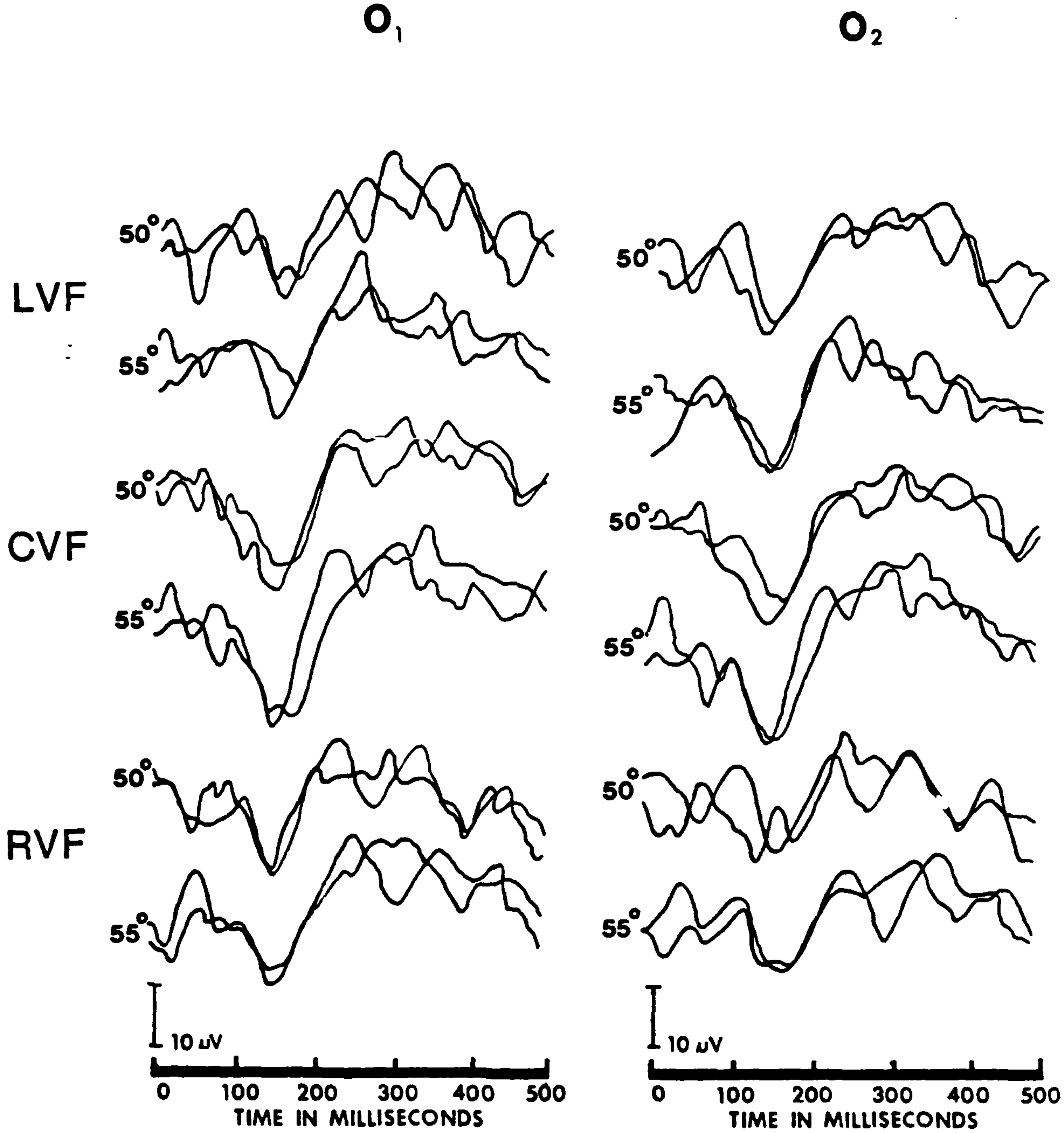

FIGURE 2 Visual ERP traces of one male subject (J.R.) for the two line orientations, three visual fields and two scalp locations (O_1 and O_2). Negativity is downward.

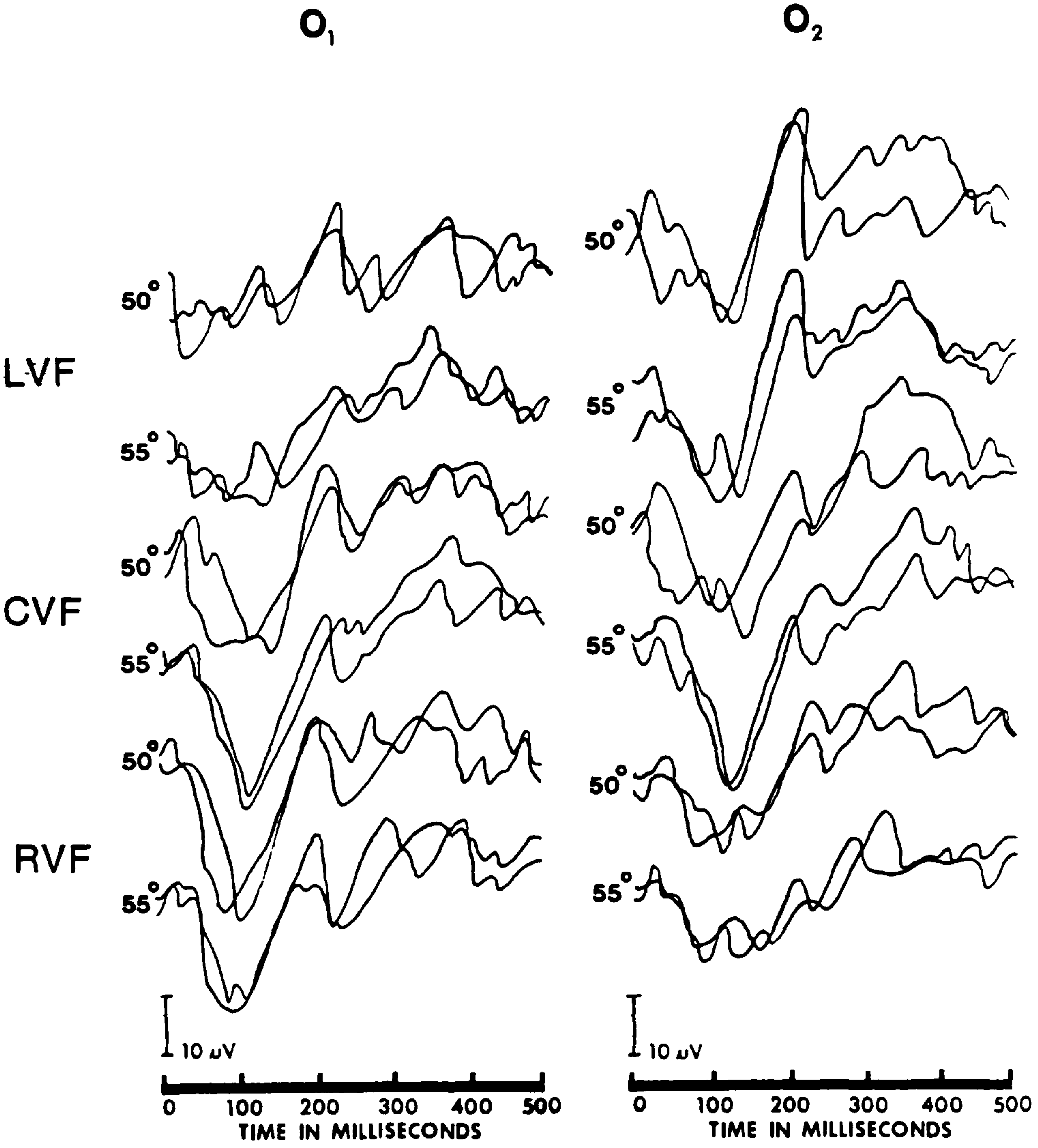

FIGURE 3 Visual ERP traces of one female subject (M.L.) for the two line orientations, three visual fields and two scalp locations (O_1 and O_2). Negativity is downward.

TABLE 2

Mean Latency (msec) and Amplitude (uV) for Visual ERP
Components N2, and N2-P2 for Males, Females,
Males and Females Combined for Placements and Conditions

	O_1						O_2					
	(N=12) Males		(N=12) Females		(N=24) Combined		(N=12) Males		(N=12) Females		(N=24) Combined	
	N2 LAT	N2-P2 AMP	N2 LAT	N2-P2 AMP	N2 LAT	N2-P2 AMP	N2 LAT	N2-P2 AMP	N2 LAT	N2-P2 AMP	N2 LAT	N2-P2 AMP
LVF 50°	172	20.3	176	18.7	174	19.5	165	23.1	165	22.8	165	22.9
LVF 55°	171	20.8	171	18.7	171	19.7	163	21.8	160	24.7	162	23.2
CVF 50°	155	23.4	160	27.4	158	25.4	156	22.4	162	27.1	159	24.8
CVF 55°	158	24.7	167	26.3	163	25.5	160	23.8	168	25.2	164	24.5
RVF 50°	161	23.9	163	23.0	162	23.4	174	18.8	174	17.5	174	18.1
RVF 55°	159	23.3	159	23.3	159	23.1	175	18.0	179	16.7	177	17.4

trend indicating an amplitude advantage at the recording site contralateral to the field of presentation.

N3-P3 Amplitude -- The three-way ANOVA (Subject X Condition X Placement) that compared amplitudes to the 50° line with amplitudes to the 55° line revealed that the condition effect was non-significant ($p > .05$ for males, females and the two combined). Additional Newman-Keuls tests showed that, when the amplitude of responses to the 50° line were compared with those to the 55° line (collapsed across visual fields), there were no significant differences ($p > .05$ combined group). Thus, the expectation that the P3 amplitude advantage would switch to the 50° line in this study was not confirmed. Separate Newman-Keuls tests were conducted on the male and female data (i.e., 50° vs 55°) and were also found to be non-significant ($p > .05$).

N2 Latency -- Similar to the combined ANOVA on N2-P2 amplitude, the three-way ANOVA (Gender X Condition C Placement) on the N2 latency data also showed a significant condition effect ($F=2.68$, 5/288, $p < .02$). Thus, CVF stimulation produced the shortest latency responses at both scalp locations,

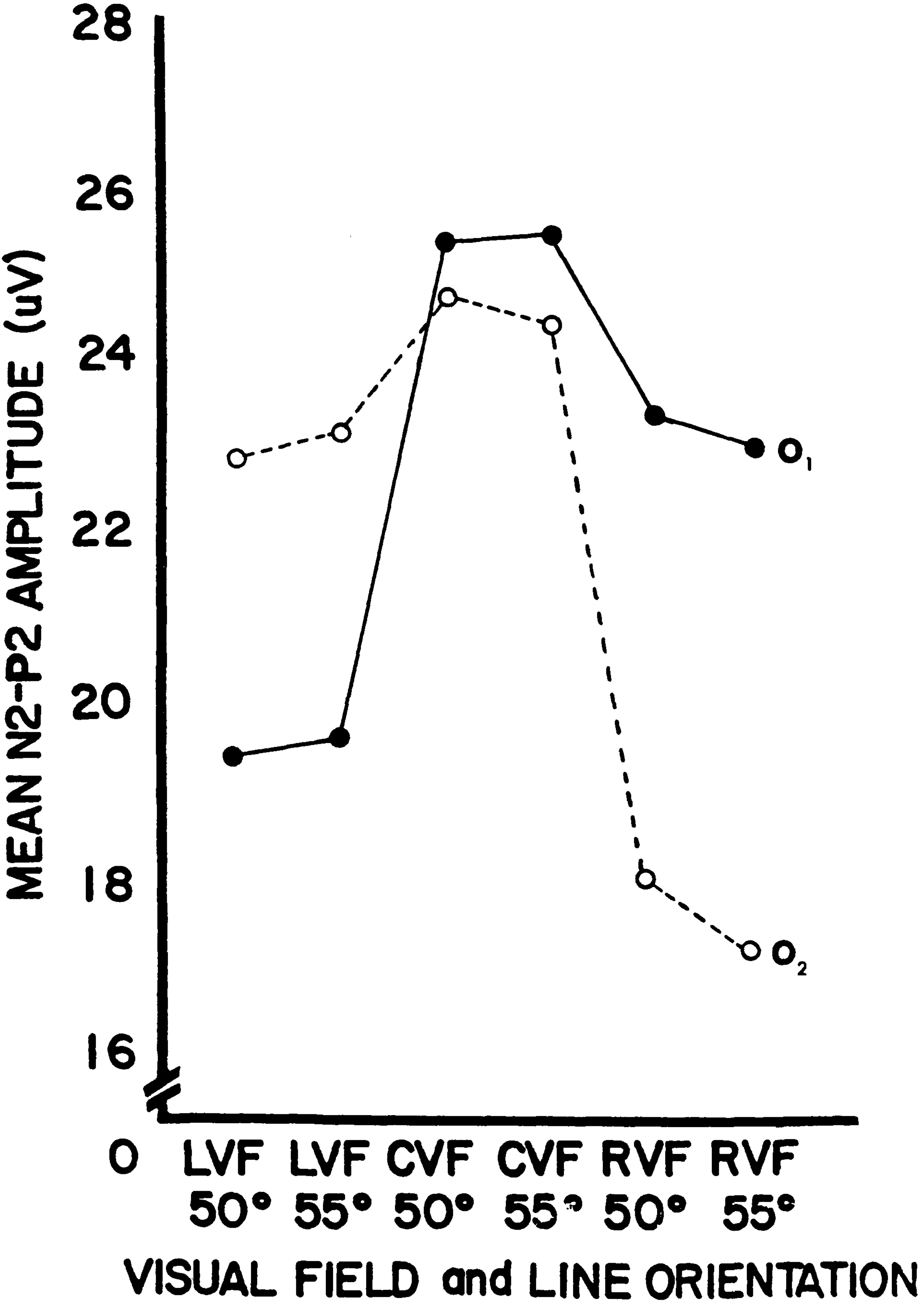

FIGURE 4 Mean N2-P2 amplitude under various conditions for 24 subjects. Note the larger amplitudes that occur with contralateral stimulation.

as further supported by Newman-Keuls test results ($p < .05$ for combined groups). A significant Condition X Placement interaction effect was also obtained in the combined ANOVA (F=4.66, 5/288, $p < .001$). The Table and Figure depicting the latency data (Table 2 and Figure 5) show that N2 latencies were shortest at the recording site contralateral to the field of presentation. Additional Newman-Keuls tests show that this was significant, at $p < .05$ for visual field comparisons with the combined group.

P2 Latency -- The only significant effect obtained in the three-way ANOVA on this component was Gender (F=8.12, 5/288, $p < .005$).

