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EVOKED CORTICAL POTENTIALS AND INFORMATION  
PROCESSING

John L. Andreassi, et al

Baruch College of the City University of New York

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asymmetries in the auditory evoked potential under conditions of monaural and binaural stimulation. The main finding was that larger amplitude evoked potentials were produced in the hemisphere contralateral to the stimulated ear, as compared to the ipsilateral hemisphere. In the second experiment, we examined hemispheric latency asymmetries in the visual evoked potential as a function of visual stimulus location. Stimuli originating in the left visual field of subjects produced shorter latencies in the right occipital area than the left, and the opposite occurred for stimuli presented in the right visual field.

The effects of cigarette smoking upon the visual evoked potential and on perception span for digits was the topic of Experiment III. It was found that one component of the evoked potential occurred faster with the smoking versus the non-smoking condition. The perception span for digits showed no significant difference with smoking.

Experiments IV and V were concerned with the effects of varying complexity, sequential sets of stimuli, upon visual masking and the evoked potential. There was suggestive evidence that visual masking was accompanied by decreased amplitude of evoked potentials. Further study of this phenomenon is planned.

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## Evoked Cortical Potentials and Information Processing

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Second Annual Report

31 December, 1974

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## Second Annual Report

### Abstract

This is the second annual report to originate from the Psychophysiology Laboratory of the Psychology Department at Baruch College. The research completed over the past year has included a number of studies concerned with visual and auditory evoked cortical potential correlates of stimulus processing. The present report will detail the results of five separate experiments.

The first of these experiments was concerned with hemispheric amplitude asymmetries in the auditory evoked potential under conditions of monaural and binaural stimulation. The main finding was that larger amplitude evoked potentials were produced in the hemisphere contralateral to the stimulated ear, as compared to the ipsilateral hemisphere. In the second experiment, we examined hemispheric latency asymmetries in the visual evoked potential as a function of visual stimulus location. Stimuli originating in the left visual field of subjects produced shorter latencies in the right occipital area than the left, and the opposite occurred for stimuli presented in the right visual field.

The effects of cigarette smoking upon the visual evoked potential and on perception span for digits was the topic of Experiment III. It was found that one component of the evoked potential occurred faster with the smoking versus the non-smoking condition. The perception span for digits showed no significant difference with smoking.

V

Experiments IV and V were concerned with the effects of varying complexity, sequential sets of stimuli, upon visual masking and the evoked potential. There was suggestive evidence that visual masking was accompanied by decreased amplitude of evoked potentials. Further study of this phenomenon is planned.

## Experiment 1: Hemispheric Amplitude Asymmetries in the Auditory Evoked Potential With Monaural and Binaural Stimulation

Asymmetries in the evoked potential recorded from right and left hemispheres have been reported in a number of recent investigations. For example, Morrell and Salamy (1971) found that the amplitude of auditory evoked potential (AEP) components recorded from over the left hemisphere were larger than those from the right in response to auditory speech stimuli. This finding is consistent with known functions of the left hemisphere as the main language center for most persons (e.g. Sperry, 1968). Wood, Goff and Day (1971) report that AEPs from the left hemisphere differed when linguistic information was presented, as compared to when nonlinguistic patterns of the same acoustic signal were presented. The right hemisphere AEPs were the same for linguistic and nonlinguistic auditory stimuli. Matsumiya et al (1972) report interhemispheric asymmetries of AEPs to speech and mechanical sound-effect stimuli. A positive wave with peak asymmetry occurred 100 msec. after signal onset. Matsumiya et al provide evidence which indicates that the amount of asymmetry in the amplitude of this wave is related to meaningfulness of the auditory stimulus to subjects, rather than merely verbal vs. non-verbal stimulus processing.

The present experiment is concerned with the measurement of AEPs from both hemispheres to meaningless stimuli (burst of white noise) as a function of left and right ear presentations. The notion to perform the present experiment was derived from a series of behavioral studies in which it was indicated that subjects show superior performance

in the detection of verbal stimuli presented to the left ear in a situation where both ears are stimulated simultaneously by similar stimuli (Kimura, 1961b; Kimura, 1967). The testing technique which led to the finding of performance differences involves the presentation of two different digits simultaneously to the two ears through earphones, one to the left, the other to the right. Three such pairs are presented, and at the end of the six, the subject is asked to report all the numbers he heard, in any order. This is termed a "dichotic" listening task. An explanation for the superiority of the right ear in a dichotic listening task is suggested by electrophysiological experiments by Tunturi (1946) with dogs, and similar experiments by Rosenzweig (1951) with cats. Tunturi found that contralateral (crossover) pathways are greater in numbers and units than ipsilateral (same side) pathways, and Rosenzweig reports the same for cats. Rosenzweig has also proposed that there is a point of overlap between the ipsilateral and contralateral pathways and that the contralateral are capable of blocking impulses along the ipsilateral paths. In terms of the dichotic listening results, it would mean that stimuli from the right ear have priority over those from the left ear at the left hemisphere. Since the left hemisphere is concerned with language functions, the right ear stimuli are processed more efficiently than those arriving from the left. On the other hand, the stimuli from the left ear have priority in the right hemisphere over right ear stimuli, but this does not result in a performance difference in favor of the left ear since the right hemisphere is not concerned with language functions in the vast majority of persons. Kimura's



(1961a) data with brain damaged patients also indicates that the crossed auditory pathways are stronger than the uncrossed. In that study, Kimura found that the total number of digits correctly reported was smaller for a group of patients with lesions of the left temporal lobe than for a group with lesions of the right temporal lobe.

Since the neural connections from one ear to the hemisphere on the opposite (contralateral) side are stronger than the connections to the hemisphere on the same side (ipsilateral) we reasoned that simple auditory stimuli should result in greater amplitude AEPs in the contralateral hemisphere than in the ipsilateral hemisphere. It was also thought that because of the stronger contralateral representation the latencies of major AEP components would be shorter in the contralateral as compared to the ipsilateral hemisphere.

Three conditions were established for the purpose of testing the hypotheses of this study:

- Condition A - Auditory stimulus in left ear alone
- Condition B - Auditory stimulus in right ear alone
- Condition C - Auditory stimulus in both ears simultaneously

More specifically, the hypotheses with respect to AEP amplitude are:

- 1) Condition A: Amplitude of response in right hemisphere greater than left hemisphere
- 2) Condition B: Amplitude of response in left hemisphere greater than right hemisphere

- 3) Condition C: Amplitude of response in left hemisphere equals that of right hemisphere

With respect to latencies:

- 4) Condition A: Latency of response in right hemisphere faster than in left hemisphere
- 5) Condition B: Latency of response in left hemisphere faster than in right hemisphere
- 6) Condition C: Latency of response in left hemisphere equals that of right hemisphere

#### METHOD

Subjects: The subjects (s) were five male and four female graduate and undergraduate students associated with the Baruch College of the City University of New York. The ages ranged from 20 to 63. None had auditory system defects.

Apparatus and Procedure: Ss were seated in an electrically shielded sound-attenuated room (IAC Chamber) while EEG was recorded from C<sub>3</sub> and C<sub>4</sub> ("Ten-Twenty" system, Jasper, 1958) with Grass silver electrodes referenced to another electrode on S's left ear lobe. A Beckman Type RM Dynograph was used to record the EEG and a Mnemotron Computer of Average Transients was used to obtain the averaged evoked potential. The AEP traces were drawn by a Hewlett-Packard X-Y Plotter. A Grason-Stadler noise generator was used to present an 80 db burst of white noise to Ss over headphones. A Hunter decade/interval timer was used to time the stimulus at 200 msec. Each time a noise burst was presented, the CAT was triggered by a pulse controlled by the timer. The intensity of noise was measured at

80dB/cm<sup>2</sup> by a General Radio sound level meter. The interval between bursts was one second.

The S was asked to close his eyes and relax while listening to sounds coming in over headphones. He was asked to count the bursts of noise silently and to let the experimenter know that 150 presentations occurred by saying "150" aloud when this number was reached. S was asked not to blink his eyes or to move about excessively lest the recordings be spoiled. After answering S's questions and giving samples of sounds as they would be presented to the left ear, the right ear, and both ears simultaneously, the experiment was begun.