TABLE 3

Mean Latency (msec) and Amplitude (uV) of the Visual ERP Component N3-P3 of Males, Females, and Males and Females Combined, for Placements and Conditions

	O_1						O_2					
	Males		Females		Combined		Males		Females		Combined	
	P3	N3-P3	P3	N3-P3	P3	N3-P3	P3	N3-P3	P3	N3-P3	P3	N3-P3
LVF 50°	346	12.2	333	12.5	340	12.4	350	11.3	334	11.4	342	11.4
LVF 55°	348	10.9	333	14.3	341	12.6	349	10.4	325	13.4	337	11.9
CVF 50°	348	12.0	323	13.7	336	12.9	349	12.0	325	14.6	337	13.3
CVF 55°	346	10.7	342	13.3	344	12.0	355	11.0	345	13.3	350	12.2
RVF 50°	340	10.1	334	13.1	337	11.6	341	9.9	333	13.4	337	11.6
RVF 55°	351	10.0	344	12.1	348	11.1	351	11.7	341	14.0	346	12.8

P3 Latency -- The three-way ANOVA (Gender X Condition X Placement) showed significance for Gender (F=22.86, 1/288, $p < .001$). A closer analysis of these effects revealed that females produced shorter P3 latencies than males. Separate ANOVAs on the male and female data revealed that females showed a significant Condition effect (F=4.84, 5/144, $p < .01$) whereas males did not (F=1.45, 5/144, $p > .05$), which indicated that, for females, P3 latencies with the 55° line orientation were significantly longer than those with the 50° line.

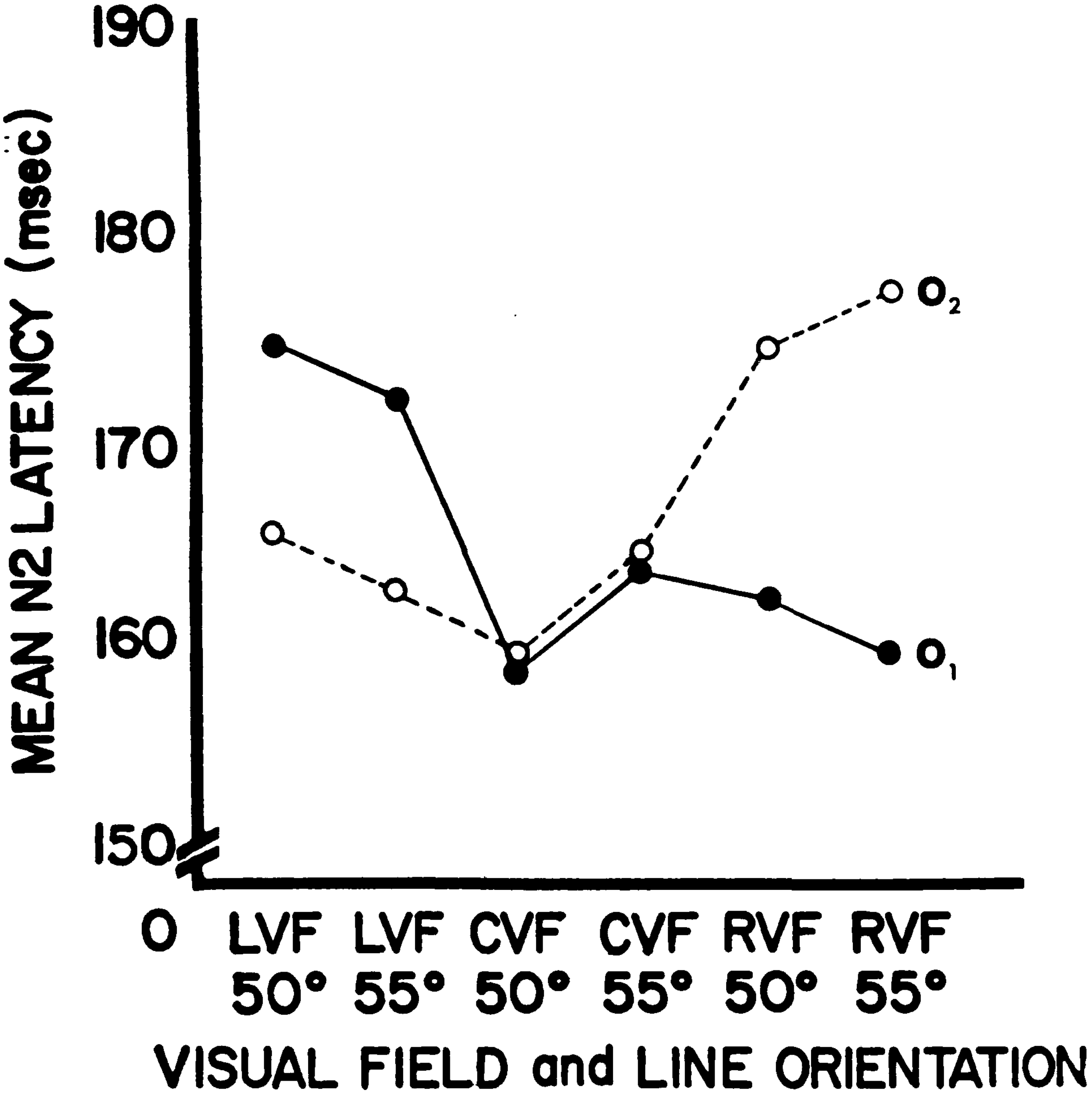

FIGURE 5 Mean N2 latency under various conditions for 24 subjects. Note the shorter latencies that occur with contralateral stimulation.

DISCUSSION

The hypothesis that the P3 amplitude advantage previously associated with the 55° line orientation would switch to the 50° line in the present study because of the positive label "yes" now associated with 50°, was not supported. The data for twenty-four additional subjects (twelve male and twelve female) show no differences in amplitude of the P3 component with either line, despite the fact that a "yes" response was now required to the 50° line in this follow-up study. Thus, our original proposition that the greater P3 amplitude might reflect some implicit cognitive process that attributes greater relevance or importance to a stimulus that requires a "yes" response was not upheld.

The remaining event related potential data also revealed no hemispheric differences when the major components (N2 and P2) were analyzed for both latency and amplitude of response. Since the initiation of our studies of hemispheric differences in ERP response, there have been more failures to find brain response differences originating from the two hemispheres than successes. This was true for a wide variety of perceptual situations used and more will be said about this later.

When one considers the performance data for the twenty-four subjects as a whole, there were no hemispheric differences with respect to accuracy of line orientation discriminations. That is, discrimination accuracy in the RVF (left hemisphere) was not significantly different from the LVF (right hemisphere). This result does not support the hypothesis of superior right hemisphere performance with a spatial discrimination task (line orientation) such as that used in the present study. Further, when the results for the twelve male and twelve female subjects were compared, no hemispheric differences were found. These results run counter to those reported in a preliminary study in which males showed a right hemisphere (LVF) superiority in discrimination accuracy, while females showed no differences between the hemispheres.

One finding proven to be extremely robust throughout this series of studies has been the latency and amplitude advantages obtained with stimulation in the visual field contralateral to the recording site. For example, N2 latency was consistently shorter and N2-P2 amplitude larger when visual stimulation occurred in the LVF and the ERP was derived from the right hemisphere recording site as compared to the left hemisphere. These consistent findings reflect the organization of the visual system in which stimuli in the RVF and LVF project primarily to the contralateral occipital lobe.

It has been suggested in the literature that tasks requiring analytic, verbal and sequential processing are the domain of the left hemisphere, while non verbal, synthetic, and visuo-spatial tasks are primarily processed by the right hemisphere. When we consider both the ERP and performance data obtained in our series of studies, these hypotheses seem to require qualification and receive less than moderate support. For example, in nine studies completed to date, there were only two instances where ERPs indicated hemispheric differences. Both of these occurred in a study where subjects were required to observe and describe differences between apparently moving and stationary stimuli. The female participants had larger right hemisphere responses to motion, compared to the left hemisphere derived measures with CVF stimulation. The male subjects produced longer latency left hemisphere responses under similar conditions of stimulation. In a variety of other studies involving discriminations of line length, line orientation judgments, backward masking in peripheral vision, discriminations of motion velocity, detection and identification of signals over a 78 minute time period, color discriminations in three visual fields, shape and letter discriminations in peripheral vision, there was no evidence for ERP differences recorded from over the right and left hemispheres (Andreassi, Rebert and Larsen, 1980; Andreassi and Juszczak, 1981; Andreassi and Juszczak, 1982; Andreassi and Juszczak, in preparation). There *were* a number of interesting ERP results, but these involved the P3 response and did not relate to laterality at all. For example, in the study of line length discriminations, it was found that the P3 response was significantly delayed with the most difficult (ambiguous) judgment (Andreassi and Juszczak, 1981). In the velocity of motion discrimination study, the right hemisphere derived P3 response was greater in amplitude with the higher velocity condition (Andreassi and Juszczak, 1982). The P3 component, related to making decisions about signals, was found to be significantly larger at parietal scalp derivations as compared to occipitally derived responses (Andreassi, Rebert and Larsen, 1980).

The performance data in seven of the studies indicate that laterality is not supported in the majority of the instances. Laterality was not observed in the discrimination of line length, nor in the replication of the line orientation study. In the first line orientation discrimination study, males showed a right hemisphere superiority, but females did not. The velocity discrimination experiment revealed a female left hemisphere superiority. There was some evidence for superior hemispheric processing of compatible stimuli, e.g., left hemisphere process T better than ⊥, presumably because the T is verbal and the ⊥ is non-verbal. On the other hand, laterality was not in evidence for either males or females in peripheral masking, peripheral shape discriminations or in color discriminations.

Thus, when the results of our experimental series are examined, considering both the ERP and performance data, the bulk of the findings do not lend support to the usual notions of laterality. While there is some support, it is not always in the expected direction. For example, the finding of larger right hemisphere ERPs for women in response to apparently moving stimuli was inconsistent with expectations suggested by the literature. The literature would have led us to expect that male subjects would show greater right hemisphere sensitivity to a stimulus which is spatial in nature, i.e., moving across a defined space. One of the concepts proposed is that males are more highly lateralized than females with respect to the kinds of tasks that would be expected to differentially engage the two hemispheres (Harris, 1978). However, others disagree and advance the hypothesis that it is females who are more highly lateralized and that males tend to be bilaterally efficient with verbal and non-verbal tasks (Buffery and Grey, 1972). There is considerable controversy as to the degree to which males and females evidence brain lateralization with respect to particular abilities (for a review, see McGlone, 1980). Our series of studies would seem to lend more support to the hypothesis that males and females do not differ in degree of laterality. We must also point out that ERPs did not emerge as strong indicants of laterality. The fact that ERPs have not always consistently revealed robust signs of lateralization has recently been emphasized by Gevins et al. (1983). Gevins and his colleagues have reported the use of multi-scalp locations, single trial analyses and extensive intercorrelation techniques in their findings of rapidly shifting changes in the side and site of localized brain processes. They suggest that these rapid shifts may account for conflicting reports of lateralization in studies which do not have the same spatial and temporal resolution. Their subjects performed in a visuo-spatial task which required that they make a movement to complete the activity. The results seem to show that, in the N100-P200 interval, the activity in the brain is generalized to both hemispheres; shortly after, during the P300 sample period, a right hemisphere focus occurs as subjects perform the spatial task. Finally, in the 436-611 msec interval after stimulus presentation (their RP period), there is a left hemisphere focus as the right-handed subjects make the required motor response. What Gevins and colleagues seem to be saying is that lateralization occurs, but that it is fleeting. Furthermore, extremely rapid sampling and sophisticated analytic techniques are required to observe these quick shifts between hemispheres and the changes in hemispheric activities which reflect the task changes. Perhaps, through techniques such as those just described, questions as to the nature and degree of lateralization of function of the human brain may be more fully answered with electrophysiological approaches.

EXPERIMENT II -- Left and Right Hemisphere Derived ERPs in Response to Color Stimuli

INTRODUCTION

At least one behavioral investigation seems to suggest that color processing and perception may be a right hemisphere activity (Pennal 1976). In Pennal's study, manual reaction time and accuracy were used as the principal measures of left and right hemisphere performance in a color discrimination task, and right hemisphere discriminations were found to be significantly better than those of the left. To explain this right hemisphere superiority, Pennal proposed a localized right hemisphere color processing area.

The notion of a right hemisphere color processing mechanism is interesting, since existing data suggest that other non-verbal functions (e.g., spatial ability) are controlled by the right hemisphere (Umilta et al., 1974, 1978; Koss, 1981). Pennal's proposition is based purely on behavioral measures (i.e., reaction time accuracy and latency). It would be of interest to determine whether physiological response of the two hemispheres, such as that indicated by the visual event related potential (ERP), will differ as a function of color. Previous investigations have indicated that the visual ERP may be a reliable and objective indicator of the brain processes underlying color perception (Perry et al., 1972; White et al., 1977). Thus, the primary aim of this investigation will be to examine left and right hemisphere derived visual ERPs to color stimuli (blue and red) presented in three visual fields. A secondary aim concerns the relationship of visual ERPs to differences in sensitivity of the photopic visual system (cone receptors) to colors. For example, the photopic (cone) sensitivity curve (see Schiffman, 1982) indicates that the photopic system is more sensitive to relatively short wavelengths within the visible spectrum. Would the visual ERP index this differential sensitivity?

As previously mentioned, some studies suggest the use of visual ERPs as objective indicators of color processing. For example, several investigators have reported that the waveform of the ERP was changed with different colors. Clynes and Kohn (1967) indicated that evoked responses to lines and dots were color-sensitive with respect to the color of the surrounding field. Different ERP waveforms were obtained to stimulation with red, green, yellow, and orange stimuli. White and Eason (1966) also found that different components of the visual ERP varied as a function of stimulus color. Differences in response patterns were observed with stimulation by red, green and blue and by the three colors simultaneously. Shipley et al. (1966) reported that visual ERP waveforms changed with wavelengths over a range of 380 nanometers (nm) to 680 nm. For example, in the red range (640 to 680 nm), a larger positive component appeared at about 200 msec, while smaller biphasic responses appeared with wavelengths in the violet range (380 and 420 nm). Perry et al. (1972) used a technique that maintained intensity of red and green stimuli constant and their size small enough to be presented entirely within the fovea (i.e., they produced a size of .5° of visual angle). The differences found in ERPs with red and green stimuli led Perry and associates to conclude that there appear to be fundamental differences in cortical processing of red and green. Specific components of the visual ERP were related to the three basic color processes, red, green, and blue (White et al., 1977). White and his colleagues were able to isolate and identify three specific color evoked responses. In an earlier study (Bartlett, Eason and White, 1968), sample ERPs for one subject indicated a larger amplitude ERP component (between 100 and 200 msec post-stimulus) to a blue stimulus as compared to a red stimulus. The red and blue stimuli had been roughly equated for apparent brightness.

The research questions posed in this investigation are:

1) Will the visual ERP reflect differential hemispheric processing of color stimuli, i.e., will latencies and amplitudes of major ERP components differ to the colors red and blue?

2) Will the visual ERP indicate differential response to color regardless of hemisphere? Again this would be examined for both latencies and amplitudes of the major ERP components.

3) Will the ERPs reflect a greater sensitivity to shorter wavelengths through larger amplitude response to blue vs red?