The three conditions were counterbalanced over the nine Ss in a latin-square design. Each S started the experiment with a different condition, and this design was repeated for each group of three Ss. The S completed three conditions and then the three conditions were repeated again to make one complete session. Thus, each S produced two AEPs for each of the conditions and for each of the electrode recording sites. The S was given a two minute rest between each trial of 150 noise bursts. Total testing time was approximately one hour.

#### RESULTS AND DISCUSSION

The averaged AEPs were analyzed with regard to the amplitude (microvolts) and latencies (milliseconds) of their P1, N2 and P2 components. The mean amplitude data for these components is shown in Table 1 for the C<sub>3</sub> and C<sub>4</sub> locations. The mean latency data for these components is shown in Table 2 for C<sub>3</sub> and C<sub>4</sub>.

Table 1

Mean Amplitude (Microvolts) for Major AEP Components  
of C<sub>3</sub> and C<sub>4</sub> Under Conditions A (Left Ear), B (Right  
Ear) and C (Both Ears) Across Nine Subjects

Electrode Location	AEP Component	Condition		
		A	B	C
C <sub>3</sub> (Left Hemisphere)	P1	1.25	1.18	1.66
	N2	2.29	2.79	2.45
	P2	3.79	2.45	4.58
C <sub>4</sub> (Right Hemisphere)	P1	1.43	1.33	1.86
	N2	2.94	2.45	2.84
	P2	4.37	3.65	4.83

Table 2

Mean Latencies (Milliseconds) for Major AEP Components  
From C<sub>3</sub> and C<sub>4</sub> Under Conditions A (Left Ear), B (Right  
Ear) and C (Both Ears) Across Nine Subjects

Electrode Location	AEP Component	Condition		
		A	B	C
C <sub>3</sub> (Left Hemisphere)	P1	93	80	81
	N2	127	134	118
	P2	200	203	205
C <sub>4</sub> (Right Hemisphere)	P1	77	76	81
	N2	128	128	119
	P2	189	205	205

The data from Tables 1 and 2 were plotted as averaged  
"idealized" curves taking latencies and amplitudes into account.

Figure 1 shows, in effect, averaged latency and amplitude curves across the nine Ss, indicating the AEPs for the right ( $C_4$ ) and left ( $C_3$ ) hemispheres for Conditions A, B, and C. Figure 1 shows that the AEPs are in the hypothesized directions for the N2 and P2 components, i.e., the amplitudes from the right hemisphere are greater than those from the left hemisphere when the stimulus is presented to the left ear. The data were further analyzed by t-tests for correlated data, one-tailed criterion (N2 and P2 amplitude and latency data only). The t-ratio computed for the difference between  $C_3$  and  $C_4$  amplitude under Condition A yielded a value of 2.32 for N2 ( $p < .025$ , 8 d.f.) and a value of 2.18 for P2 ( $p < .05$ , 8 d.f.). Figure 1 also shows the expected result for N2, under Condition B, i.e., greater  $C_3$  amplitude than for  $C_4$  ( $t = 1.94$ ,  $p < .05$ , 8 d.f.) but not for the P2 component. For Condition C it can be seen that the N2 response is greater in amplitude for  $C_4$  than for  $C_3$ , an unexpected result ( $t = 3.41$ ,  $p < .005$ , 8 d.f.). The P2 amplitudes for  $C_3$  and  $C_4$  do not differ under Condition C. None of the latency comparisons proved to be significantly different for any of the conditions.

The results of this experiment provide support for Hypotheses 1 and 2 since the auditory stimulation produced larger amplitude evoked potentials in the contralateral hemispheres. Thus, further evidence is obtained for the predominance of the contralateral pathways of the auditory system. However, one puzzling finding emerges since the N2 component of the AEP recorded from the right hemisphere is greater than that recorded from the left hemisphere