METHOD

Subjects: The subject were six male and six female right-handed students associated with the City University of New York. They ranged in age from 18-45 years. Right-handedness was determined by a handedness questionnaire (Annett,1970) which asked subjects to report the preferred hand used in a variety of tasks and to indicate familial history of handedness. None of those used in the experiment reported any personal or familial history of left-handedness. A Bausch and Lomb Orthorator was used to test subjects for binocular visual acuity, color vision, and vertical and lateral orthophoria (normal eye muscle balance). The vertical and lateral phoria tests estimated the subject' ability to fixate (Andreassi and Juszczak)[1]. All

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[1] Previous research has shown that persons with abnormal eye muscle balance (strabismus) have difficulty fixating on some central fixation point and consequently may not show expected contralateral visual field effects which result when stimuli are differentially presented to right and left hemispheres.

subjects met the criteria of acceptable visual acuity (corrected to at least 20/25), color vision, and 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 linked ears. A Beckman Type RM Dynograph recorded the EEG and the 9806 coupler of the Dynograph conditioned the EEG signal (bandpass set at 0.5 to 32.0 Hz). A PDP8/E computer triggered a Computer of Average Transients (CAT 1000) to take EEG samples of 500 msec duration immediately following presentations of visual stimuli to subject. The resultant summated visual ERP trace was plotted on a Hewlett Packard X-Y plotter. Eye blinks and movements were recorded with a two-channel eye movement monitor (Washington University resetting differential amplifiers) and were measured by placing two biominiature electrodes above and below the left eye. The resultant electrooculogram (EOG) was displayed continuously on a voltmeter in the Washington University apparatus and on a Tektronix dual-trace oscilloscope. Artifacts produced by such eye movements appeared as left or right deviations from zero on the EOG device and as abrupt changes from baseline on the storage oscilloscope. Trials with suspected contamination were discarded.

The visual stimuli were displayed on a Digital Equipment Corporation VR-14 cathode ray tube (CRT) which was mounted at the subject's eye level outside the chamber at a distance of 114.3 cm (45 in). A brief persistence P24 phosphor specially installed in the VR-14 assured rapid stimulus decay (50 usec).

The stimuli were .5 X 1.0 cm (height X width) blue or red rectangles, each displayed on the CRT for 40 msec at center, and 5 cm to the left and right of central fixation (the fixation point was a dim .001 mL red neon light). The 5 cm distance between the leading edges of the rectangles (proximal) produced a visual angle of 2.5° from center for both right visual field (RVF) and left visual field (LVF). The .5 X 1.0 cm dimension of the rectangles produced a visual angle of 15' vertically and 30' horizontally, respectively. The blue and red rectangles were generated by presenting a .5 X 1.0 cm yellow-green grid through blue and red filters[2] mounted on a 21.6 X 15.2 cm black matte CRT covering. This resulted in the perception of deeply saturated blue or red rectangles appearing in left, central, and right visual fields.[3] The luminance of the blue and red stimuli were equated to measure .4 millilamberts (mL) as measured by a J-16 photometer. Thus, there were six experimental conditions as follows: Blue-LVF, Red-LVF, Blue-CVF, Red-CVF, Blue-RVF, Red-RVF. The order of presentation of the two colors was determined by an ABBABAAB design, with timing between presentations a constant 4 sec. The colors were then randomly presented in the three visual fields. Randomization was restricted in that each color appeared in each visual field an equal number of times, i.e., ten presentations of blue and red in left, central, and right visual fields. The EEG averaging was continued until ten uncontaminated samples were obtained for each visual field. Subjects were presented with the six conditions two times within a given session. A second session was repeated on a separate day. Thus, four visual ERP traces were obtained for each condition, for a total of twenty-four traces from O_1 and O_2 for each subject.

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[2] Roscolux #80 primary blue filter with peak transmission between 400 and 420 nm (410 nm) and Roscolux #25 orange-red filter with peak transmission between 640 and 680 nm (660 nm).

[3] Blue and red color perception was pre-experimentally determined in pilot trials with several subjects. These individuals were not part of the experiment proper.

Data collection lasted for about 45 min, i.e., the subjects were seated in the IAC chamber and data on the first six conditions were collected during the first 20 min. There was then a 5 min rest period, after which data collection continued for about another 20 min on the remaining six conditions. Thus, there was an opportunity for some dark adaptation during each 20 min segment. The IAC chamber door was closed and a black cloth was placed over the IAC window to prevent light from the outside laboratory from entering the chamber.

In the first session, subjects were presented with the red rectangles 6 mm below the fixation point and the blue rectangles 2 mm below the red. In the second session, the locations of the blue and red rectangles were reversed, i.e., the blue rectangles appeared above the red. This was done to counterbalance possible location effects.

Subjects were seated in the IAC chamber and asked to focus on the small fixation point at all times and to avoid unnecessary eye blinks and eye or head movements, especially during and immediately after presentations of stimuli. These instruction, together with EOG recordings, insured that subjects maintained a central fixation. The standardized instructions asked subjects to simply report the color seen on the screen. For example, if a blue rectangle appeared, subjects were told to say "BLUE." If the red one appeared, they were asked to say "RED." Subjects were asked to give their responses out loud about 1 sec after the stimulus appeared. They were also advised to avoid anticipating any stimuli within the visual fields, i.e., they were told that the order of presentation was completely randomized so that it would be virtually impossible to predict the color and location. Subjects were reminded to fixate on the red neon light at all times to avoid missing stimuli. They were also asked to look, but not stare, at the fixation point. This additional instruction minimized the problem of eye strain and tears, a problem often associated with prolonged fixation. The verbal responses were continuously monitored by the experimenter via an intercom system to insure that subjects responded to all stimuli.

RESULTS

The verbal responses monitored during each session indicated that all subjects perceived red and blue rectangles appearing in the left, central and right visual fields.

Visual ERPs -- Through analysis of the visual ERP traces of each subject, several major ERP components emerged. These constituted the main dependent physiological variables in the study and were identified and measured in the following way with respect to latencies and amplitudes:

Latencies -- Four individual components were identified: N2, P2, N3 and P3. The N2 latency component was measured from the peak of a large negative wave appearing between 140 and 190 msec post-stimulus in the 500 msec sample. The component designated P2 was measured from a positive peak immediately following N2 and occurred between 230 and 270 msec. The second negative wave, following P2, was termed N3, and was found to occur between 240 and 290 msec. This component was not considered for statistical analysis and simply served as an anchor for the N3-P3 amplitude measurement as described below. The latency component termed P3 was measured from a second positive peak appearing between 300 and 400 msec. If the peaks appeared more as a plateau, the midpoint of the plateau was taken as the latency measurement.

Amplitudes -- Two components were analyzed with regard to amplitude. These were N2-P2 and N3-P3. For N2-P2, the measurement in microvolts (uV) was measured as the vertical distance from the peak of N2 to the peak of P2. The same technique was applied to the measurement of N3-P3, i.e., the vertical distance from N3 to P3.

Representative visual ERP traces of one subject are illustrated in Figure 1. The four superimposed traces were obtained from the left (O_1) and right (O_2) hemisphere recording sites for the six experimental conditions. The small vertical bars indicate the N2 and P2 components. Together, they constituted the N2-P2 amplitude measurement, which, as previously described, was measured from the peak of N2 to P2.

Data analysis was accomplished by computing the mean amplitude (uV) and latencies (msec) from the ERP traces. Mean N2-P2 amplitudes and N2 latencies are depicted in Table 1 for all twelve subjects[4] under the six experimental conditions. Figure 2 depicts the data.

TABLE 1

Mean Amplitude (uV) and Latency (msec) for Visual ERP Components N2-P2 and N2 for Males and Females Combined (N=12), Placements and Conditions

Conditions	Scalp Locations and Visual ERP Components			
	----- O_1 -----		----- O_2 -----	
	N2-P2 (amplitude)	N2 (latency)	N2-P2 (amplitude)	N2 (latency)
Blue-LVF	14.3	179	19.4	169
Red-LVF	12.8	178	17.8	163
Blue-CVF	22.4	169	22.3	168
Red-CVF	16.8	164	18.1	164
Blue-RVF	21.5	169	16.0	187
Red-RVF	16.3	171	13.4	190

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[4] Separate analyses of the male and female data indicated that for these components, males and females showed no differences. Thus, only the combined data are reported.

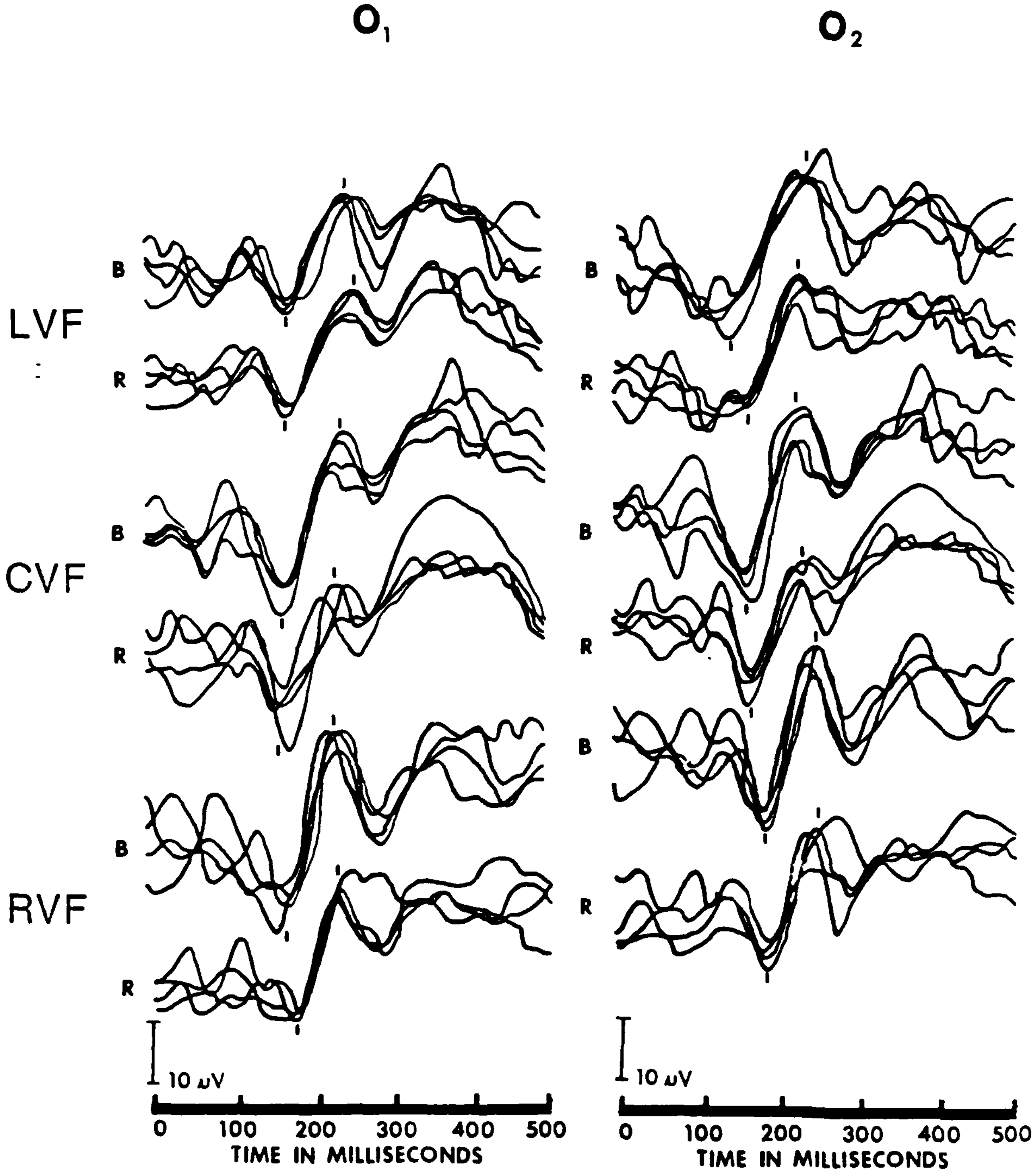

FIGURE 1 Visual ERPs of one subject (P.D.) under conditions of the present experiment. The first vertical bar indicates the N2 component and the second, P2. Note that N2-P2 amplitudes are larger to blue than red. Negativity is downward.

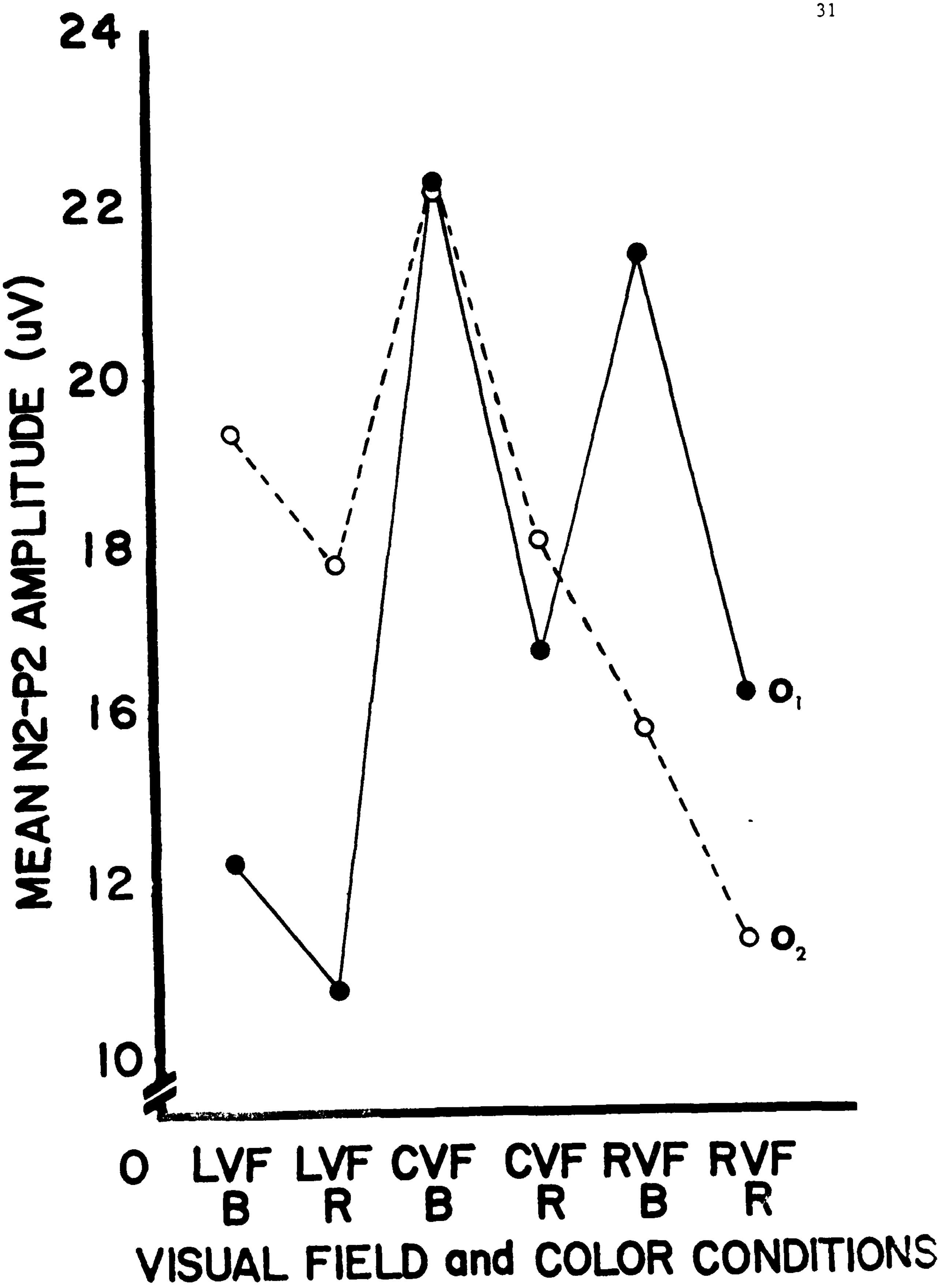

FIGURE 2 Mean N2-P2 amplitudes for the 12 subjects under the conditions of this experiment. Note that the mean amplitude N2-P2 is larger for blue than red in all three visual fields.

The above data in Table 1 were subjected to a three-way (Gender X Placement X Conditions) Analysis of Variance (ANOVA) using a fixed model (Winer, 1971). The raw data were log-transformed prior to analysis to insure conformity with the assumptions of the ANOVA model (normality of distribution, homogeneity of variance). For N2-P2 amplitude, significant effects were obtained for conditions ($F=3.52$, 5/143, $p < .005$) and the Condition X Placement interaction ($F=2.59$, 5/143, $p < .02$). The more important of the two, the Condition X Placement interaction, reflects the often replicated contralateral visual field effects that result when the left and right hemispheres are differentially stimulated. For example, the figure depicting the amplitude data (Figure 3) shows an amplitude advantage at the recording site contralateral to the visual field of presentation (with $p < .01$ for all visual field comparisons - Newman-Keuls test). The figure also reveals that, at both hemisphere recording sites and within each visual field, N2-P2 amplitudes were larger with blue presentations than with red. Additional Newman-Keuls tests were conducted to ascertain whether this response advantage favoring the blue was significant. The results indicated three significant comparisons: O_1 - Blue-CVF vs Red-CVF; O_2 - Blue-CVF vs Red-CVF; O_1 - Blue-RVF vs Red-RVF ($p < .01$ for all three). At O_2, with CVF presentations, the mean difference in amplitudes produced by red and blue was 4.2 uV, while at O_1 the mean difference was 5.6 uV, with responses favoring the blue in both situations.

A similar three-way ANOVA was conducted on N2 latency. Significant Condition effects were obtained ($F=4.10$, 5/143, $p < .002$) and the Condition X Placement interaction effect was also significant ($F=5.63$, 5/143, $p < .001$). The Newman-Keuls results revealed that the shortest latencies occurred when stimuli were delivered centrally (i.e., latencies with CVF were shorter than RVF and LVF, at both scalp locations, $p < .01$) and contralaterally (e.g.,

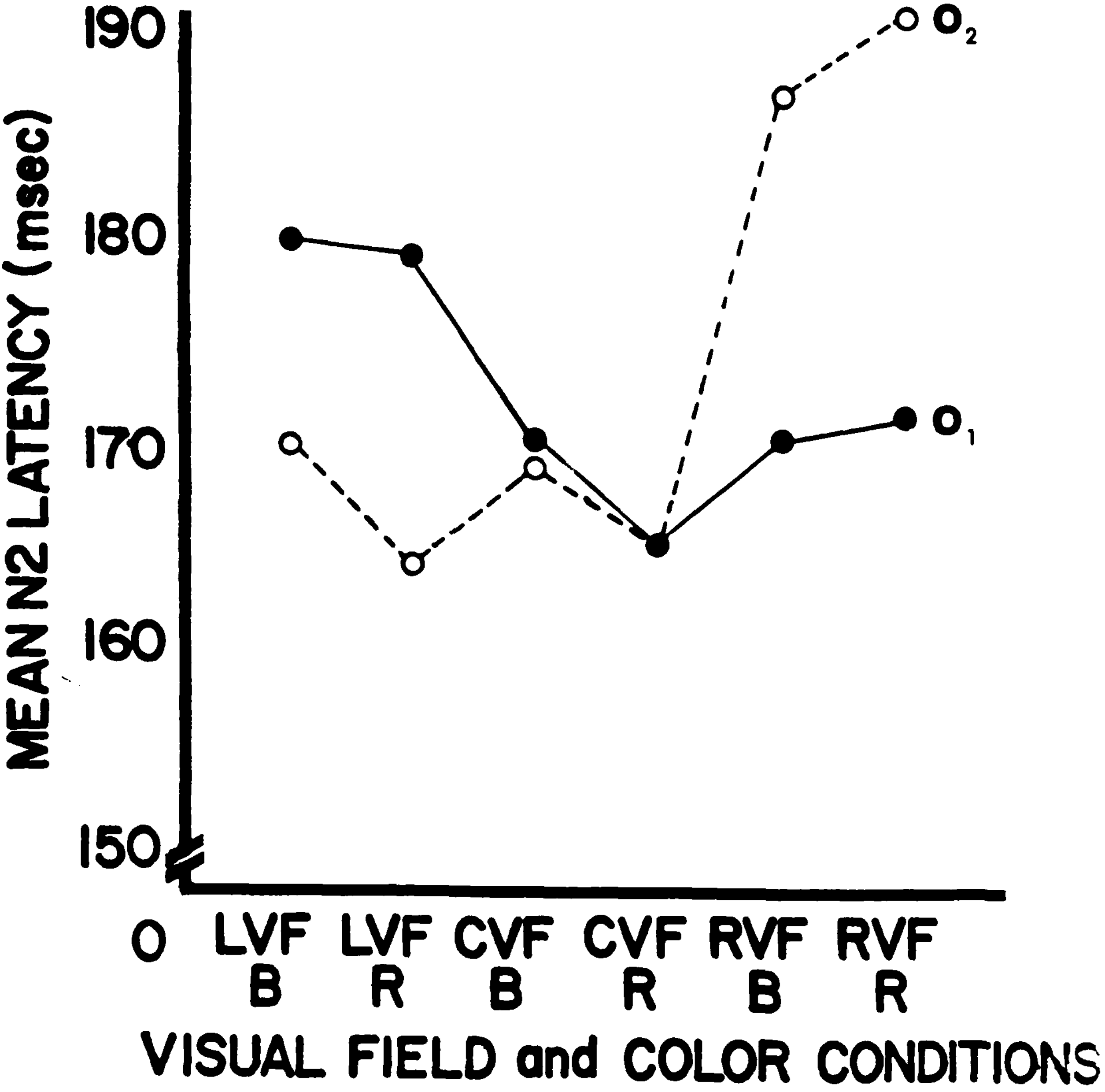

FIGURE 3 Mean N2 latency for the 12 subjects under the conditions of this experiment. Note the contralateral visual field effects, i.e., with LVF stimulation. O_2 latencies are shorter than O_1, and vice versa for RVF stimulation.

latencies at O_1 were shorter than latencies at O_2 with RVF presentations, $p < .01$). When ERP latencies to the two colors were compared within each visual field, there were no significant differences ($p > .05$). These CVF and contralateral visual field effects, which were expected, can be clearly seen in Table 1 and Figure 3. With regard to the remaining components (i.e., N3-P3 amplitude and P2 and P3 latencies), no significant effects were obtained.

DISCUSSION

One of the questions addressed at the outset of this investigation concerned whether the colors red and blue would produce different visual ERPs. Our data indicate that they do. This is seen in the finding that visual ERPs in response to blue stimuli were larger in amplitude than those produced by red, especially with foveal stimulation (CVF). We propose that the N2-P2 amplitude advantage in favor of blue may reflect greater sensitivity of the human visual system to blue. This hypothesis is consistent with psychophysical data which show that the visual system, in particular the cone system, is most sensitive to intermediate wavelengths (e.g., green and blue), as compared to sensitivity to shorter (violet) and longer (red) wavelengths (Schiffman, 1982; photopic luminosity function). Our findings are additionally supported by electroretinogram (ERG) data from a study by Cavonius (1962),in which the retina showed greatest response to electromagnetic wavelengths that give rise to sensations of blue or green. Perhaps our visual ERPs reflect differential color sensitivity at the visual cortex. The possibility that higher level visual areas are differentially sensitive to varying electromagnetic wavelengths was illustrated in a study by DeValois et al. (1966). They used large patches (15° visual angle) of light as the stimulus and found that approximately 15-20% of the lateral geniculate nucleus (LGN) cells in the brain of the rhesus monkey responded to light of any wavelength, but with maximal firing rate to intermediate wavelengths (approximately 560-600 nm) at three different intensities. One might ask whether visual ERPs reflect sensitivity of the visual system at all levels, i.e., retinal, LGN, and primary visual cortex. Perhaps visual ERPs could be indicators of overall visual sensitivity to color.

The main question addressed the possibility that the left and right hemispheres of the brain might show differential ERPs to blue and red. This question was raised as a result of Pennal's (1976) findings in which the right hemisphere was found to be significantly better than the left in a color discrimination task. Our results, however, suggest that both hemispheres are equally sensitive to these colors as indicated by the finding that, at the left hemisphere, the response advantage in favor of blue was as large as the response advantage at the right hemisphere. Thus, it appears that visual ERPs do not reflect a different right hemisphere color processing mechanism as proposed by Pennal, at least in a simple color discrimination task as used in the present study. Most studies, including Pennal's, demonstrated superior right hemisphere processing only when the task was of sufficient difficulty to tax the ability of that hemisphere (e.g., Umilta et al., 1978). Our subjects were asked only to discriminate two colors. A follow-up study might include the collection of visual ERP data while subjects are engaged in a more complex color discrimination task, e.g., finer discriminations of a given color, or are required to make a motor response to various colors.

EXPERIMENT III -- Is There Differential Hemispheric Sensitivity to Backward Visual Masking?

INTRODUCTION

Backward visual masking refers to a situation in which the presentation of a second stimulus (mask) interferes with the perception of the first (target). One type of visual masking, called metacontrast, involves the presentation of two stimuli having adjacent contours, in rapid succession. The target and mask in this situation stimulate non-overlapping retinal areas, and differs from another type of masking in which the mask completely overlaps the target, such as when a briefly presented test flash is followed by a bright blanking flash. In both cases, the masking stimulus may produce complete perceptual suppression of the target, i.e., the target is never perceived, only the mask is reported. The parameters that determine the effectiveness of the mask in producing perceptual suppression are: time between presentation of target and mask (or interstimulus interval - ISI), the target-mask intensity ratio, and the spatial relationship between the target and mask.

Several investigators have explored the visual event related potential (ERP) correlates of metacontrast. For example, Schiller and Chorover (1966) investigated the question of whether or not the brightness reduction (another type of masking effect) observed under metacontrast conditions is correlated with changes in the ERP. They reported no changes in the ERP associated with the reduction of brightness induced by metacontrast and concluded that the ERP does not necessarily reflect changes in apparent brightness. Vaughan and Silverstein (1968), however, reported attenuation (i.e., reduction in amplitude of a major positive component occurring about

200 msec post-stimulus) of ERPs to foveal,but not parafoveal, stimulation with metacontrast. They suggested that the reason for the failure of ERPs to reflect perceptual suppression in the Schiller and Chorover study was due to the parafoveal conditions, i.e., the ERPs may have been generated by stray light impinging on the fovea. Andreassi et al. (1979) also showed that perceptual masking was accompanied by an attenuation of the ERP. The visual masking condition was of the metacontrast variety and consisted of presenting a square for 40 msec, followed 40 msec later by four squares contiguous with the sides of the first square. In a related study, Andreassi et al. (1976) varied the spatial characteristics of the masking stimulus to determine its effects on the perception of the target and related visual ERPs. The degree of contour interaction between the target and mask was varied from 0% (single square presented) to 100% (single square bounded by four squares). They found that the 50% contour interaction condition (square bounded on two sides) was effective in producing perceptual masking. More important, they found that, as the degree of contour interaction between the target and mask increased, the amplitude of the ERP component produced by the target was decreased, i.e., the N2-P2 component became smaller as contour interaction increased from 50% to 100%. This finding illustrated the importance of amount of contour interaction between target and mask in producing both perceptual masking and accompanying ERP changes. One question that arises concerns a possible relationship between metacontrast effects and the differential functions of the two hemispheres of the brain. Since the spatial-temporal relationship between the target and mask is critical in producing perceptual suppression and visual ERP changes, and since the right hemisphere appears to be more involved than the left in visuo-spatial processing, it is possible that the right hemisphere may be more sensitive than the left to metacontrast effects. This

notion draws some support from an investigation by Tei and Owen (1980) who showed differential effects of adaptation to a spatial stimulus in the left and right hemispheres. Specifically, the right hemisphere was found to be more sensitive to an adapting line orientation stimulus, indicating greater right hemisphere susceptibility to adaptation effects when the stimulus is of the type known to be preferentially processed by the right hemisphere.

In a previous study of metacontrast and hemispheric asymmetry, Luria (1974) attempted to determine if the right hemisphere would be superior to the left in the detection of masked targets. The results showed that the masked disk was more easily detected in the right visual field, indicating left hemisphere superiority. This finding could also be taken to suggest greater right hemisphere susceptibility to masking.

Thus, the purpose of the current investigation will be to determine if the right hemisphere is more susceptible than the left hemisphere to visual masking. The strategy will be to present a metacontrast situation in left, central, and right visual fields while visual ERPs are recorded from over the left and right hemispheres of the brain. Our experimental design will require that subjects make visual discriminations. Thus, it is also expected that subjects will produce a P3 component, i.e., a positive component related to cognitive processes and occurring approximately 300 msec after the initiating stimulus. A subsidiary question will address the effect of the mask on the P3 component, i.e., could the timing of the mask affect the occurrence of P300?

The following hypotheses are proposed:

1) Subjects will experience perceptual masking in the three visual fields, however, masking will not be as effective in the right visual field (left hemisphere) as compared to left visual field (right hemisphere).

2) Perceptual masking will be accompanied by an amplitude attenuation of the N2-P2 component of the visual ERP in all three visual fields,

however, right hemisphere derived amplitudes will show greater attenuation than those recorded from over the left hemisphere, suggesting greater right hemisphere susceptibility to masking.

With regard to the P3 component, the following questions will be asked:

1) What effect will the visual masking conditions have on P3 latency?

2) What effect will the visual masking conditions have on P3 amplitude?

METHOD

Subjects: The subjects were seven right-handed students (six females and one male) associated with the City University of New York. They ranged in age from 18-45 years. Each subject was administered a vision test battery with a Bausch and Lomb Orthorator. Handedness was determined with a questionnaire (Annett, 1970). The vision test battery screened subjects for vertical and lateral phoria and binocular visual acuity (both at near and at distance). The handedness questionnaire asked subjects to report the preferred hand used in a variety of tasks and to indicate any familial history of left-handedness. All subjects met the criteria of normal visual acuity (corrected to at least 20/25 with glasses) and eye muscle balance (Orthophoria) as established by the Bausch and Lomb Occupational Vision Standards. None reported any personal or familial history of left-handedness.