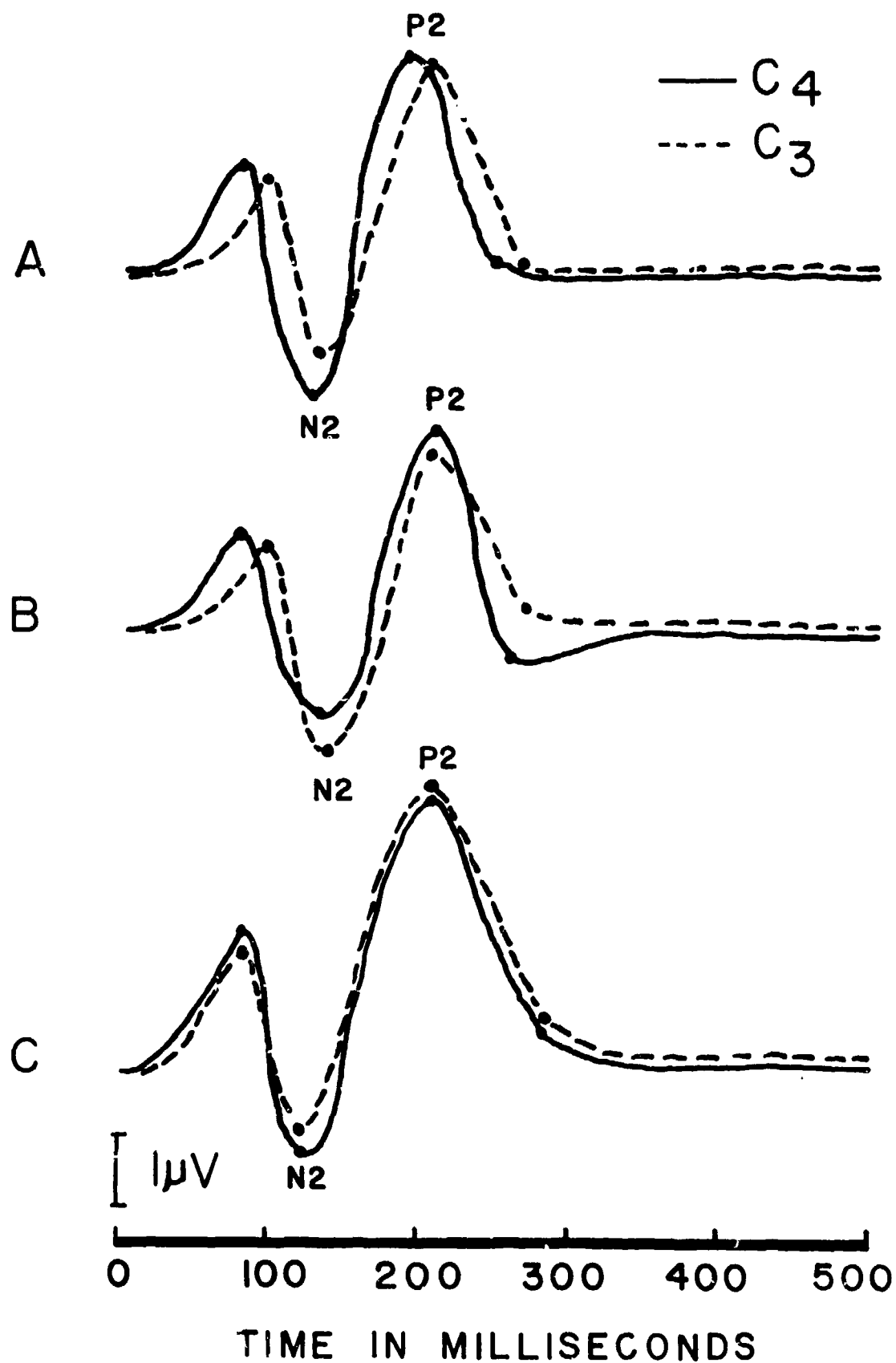


Figure 1 - Averaged and smoothed amplitude and latency curves for C<sub>3</sub> (left hemisphere) and C<sub>4</sub> (right hemisphere) across nine Ss for conditions A, B, and C. Negativity is downward.

when both ears were stimulated simultaneously. An examination of Table 1 indicates that for eight of the nine listed means the amplitude of response was greater for the right hemisphere than for the left hemisphere under the identical conditions of stimulation. Therefore, for this group of nine Ss there seems to be a greater responsiveness to the white noise stimulus in the right hemisphere as compared to the left. The reason for this is not known.

Figures 2 (M.A.) and 3 (L.C.) show the raw AEP traces of two Ss who participated in this experiment. The results for these two Ss were representative and reflect the main findings of this study.