Apparatus and Procedure: Subjects were seated in an electrically shielded sound attenuated Industrial Acoustics Corporation (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 subject's left ear lobe. A Beckman Type RM Dynograph was used to record the EEG and 9806 A couplers 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 PDP8/E computer, sampled EEG for 500 msec following presentation of stimuli to subjects. The summated visual ERP trace was plotted on a Hewlett Packard X-Y plotter.

Eye blinks and eye movements were recorded with a two-channel eye movement monitor (Washington University resetting differential amplifiers) and were measured by placing two Beckman biominiature electrodes above and below the left eye. The resultant electrooculogram (EOG) was displayed continuously by the Washington University apparatus and a Tektronix dual-trace oscilloscope. Artifacts produced by eye movements appeared as left or right deviations from zero on the EOG monitor and as abrupt changes from baseline on the storage oscilloscope. Trials which contained eye movement 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. The stimuli consisted of 0.5 cm grids formed from a 5 X 7 matrix of yellow-green dots of light. There were three stimulus conditions each projected in left, central, and right visual fields. They were as follows:

1) Target alone: Single grid on for 20 msec presented in left, central, and right visual fields (LVF, CVF, and RVF).

2) Target plus two grid mask: Single grid on for 20 msec followed 40 msec later by two grids (on time 20 msec), contiguous with the left and right sides of the single grid, presented in left, central, and right visual fields.

3) Target plus four grid mask: Single grid on for 20 msec followed 40 msec later by four grids (on time 20 msec), contiguous with the four sides of the single grid, presented in left, central and right visual fields.

Figure 1 indicates schematically the temporal and spatial arrangement of the grids as they appeared on the CRT display. The numbers indicate the order of appearance. Stimulus conditions (2) and (3) (i.e., single grid followed by either two grid or four grid masking stimuli), produced clear backward visual masking effects. The presentation of the three stimulus conditions within the three visual fields was randomized so that the subject could not predict the stimulus nor the visual field in which it appeared. For example, a single grid (target) might appear in the LVF, followed by a single and four grid combination (target and mask) presented in the RVF. The time interval between presentations was 4 sec. The stimulus conditions appeared within each visual field ten times. The CAT was under program control of the experimenter so that selective EEG samples could be obtained for the single grid and the single plus four grid display. Responses to the single plus two grid display were not averaged since they were intended to serve as an additional performance measure. Each visual ERP trace average was based on ten samples. There were six conditions: LVF Target, LVF Target + Mask, CVF Target, CVF Target + Mask, RVF Target, RVF Target + Mask.

Each stimulus was presented 2.5^{o} to the left and right of central fixation (as measured from the side of the masking grid closest to the fixation point) and directly below (6 mm) the fixation point (.001 mL red neon light).

The single grid produced a visual angle of 15' of arc at the viewing distance used while the four and two masking grids produced a visual angle of 45' of arc (measured horizontally). The intensity of the single grid was 2.0 millilamberts (mL) while the four grid masking stimulus was 5.5 mL.

The task required that subjects simply report the number of grids or "boxes" seen. For example, if a subject saw one box, the response was "one."

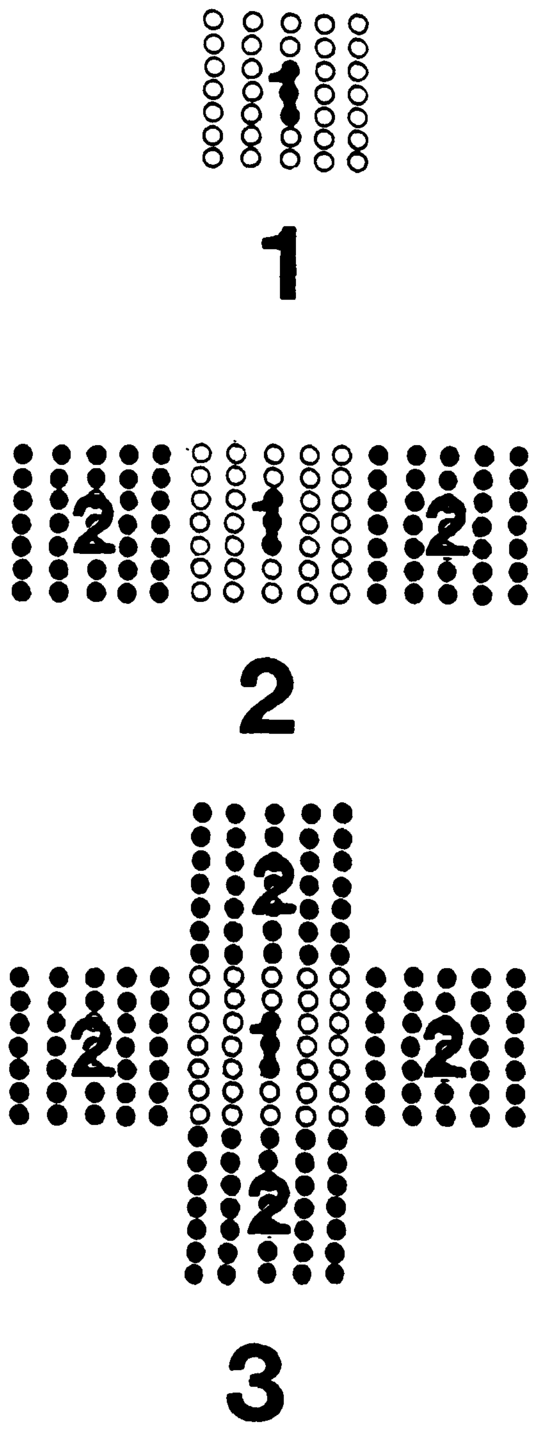

FIGURE 1 Schematic of three conditions used in this experiment. The target grid always comes first and is labeled with a "1" at its center. The "2" indicates that the mask appears second, after the target.

If they saw two boxes they were to report "two," and so forth. Subjects were also advised to avoid anticipating any stimuli within the visual fields, i.e., they were told that the order of presentation was randomized so that it would be virtually impossible to predict the order and the visual field of presentation. In addition, subjects were reminded to fixate on the red neon light at all times so as to avoid missing stimuli. They were also asked to look and not stare at the fixation point. This additional instruction minimized the problem of eye strain and tears, often associated with prolonged fixation. The verbal responses were monitored via an intercom system and recorded by the experimenter. The six conditions were randomized across subjects over a period of two days and resulted in a total of twelve ERP traces from O_1 and O_2. The seven subjects were tested in pilot trials and all experienced visual masking with the target-mask combinations used.

RESULTS

The verbal responses recorded by the experimenter indicated that all subjects saw either one, two, or four boxes within the three visual fields. Thus, under conditions of backward visual masking, the first grid was never perceived. A comparison of the verbal reports for left and right visual field presentations revealed no difference in the number of boxes seen under the masking conditions indicating that both left and right hemispheres were equally affected by the mask.

Data analysis was accomplished by computing the mean latencies and amplitudes of the averaged visual ERP trace for each subject and scalp location. For latencies, four components were identified, each falling within various time periods of the 500 msec sample. The latency component

N2 was a negative wave which appeared between 150 and 170 msec post-stimulus, while P2 was a positive wave that occurred between 210 and 230 msec. The N3 was a negative wave following P2 and appeared between 250 and 280 msec. The P3 component was a positive deflection appearing between 310 and 360 msec post-stimulus. For amplitudes, two components were measured, N2-P2 and N3-P3. The N2-P2 measurement was made as the vertical distance from the peak of N2 to the peak of P2, while P3 was measured from the peak of N3 to the peak of P3. Figure 2 shows the visual ERP trace for one subject under the six experimental conditions for O_1 and O_2, respectively.

Table 1 shows the mean latencies and amplitudes under the six experimental conditions and for each scalp location. (The T in Table 1 refers to target alone while the T+M indicates the conditions in which the target was followed by a four grid mask.) Figure 3 graphically depicts N2-P2 amplitudes under the various conditions.

TABLE 1

Mean Latency (msec) and Amplitudes (uV) for the Visual ERP Components N2, P2, P3, and N2-P2 and P3 for All Conditions and Scalp Locations

	O_1					O_2				
	Latency			Amplitude		Latency			Amplitude	
	N2	P2	P3	N2-P2	P3	N2	P2	P3	N2-P2	P3
LVF T	170	224	317	16.4	13.8	162	217	319	17.7	11.5
LVF T+M	161	225	349	17.6	13.1	159	220	348	20.3	12.6
CVF T	160	220	336	18.9	9.6	158	223	329	18.9	10.3
CVF T+M	164	220	350	14.2	12.1	165	217	360	13.6	11.2
RVF T	156	213	321	16.8	10.4	164	217	324	13.5	12.1
RVF T+M	161	218	346	18.8	10.5	170	219	344	16.5	12.9

The amplitude and latency data were subjected to separate three-way (Subjects X Conditions X Placements) ANOVAs using a fixed model (Winer, 1971). Raw scores were log-transformed to insure conformity with the

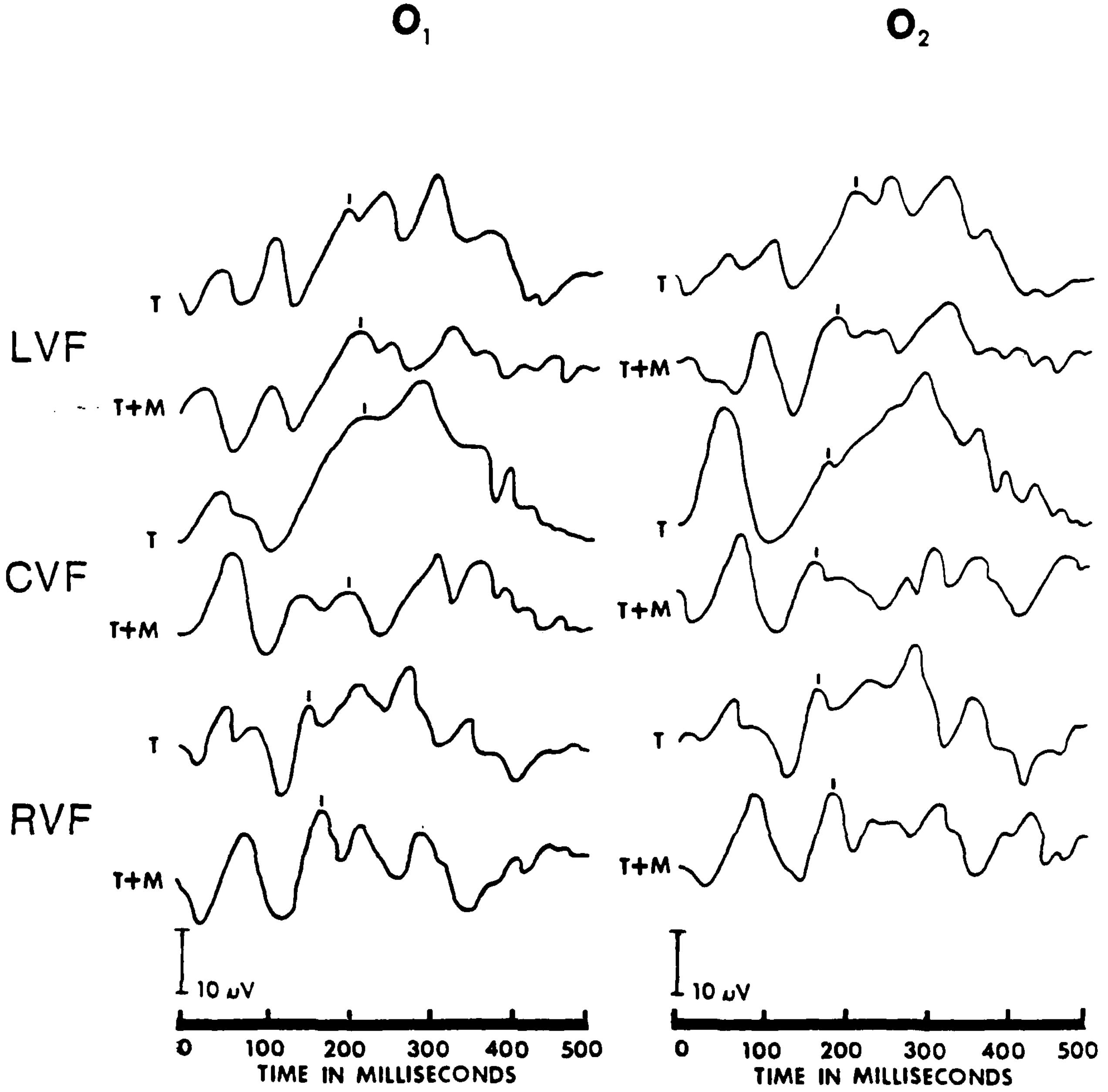

FIGURE 2 Visual ERPs of one subject (D.M.) under the conditions of the present experiment. The vertical bar indicates the occurrence of the P2 component of the ERP. Negativity is downward.

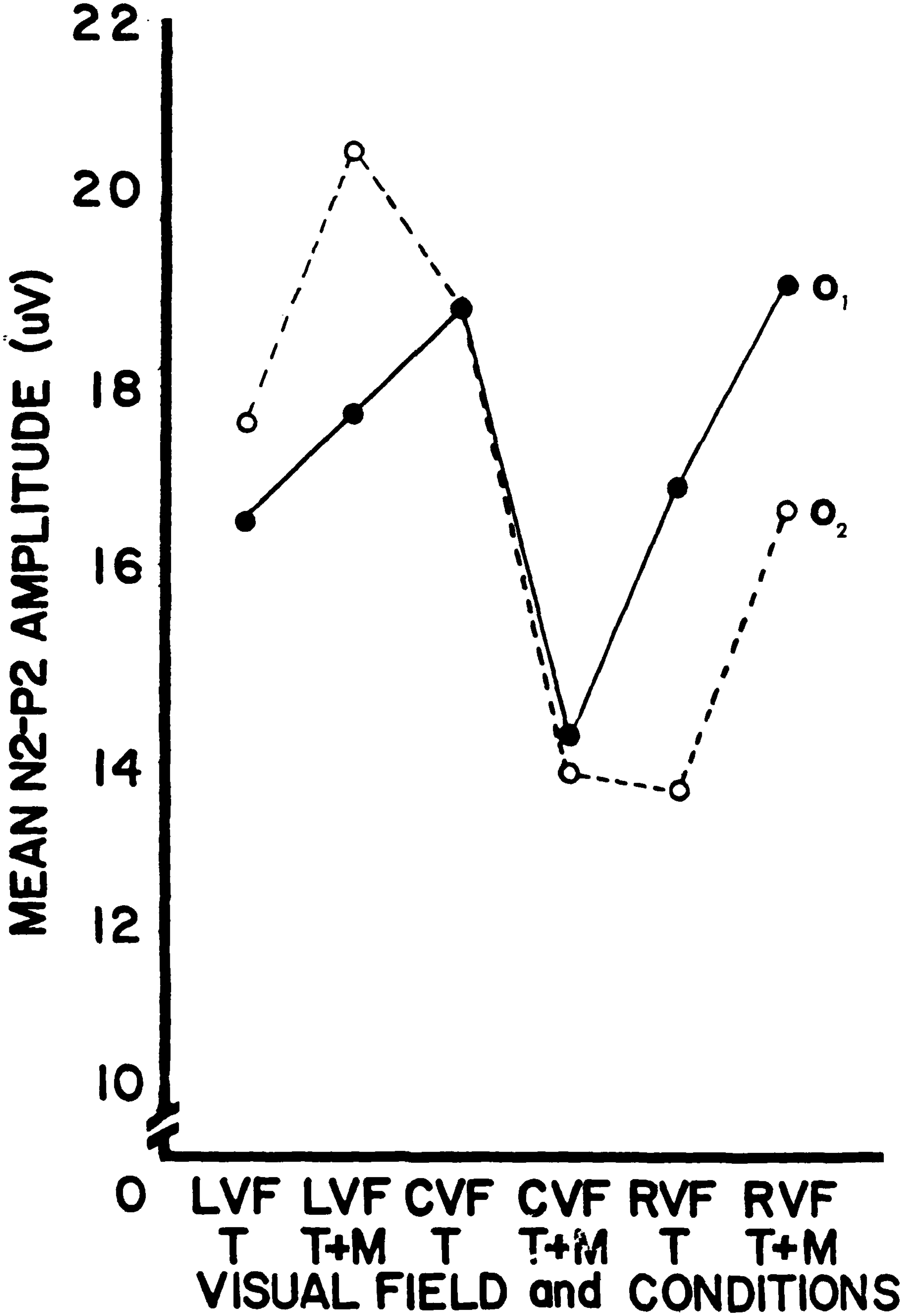

FIGURE 3 Mean N2-P2 amplitude for the seven subjects under the masking and no-masking conditions. Note that visual ERP attenuation under masking condition is greatest when stimuli are central (CVF). An equal amount of attenuation occurs for O_1 and O_2 with CVF stimulation.

assumptions of the ANOVA. A significant Condition effect was obtained for the N2-P2 amplitude (F=4.19, 5/84, $p < .01$). A Newman-Keuls multiple comparison test, which examined this effect in greater detail, showed two significant condition comparisons, i.e. LVF target and mask (T+M) was significantly larger than CVF (T+M), $p < .01$, and RVF target (T), $p < .01$. Table 1 and Figure 3 also reveal that under conditions of central visual field stimulation (CVF), N2-P2 amplitudes in response to the T+M condition showed greater attenuation than produced by the T alone condition. This amplitude advantage in favor of the target (T) alone condition was, on the average, 4.7 and 5.3 uV for the left (O_1) and right (O_2) hemisphere scalp locations, respectively. Additional statistical tests (t-test for correlated data) indicated that these left and right hemisphere response advantages with the target were significant (O_1: t=1.95, $p < .05$; O_2: t=2.38, $p < .05$, 6df, one-tailed criterion for both). An additional t-test showed that the degree of attenuation with CVF masking was not different for the left and right hemispheres (O_1 vs O_2; t=.42, 6df). Visual ERPs to the target stimulus were not attenuated under conditions of LVF and RVF stimulation since there was a non-significant trend in which left and right hemisphere derived amplitudes increased in response to the T+M situation (see Figure 3).

For N2 and P2 latencies, there were only significant subject effects: N2: F=35.1 (6/84, $p < .01$) and P2: F=28.0 (6/84, $p < .01$). Contralateral visual field effects for amplitude and latency may be observed in Table 1.

The ANOVA for P3 latency showed a significant Condition effect: F=13.0 (5/84, $p < .01$). The Newman-Keuls tests revealed that within each scalp location and visual field, P3 latencies were significantly longer with the T+M condition as compared to latencies with the T alone condition ($p < .05$ for all comparisons). It can be seen in Figure 4 that P3 latencies

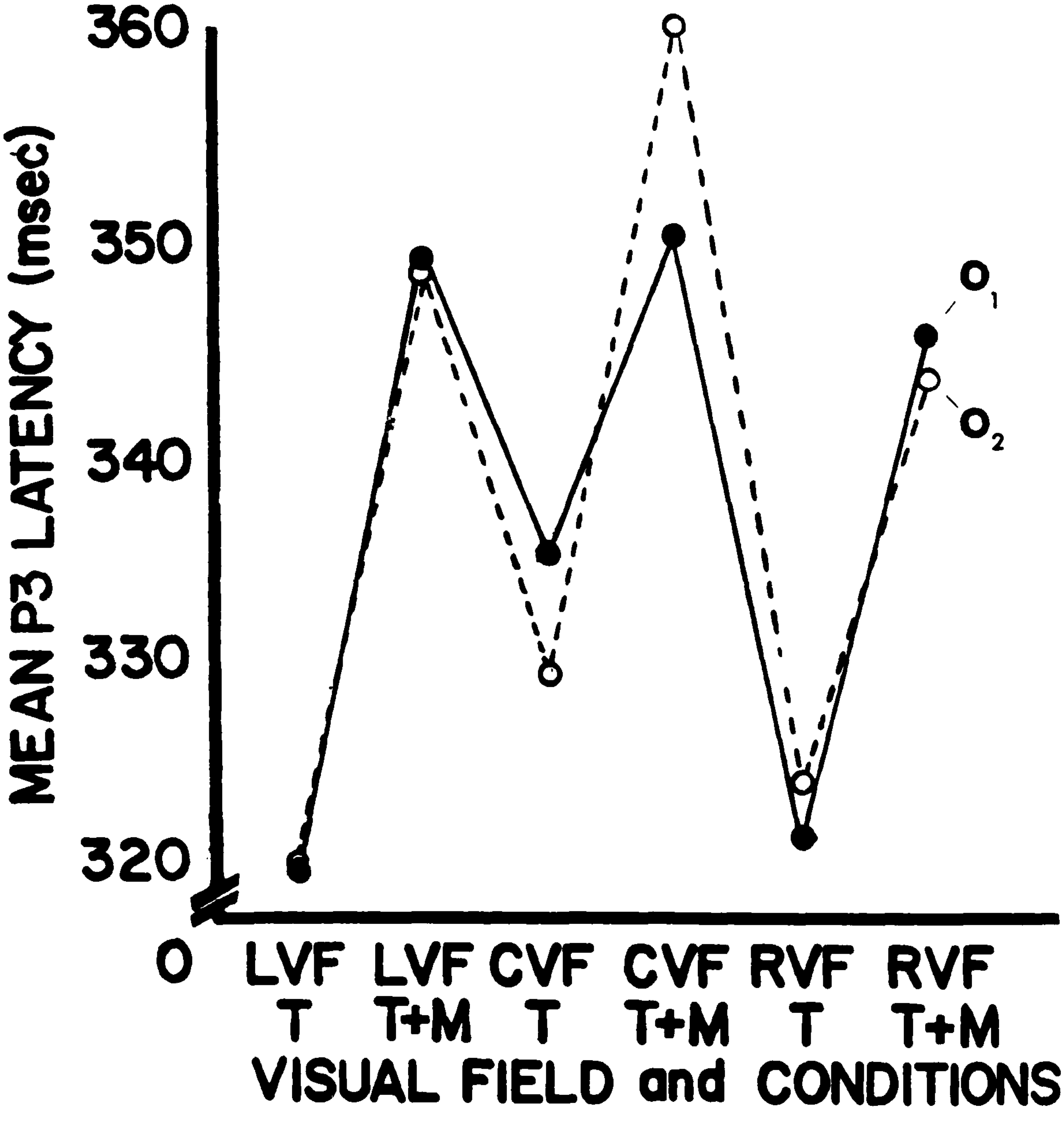

FIGURE 4 Mean P3 latency for the seven subjects under masking and no masking conditions. Note that P3 was significantly delayed when the mask followed the target (T+M). This suggests that the presentation of the mask interfered with the occurrence of P3 and delayed its appearance.

were, on the average, 25 msec longer for the T+M vs the T alone condition, and suggest interference by the mask, which, as mentioned previously, appeared 60 msec after initiation of the target stimulus and was about three times as intense as the target. There does not, however, appear to be an effect on P3 amplitude, since this component did not change significantly when the mask was presented.

DISCUSSION

We hypothesized that the right hemisphere would show greater susceptibility than the left to backward visual masking. It was expected that this would be expressed in one of two ways. First, under masking conditions, subjects would be more likely to detect targets in the RVF (left hemisphere) as compared to LVF. Second, visual ERPs derived from over the right hemisphere would show significantly greater attenuation than the left with target masking. It appears, however, that both hemispheres were equally susceptible to masking, since, under conditions of CVF presentations, the visual ERP response differential between the "masking" and "no masking" condition from each hemisphere was virtually the same (approximately 5 uV at both O_1 and O_2). In addition, when the masking conditions were lateralized to the left and right hemispheres, the mask was equally effective in producing backward visual masking at both hemipsheres. These results are different from those of Luria (1974) who found evidence for left hemisphere superiority in detecting the target in a masking experiment.

The visual ERP data obtained under conditions of LVF and RVF stimulation also failed to indicate differential hemispheric sensitivity to masking since perceptual masking was not accompanied by smaller visual ERPs at either the O_1 or O_2 scalp location. This finding is not unprecedented since Vaughan and Silverstein (1968) reported ERP attenuation during metacontrast suppression when the stimuli were delivered foveally (centrally) but not when they were presented parafoveally (peripherally). They reasoned that the failure of visual ERPs to reflect metacontrast suppression during parafoveal stimulation may have been due to stray light impinging on the fovea. Vaughan and Silverstein's explanation could account for the failure of our visual ERPs generated during LVF and RVF presentations to reflect differential sensitivity to masking. Another possible explanation is that the visual ERP attenuation associated with backward masking depends on appropriate retinotopic representation. That is, the one-to-one relationship between retinal receptor cells and cortical neurons, to which they project, is discretely organized at cortical areas for foveal receptors but is not organized as discretely for parafoveal receptors (Ruch, et al., 1965). In addition, the presumed inhibitory-excitatory activity at the visual cortex that is generated as a result of the interaction between contours of the target and mask depends on the close relationship between adjacent cells in the fovea (see Ratliff and Hartline, 1963, for a retinal analog).

The major positive finding in this experiment was that with CVF presentations perceptual masking was accompanied by a significant attenuation of the N2-P2 amplitude component of the visual ERP. When conditions were such that masking was not produced, visual ERP amplitudes were larger. These visual ERP correlates of backward visual masking are like those of Andreassi et al. (1976). The explanatory mechanism involves excitatory-inhibitory activity at the visual cortex that results from the interaction between target and mask. More specifically, the excitatory neuronal responses produced in the visual cortex by the target stimulus are decreased in their activity by the inhibitory fields produced by the later presented masking stimulus in areas adjacent to and completely surrounding the excitatory area.

Another finding was that P3 latencies were significantly longer under masking conditions. This effect was observed in each visual field. Recall that the masking stimulus was presented 40 msec after the target. It seems possible, therefore, that the P3 response in this study was delayed under backward masking conditions because of the target-mask interval required and not because of differential cognitive activity. This limitation would seem to make it difficult to meaningfully study the P3 response in a backward masking paradigm.

EXPERIMENT IV -- Hemispheric Identification and Visual Event Related Potential with Letter and Geometric Stimuli

INTRODUCTION

The question to be addressed in the context of the present study is whether brain event related potentials (ERPs) will indicate differential hemispheric processing of geometric forms and letters of the alphabet. There is existing evidence that brain responses will differ as a function of such variables as shape, pattern size, corners, and orientation of stimuli. But these data do not extend to the matter of ERP response differences in the left and right hemispheres. It would be instructive to review some of the existing literature on form, pattern, and orientation of figures and the related visual ERPs. A search indicates that little has been published on the question of shape and ERPs after 1975.

Shape -- Spehlmann (1965) reported differences between visual ERPs produced by a patterned field vs an unpatterned one. A positive ERP component which peaked at 180 to 250 milliseconds (msec) was much larger to patterned stimuli. John et al. (1967) found that different geometric shapes (e.g., square, diamond) produced different VEP waveforms. Little change in waveform of the VEP occurred with variation in the size of the figure (i.e., a small or large square evoked similar VEPs). They also reported that VEPs for a blank flash were different from those produced by geometric shapes.

Honda (1973) used a pattern discrimination task that was designed to focus the subject's attention on either the size or shape of geometric figures (circles, squares). When the subjects were required to make size discriminations and ignore form, the visual ERPs were affected by stimulus size. When shape discriminations were required, however, it was form and not size that resulted in ERP changes. These results were repeated by Honda (1974) with square and diamond stimuli. He concluded that the results showed the effects of selective attention on visual ERP waveforms and reflect electrical brain activities related to perceptual processing of patterns.

Pattern Size -- White (1969), using four stimulus patterns -- a checkerboard, a horizontal grating, a set of concentric circles and a set of radial lines -- found striking differences in VEP waveforms with the different stimulus patterns. He described an additional experiment in which VEPs were recorded to checkerboard patterns composed of different check sizes. It was observed that larger checks produced smaller amplitude VEPs (e.g., a check size that subtended 10' of visual angle produced a response approximately twice the amplitude of that produced by a check that was four times larger). Harter (1970) and Siegfried (1975) confirmed White's result with respect to the inverse relationship between VEP amplitude and check size. Harter (1970) also reported that this relationship depends on the portion of the retina stimulated. That is, when the foveal area (central 2 to 2.5° of vision) was stimulated, relatively small checks (15 to 30' of visual angle) evoked the greatest amplitude responses. However, when porgressively more pheripheral areas of the retina were stimulated (7.5° out from the fovea), larger check sizes (up to 60' of visual angle) produced the greatest amplitude ERPs. Check size had little effect on VEP when the retina was stimulated 12.5 to 27.5° from the fovea. Hypotheses regarding the factors that may be operating here include:

1) the greater number of edges separating light and dark areas, that is, patterns with many edges may produce larger responses, and

2) the angles, or total number of pattern elements, may affect VEP amplitude (Armington et al., 1971).

Harter and White (1968) noted that defocusing a checkerboard pattern resulted in lower amplitude VEPs. That is, with sharper checkerboard pattern images, the VEP was larger. This has led to suggestions by White (1969) that VEP amplitude differences may be used as a basis for testing vision, especially refractive errors in persons who cannot verbalize well enough for adequate testing by many of the currently used testing methods (e.g., retarded individuals or young children).

Eason et al. (1970) stimulated the upper and lower halves of the visual field and reported that VEP amplitude varied with visual field and check size. That is, checks subtending 10' of angle produced larger VEPs in the upper field, while checks subtending 40' of visual angle were optimal for lower field stimulation. The overall ERP amplitudes suggested to Eason and his colleagues that the cortical visual system is more responsive to patterned stimuli appearing in the lower visual field than in the upper. However, it also seemed that the system may be relatively more sensitive to smaller objects in the upper field. They speculated that the differential sensitivity of the upper and lower visual fields may have survival value for man as a ground-dwelling animal. That is, the upper field may be more attuned to "specks in the sky" which move rapidly and must be detected at a distance if the organism is to respond appropriately. However, ground objects that are close enough to pose a threat produce a larger visual angle. Thus, the part of the visual system responding to them (lower field) may have greater sensitivity to objects subtending angles of 30' or more.

Corners -- Patterns that include corners have been found to produce larger amplitude visual ERPs than those containing stripes (MacKay, 1969; Rietveld et al., 1967). Moskowitz et al. (1974) measured ERPs to rounded and sharply cornered stimuli, which varied in angularity, in 45^{o} steps, from 180 to 45^{o}. The visual ERP was greatest in amplitude for the 90^{o} sharply-cornered pattern. Cornered and rounded corner patterns produced larger ERPs than straight lines (180^{o}). The peak latency of responses to cornered patterns was shorter than that of responses to rounded and straight patterns. Moskowitz et al. postulated a "center-surround receptive field" model of the visual cortex to explain the major portion of their findings. The arugment presented was that interactions between excitatory and inhibitory areas of the visual cortex allowed maximal neuronal response to occur to the 90° cornered stimuli.

Orientation of Figures -- Maffei and Campbell (1970) presented vertical, horizontal, and oblique sets of lines (moving gratings) to subjects while visual ERPs were measured. They found VEPs to vertical and horizontal arrays to be similar, but the amplitude in resonse to the oblique array was considerably smaller than to the others. The authors concluded that the resolving power of the visual system is greater in the vertical and horizontal orientation than in the oblique. Yoshida et al. (1975) postulated that human visual cortical cells may be more responsive to horizontally and vertically oriented stimuli because our visual world is oriented mostly in horizontal or vertical planes. Leaning towers, such as the one in Pisa, are relatively rare in our visual environment.

To summarize, we might conclude that perceptions of different forms, patterns, and orientations are paralleled by changes in visual ERPs. The various experiments with checkerboard patterns indicate that effects such as check size, sharpness of image, and location in the visual field can influence the ERP. That is, ERPs are larger with small check sizes, with sharp images, and with stimuli in the lower visual field. Patterns containing sharply angled corners appear to result in larger VEPs than those with corners that are rounded or not angled as sharply. It has been suggested that the greater responsivity of the visual cortical system to stimuli oriented vertically and horizontally may be due to experiential factors which determine sensitivity of visual cortical cells.

Thus, there are studies showing that ERPs differ in response to varied patterns and shapes. The question that concerns this investigation is whether the visual ERP recorded from over the left and right hemispheres of the brain might reflect differential processing of geometric forms and letters. The contemporary model concerning hemispheric asymmetry describes the right hemisphere as the locus of spatial ability while verbal and analytic ability is attributed to the left (Sperry, 1982). Our expectation, therefore, is that left hemisphere derived ERPs will reflect processing of verbal stimuli, while ERPs obtained from over the right hemisphere will show differential response to geometric shape.

While the literature on form perception and ERPs after 1975 is rather scarce, there have been a number of studies which examined the question of verbal information and hemispheric asymmetry both before and after 1975. Buchsbaum and Fedio (1969), using verbal stimuli, found that ERP latencies derived from the left hemisphere were significantly longer than those obtained from the right, suggesting that ERPs elicited by words reflect left hemisphere processing of verbal information. Rugg and Beaumont (1978) used the ERP to investigate lateral asymmetry in the processing of visually presented stimuli, i.e., letter stimuli requiring verbal analysis and non-verbal stimuli requiring spatial analysis. They found that the first positive component was of shorter latency in the right hemisphere for both the letter and non-verbal stimuli. They concluded that the right hemisphere was dominant in the early stages of the processing of both stimulus types. Visual ERP correlates of hemispheric asymmetry and independent hemispheric processing was studied by Gott et al. (1977). They used a verbal task, which required that subjects detect rhyming words, and a spatial task consisting of comparing matching shapes. Their ERP data showed lateralization for verbal processing in the left hemisphere.

Kutas and Hillyard (1980) obtained ERPs while subjects were engaged in silently reading seven word sentences, presented one word at a time. They found that ERP response to the first six words in the sentence showed a prolonged positivity (400 to 700 msec post-stimulus) which was larger over the left hemisphere than the right. Ciesielski (1982) had subjects discriminate pairs of stimuli containing the same or different visual patterns while ERPs were recorded from over the left and right cerebral hemispheres (scalp locations C_3 and P_3; C_4 and P_4). A verbal control task was arranged at the end of the experiment. The major finding was that the N2 (i.e., occurring between 180 and 290 msec post-stimulus) and a P3 component (290 to 380 msec post-stimulus) were larger from the right heimsphere, for visual patterns, while P3 was larger at the left hemisphere for the verbal condition.

The present study is concerned with brain evoked responses and possible hemispheric performance differences with verbal and geometric stimuli. We hypothesize that:

1) Left hemisphere derived visual ERPs to letter stimuli will be larger than those obtained from a right hemisphere location, i.e., the N2-P2 amplitude component from over the left hemisphere will be larger than those from the right (occipital).

2) Right hemisphere derived visual ERPs (i.e., N2-P2 amplitudes) to geometric forms (spatial) stimuli will be larger than ERPs derived from the left hemisphere.

3) Left hemisphere N2 latency response will be shorter than right hemisphere responses to letter presentations, and the opposite will occur with form presentations, i.e., right hemisphere latencies will be shorter than those from the left.

METHOD

Subjects: The subjects were three male and six female right-handed students affiliated with the City University of New York. They ranged in age from 18 to 45 years. All subjects were screened for visual capacity and handedness. Visual ability testing was conducted with a Bausch and Lomb Orthorator which tested subjects for binocular visual acuity and vertical and lateral phoria. The phoria tests were included in the battery to estimate subjects' ability to fixate (Andreassi and Juszczak, 1981). All participants showed acceptable visual acuity (corrected to at least 20/25 with glasses) and orthophoria as established by the Bausch and Lomb Occupational Vision Standards. All were right-handed as determined by a handedness questionnaire (Annett, 1970) and none reported any familial sinistrality.

Apparatus and Procedure: Subjects were seated in an electrically shielded sound attenuated IAC chamber. All experimental sessions were conducted in the dark, i.e., the light in the chamber was turned off. The electroencephalogram (EEG) of each subject was recorded from O_1 and O_2 (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to linked ears. A Beckman Type RM Dynograph recorded the EEG and the 9806 coupler of the Dynograph conditioned the EEG signal (bandpass set at 0.5 to 32.0 Hz). A PDP8/E computer triggered a Computer of Average Transients (CAT 1000) to take EEG samples of 500 msec duration immediately following presentations of visual stimuli to subjects. The summated visual ERP trace was plotted on a Hewlett Packard X-Y plotter.

Eye blinks and eye movements were recorded with a two-channel electrooculogram (EOG) device (Washington University resetting differential amplifiers). Vertical EOGs were obtained by placing Beckman biominiature electrodes above and below the left eye. The resultant EOG was displayed continuously on two meters and on a Tektronix dual-trace oscilloscope. Any trials suspected of EOG contamination were discarded.

The stimuli were displayed on a Digital Equipment Corporation VR-14 cathode ray tube (CRT) mounted outside the chamber window at a distance of 114.3 cm (45 in) from the subject's nasion and at eye level. A brief persistence P24 phosphor was installed in the VR-14 to assure rapid stimulus decay (50 usec).

The stimuli consisted of a square and a triangle and the letters B and E. The geometric figures privided two different forms, while the letters provided form as well as a verbal component. Each stimulus was projected for 40 msec in the same horizontal plane, centrally and 2.5° to the left and right of central fixation. The fixation point was a dim .001 mL red neon light. The visual angle for both right and left visual field presentations (RVF and LVF, respectively) was computed from the 5 cm distance between the fixation point and the proximal edge of the stimuli. The 1.0 X 1.0 cm dimension of the four stimuli (i.e., square, triangle, B, E) produced a visual angle of 30' of arc, while the luminance of each measured 3.8 millilamberts (mL) as measured with a J-16 photometer. Thus, size and luminance of all four stimuli were equated.

The four stimuli were randomly presented in one visual field at a time, e.g., square, triangle, B and E were presented in the LVF, then in the RVF and finally in CVF. The visual field ordering was counterbalanced among subjects. Since the stimulus averaging was done for either the forms or letters, there were six conditions: Forms-LVF, Letters-LVF, Forms-CVF, Letters-CVF, Forms-RVF, Letters-RVF. Randomization was restricted in that each stimulus appeared in a given visual field an equal number of times, i.e., a total of forty presentations of forms and letter stimuli. The timing between presentations was always four seconds.

Prior to data collection, subjects were advised to focus on the small red neon light at all times and to avoid eye blinks and eye or head movements, especially during and immediately after presentations of the stimuli. These instructions, coupled with EOG recordings, insured that subjects maintained fixation.

The standardized instructions asked subjects to simply report the stimulus seen. For example, if a triangle appeared, they were told to say "TRIANGLE." If the letter B appeared, they were told to say "B." They were additionally reminded to wait about one second after stimulus presentations before giving their responses. This was done to minimize movement artifact. Verbal responses were monitored via an intercom system.

Data collection consisted of obtaining 40 uncontaminated visual ERP samples for the form (i.e., square and triangle averaged together) and letters (B and E averaged together), i.e., one trace for each type of stimulus and visual field from each subject. The six conditions were randomized across subjects over a period of three days. Thus, over the three experimental sessions, a total of eighteen visual ERP traces from O_1 and O_2 were obtained from each subject.

RESULTS

The verbal responses monitored during the three sessions indicated that all subjects accurately perceived the letters B and E, and a triangle or a square in the left, central, and right visual fields.

Visual ERPs -- Through analysis of the visual ERP traces of each subject, several major ERP components emerged They were identified and measured as in previous studies. The visual ERPs of one subject are presented in Figure 1.

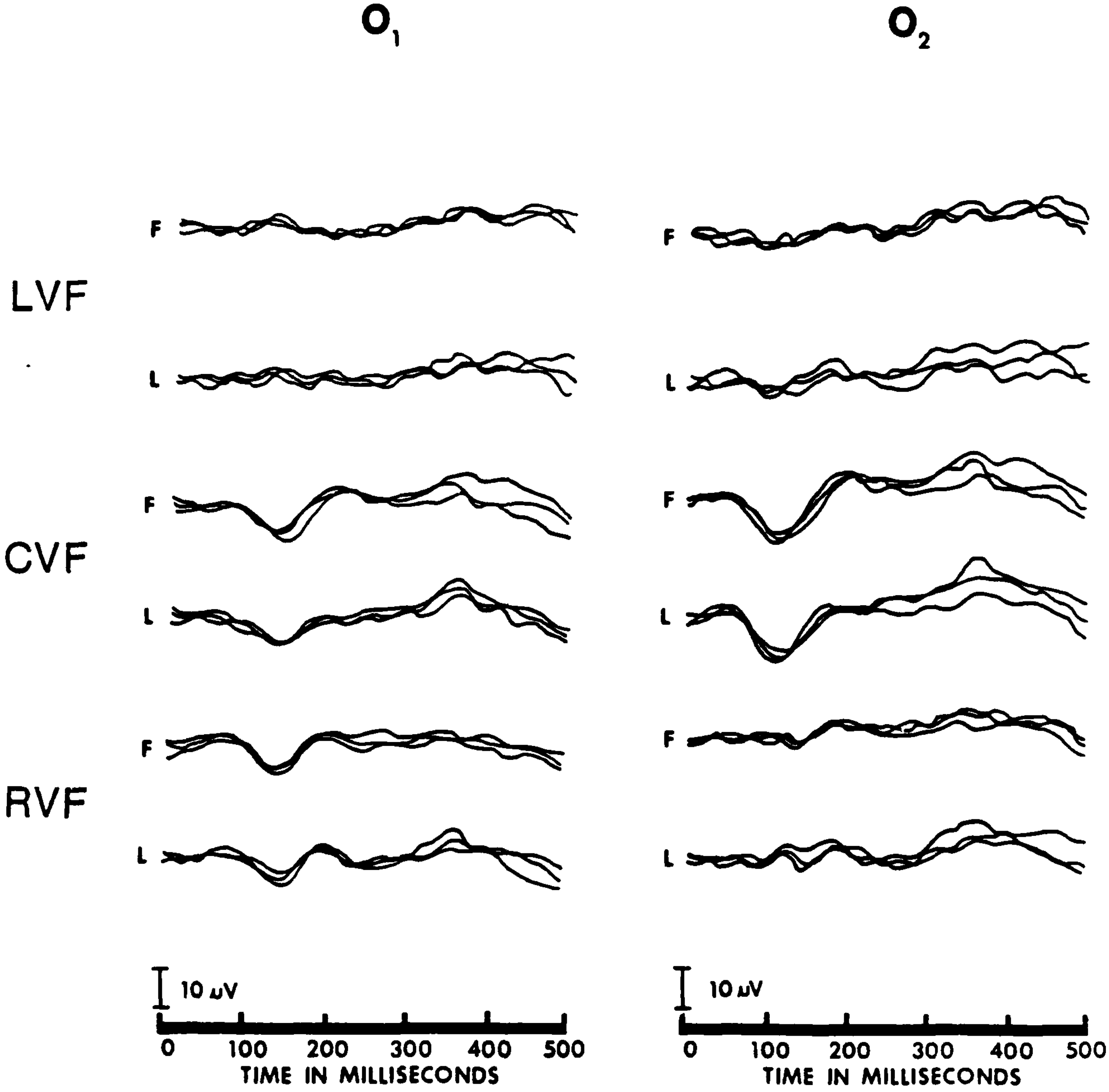

FIGURE 1 Visual ERP traces of one subject (A.D.). Each trace is based on an average of 40 responses. Negativity is downward.

Data analysis was accomplished by computing the mean amplitude (uV) and latencies (msec) from the ERP traces. Mean N2-P2 amplitudes and N2 latencies are shown in Table 1 for all nine subjects under the six different experimental situations. Figure 2 depicts the data from the table for amplitudes.

TABLE 1

Mean Amplitude (uV) and Latency (msec)
Components N2-P2 and N2 for all Subjects, (N=9),
Placements and Conditions

Conditions	Scalp Locations and Visual ERP Components			
	O_1		O_2	
	N2-P2	N2	N2-P2	N2
Forms-LVF	11.9	171	12.6	154
Letters-LVF	11.0	173	13.8	159
Forms-CVF	18.0	154	18.4	150
Letters-CVF	16.5	157	16.9	154
Froms-RVF	13.0	159	11.5	167
Letters-RVF	12.6	158	9.5	170

The above data were subjected to a three-way Analysis of Variance (ANOVA) in which Subjects (nine), Conditions (six) and Placements (two) served as main effects. Prior to data analysis, the measurements were log-transformed to insure conformity with the assumptions of normality of distribution and homogeneity of variance required by the ANOVA model (Winer, 1971). For the N2-P2 amplitude, significant effects were obtained for Conditions (F=23.5, 5/108, $p < .01$) and the Condition X Placement interaction (F=4.87, 5/108, $p < .01$). The Condition X Placement interaction reflects contralateral visual field effects, i.e., amplitudes of response were largest at the hemisphere receiving direct visual stimulation. For example, the figure

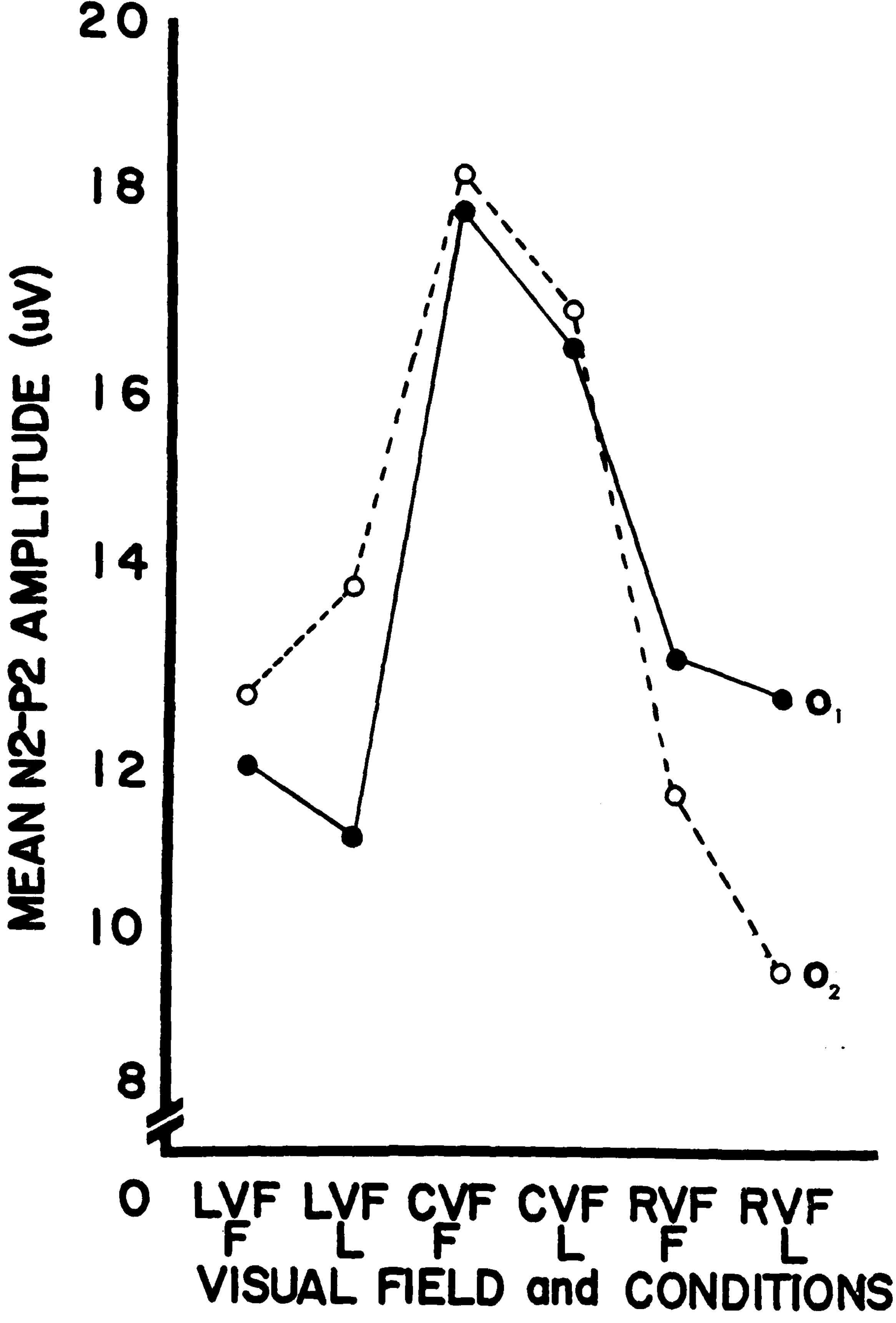

FIGURE 2 Mean N2-P2 amplitudes under conditions of this experiment for nine subjects. Larger overall amplitudes occur with CVF stimulation. Note that contralateral stimulation produces larger responses than ipsilateral stimuli.

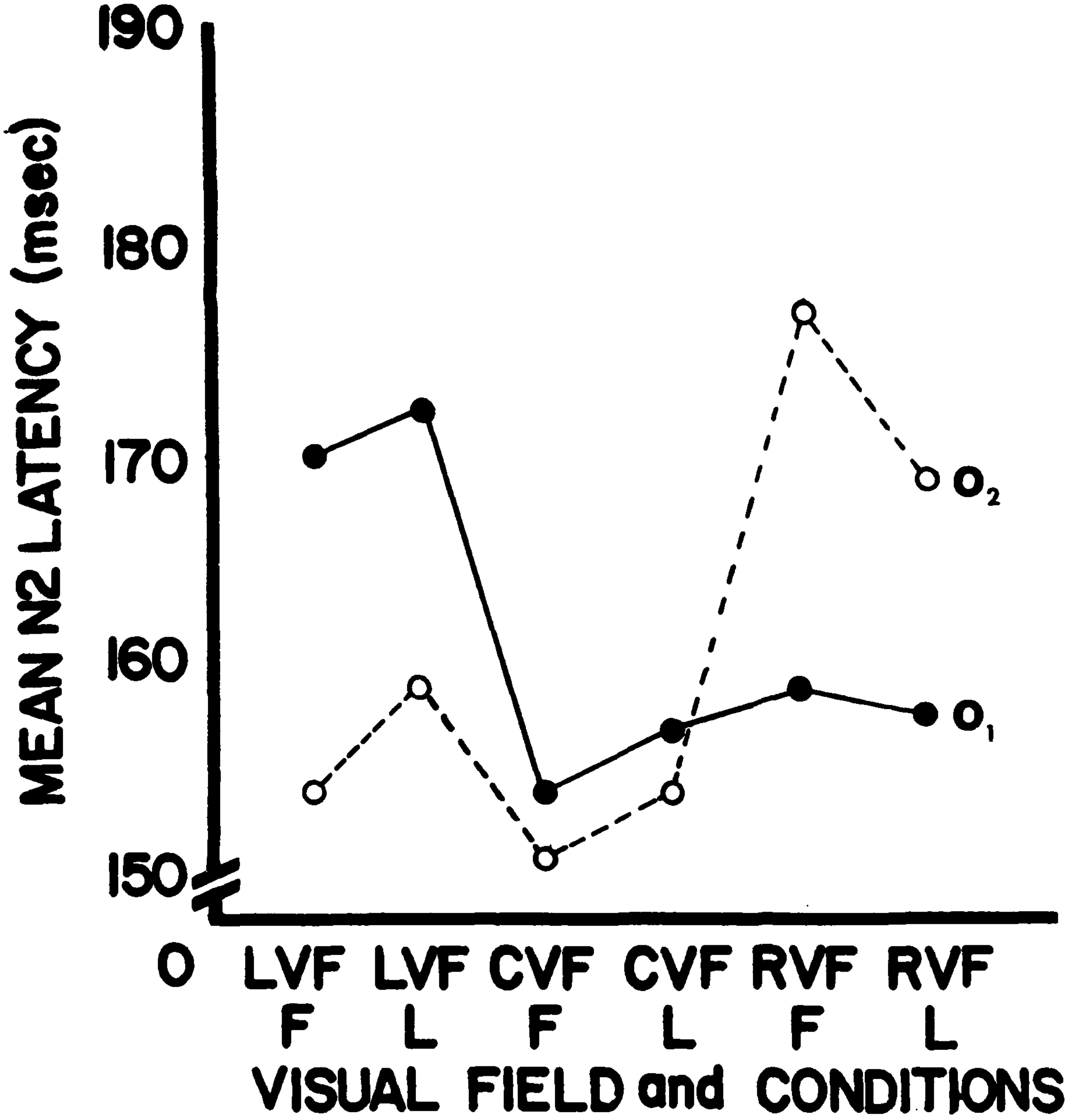

FIGURE 3 Mean N2 latency under various conditions for nine subjects. Note the shorter latencies that occur with contralateral stimulation.

depicting the amplitude data (Figure 2) shows larger amplitudes at the O_2 recording site when both types of stimuli were presented in LVF. The Newman-Keuls tests which were conducted to examine this effect in greater detail indicated that, at O_2, all visual field comparison were significant ($p < .05$). However, at O_1, similar contralateral visual field effects are indicated, but the Newman-Keuls test results revealed that these effects were non-significant ($p > .05$). In addition, at both scalp locations, N2-P2 amplitudes in response to both letter and form stimuli under conditions of CVF stimulation were significantly larger than responses obtained with RVF and LVF presentations ($p < .01$, for all CVF vs RVF and LVF comparisions; O_1 and O_2). Another consideration was whether there would be any response differential at the left or right hemisphere scalp location to the letter and form stimuli. The Newman-Keuls test results indicated that, at O_1 and O_2, N2-P2 amplitudes in response to the letters and forms were the same ($p > .05$ for the three form vs letter comparisons; LVF, CVF, RVF).

A similar three-way ANOVA was conducted on N2 latency and significant Condition and Condition X Placement interaction effects were obtained (Conditions: $F=23.3$, 5/108, $p < .01$; Condition X Placement: $F=16.67$, 5/108, $p < .01$). Our Newman-Keuls test results revealed that the shortest latencies occurred when stimuli were delivered centrally (i.e., latencies with CVF were shorter than RVF and LVF at both scalp locations, $p < .01$) and contralaterally (e.g., latencies at O_1 were shorter than latencies at O_2 with RVF presentations, $p < .01$). When latencies to the letter and form stimuli were compared within each visual field, there were no significant differences ($p > .05$). These CVF and contralateral visual field effects, which were expected, can be clearly seen in Table 1 and Figure 3 .

With regard to the remaining components (i.e., P2, P3 latencies and N3-P3 amplitude), no significant F values were obtained with any of the important main effects (i.e., Condition X Placement) or their interaction ($p > .05$).

DISCUSSION

It was hypothesized that the left and right hemispheres of the brain would show differential ERPs to letters and geometric forms in a simple discrimination task. Specifically, we hypothesized that the left hemisphere would show greater activity (i.e., larger N2-P2 amplitudes) and faster processing time (shorter N2 latencies) to letter stimuli. Conversely, we hypothesized that right hemisphere derived N2-P2 amplitudes and N2 latencies would reflect preferential processing of form stimuli, i.e., larger N2-P2 amplitudes and shorter latencies from the right hemisphere, relative to the left, to the triangle and square stimuli. Our data suggest that both hemispheres process these types of stimuli similarly, as indicated by the finding that left and right hemisphere amplitudes and latencies in response to letters and forms were similar. Our findings are not like those of Buchsbaum and Fedio (1969) since they found significantly shorter left hemisphere ERP latencies than the right to visually presented verbal (words) stimuli, while we found no latency differences to the letter and forms from the left hemisphere. Perhaps the difference in the findings between the Buchsbaum and Fedio study and ours lies in the type of verbal stimulus used. Namely, we used letters with the assumption that they would be preferentially processed by the left hemisphere. Buchsbaum and Fedio, on the other hand, used more complex verbal stimuli, such as words. Perhaps our letter stimuli were not sufficiently complex to engage the left hemisphere. From a psycholinguistic point of view, words are more complex than letters since they are usually made up of several letters and convey meaning as well. A related possibility concerns whether passive observation of letter stimuli is a sufficiently strong verbal task, i.e., the fact that left and right hemisphere response to letters and forms are similar may be due to the simplicity of the discrimination task. Recall that subjects were not required to analyze the letters but rather to simply report the letter seen. The same possibility can be applied to the finding that right hemisphere ERP responses to letters and geometric forms did not differ. Namely, the observation of geometric stimuli may not produce a visuo-spatial task which will engage the right hemisphere. Thus, under a passive observation or simple discrimination situation, both hemispheres may show equal processing capacity for simple letters and geometric forms, as mentioned previously. We are currently planning a follow-up investigation in which subjects will be required to engage in a complex verbal-spatial task. For example, the verbal task will require that subjects discriminate words that are phonetically alike, but differ in meaning (homonyms). With regard to the visuo-spatial task, subjects will make discriminations of differences in area of geometric shapes such as triangles or squares. It is our belief that these tasks should be of sufficient difficulty to tax the specialized abilities of the left and right hemispheres.

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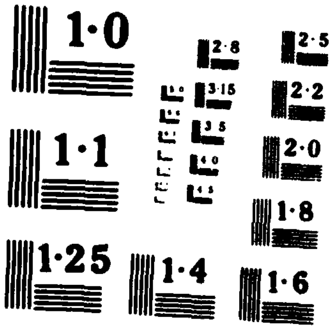
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Shape Discrimination

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

This is the final ~~annual~~ report to originate from the Psychophysiology Laboratory at Baruch College. The research completed over the last twelve months has included a number of studies concerned with evoked cortical potential correlates of visual stimulus processing in humans. The first experiment was conducted in order to replicate an earlier finding in which the amplitude of a relatively late positive component of the event related potential (ERP), known as the P3, was larger to a line orientation that

quired a "yes" response than one that required a "no." The angular ifference between the two lines was only 5°. Another purpose was to assess the reliability of the better right hemisphere performance found with male subjects in the line orientation discrimination task used.

The hypothesis that the P3 amplitude advantage previously associated with a 55° line orientation would switch to the 50° line in the present study because of the positive label "yes" associated with 50° was not supported. The remaining ERP data also revealed no hemispheric differences when other components (N2 and P2) were analyzed for both latency and amplitude of response. Analysis of the performance data did not support a preliminary finding of right hemisphere advantage for male subjects in spatial discrimination. The twelve males and twelve females performed equally well with left and right hemipshere discriminations.

In Experiment II, we examined the possibility of hemipsheric asymmetry in response to two different colors (red and blue). The two hemipsheres responded in essentially the same manner to the two colors. However, an interesting finding was the larger ERPs of both left and right hemispheres to the color blue, especially with central visual field stimulation. These results are consistent with psychophysical data which show that the visual system, especially the cone system, is most sensitive to intermediate wavelengths (e.g., green and blue) as compared to shorter (violet) and longer (red) wavelengths.

The third experiment was directed at the determination of whether the right hemisphere would be more sensitive to visual maksing than the left, espeically with a metacontrast paradigm which is dependent on spatial factors to produce the masking effect. The performance and ERP data did not reveal a hemispheric difference with respect to this variety of backward visual masking.

The fourth experiment was performed to determine the relative responsivity of the two hemispheres to verbal (letter) and spatial (geometric form) stimuli. Letter (B and E) and geometric (square and triangle) stimuli were presented in three visual fields. Both performance and ERP data indicated no laterality in response to the two types of stimuli. Several past studies had indicated hemispheric differences with these two types of stimuli. Perhaps the simplicity of our task (identifying the letters and forms) was not demanding enough to engage the two hemispheres differentially.

The foregoing account has summarized the work of our final annual report. The focus of our experimental work in the first annual report was upon hemispheric asymmetries of performance and ERPs in a signal detection task. In the second annual report, we studied possible hemispheric asymmetries in the perception of motion and line length. Investigations of hemispheric asymmetries during discriminations of line orientation and velocity of motion were conducted and reported on in the third annual report.