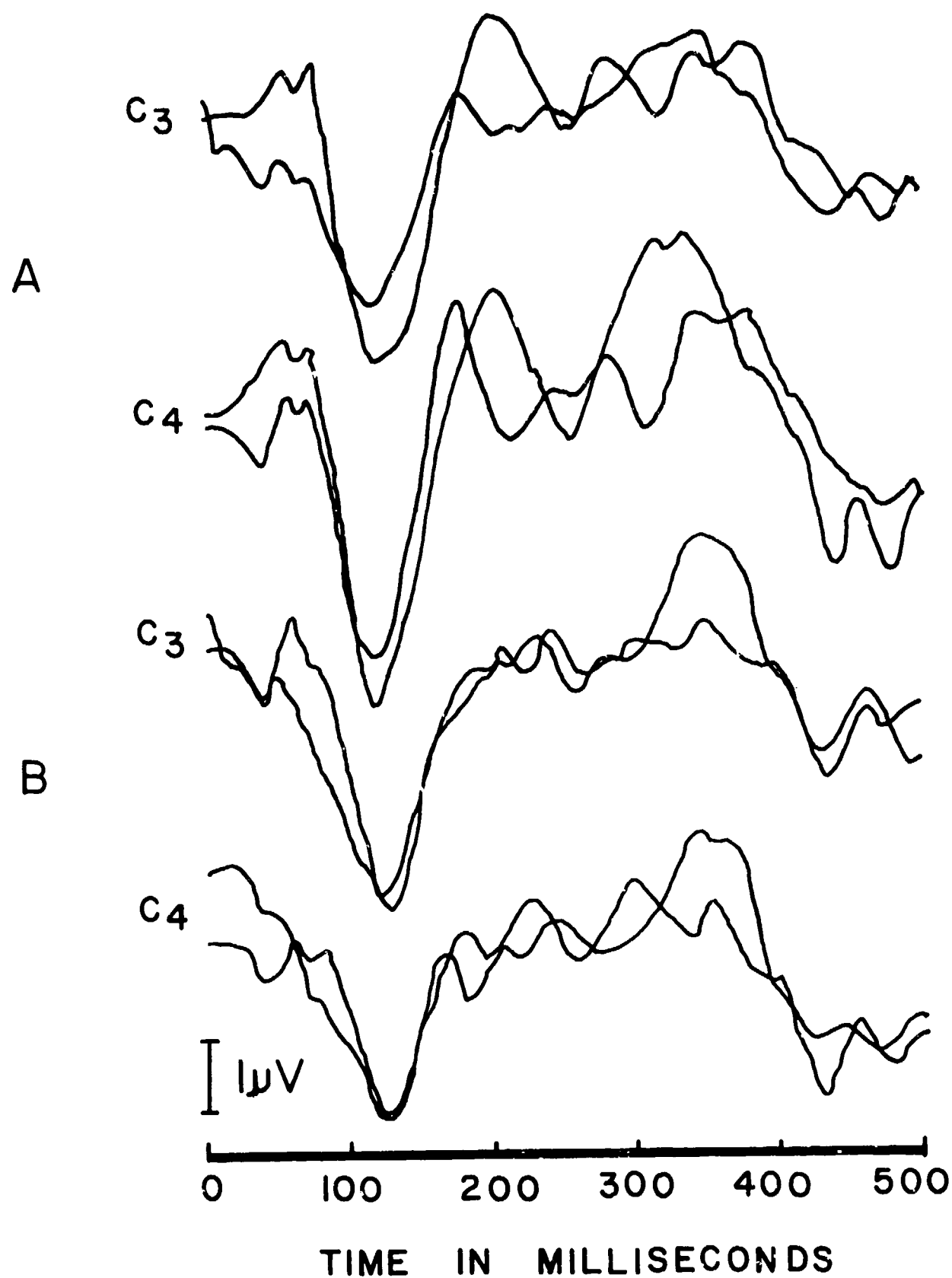


Figure 2 - Raw AEP traces for one subject (L.C.) under conditions A (left ear), B (right ear) and C (both ears). Traces are based on 150 presentations. Negativity is downward.



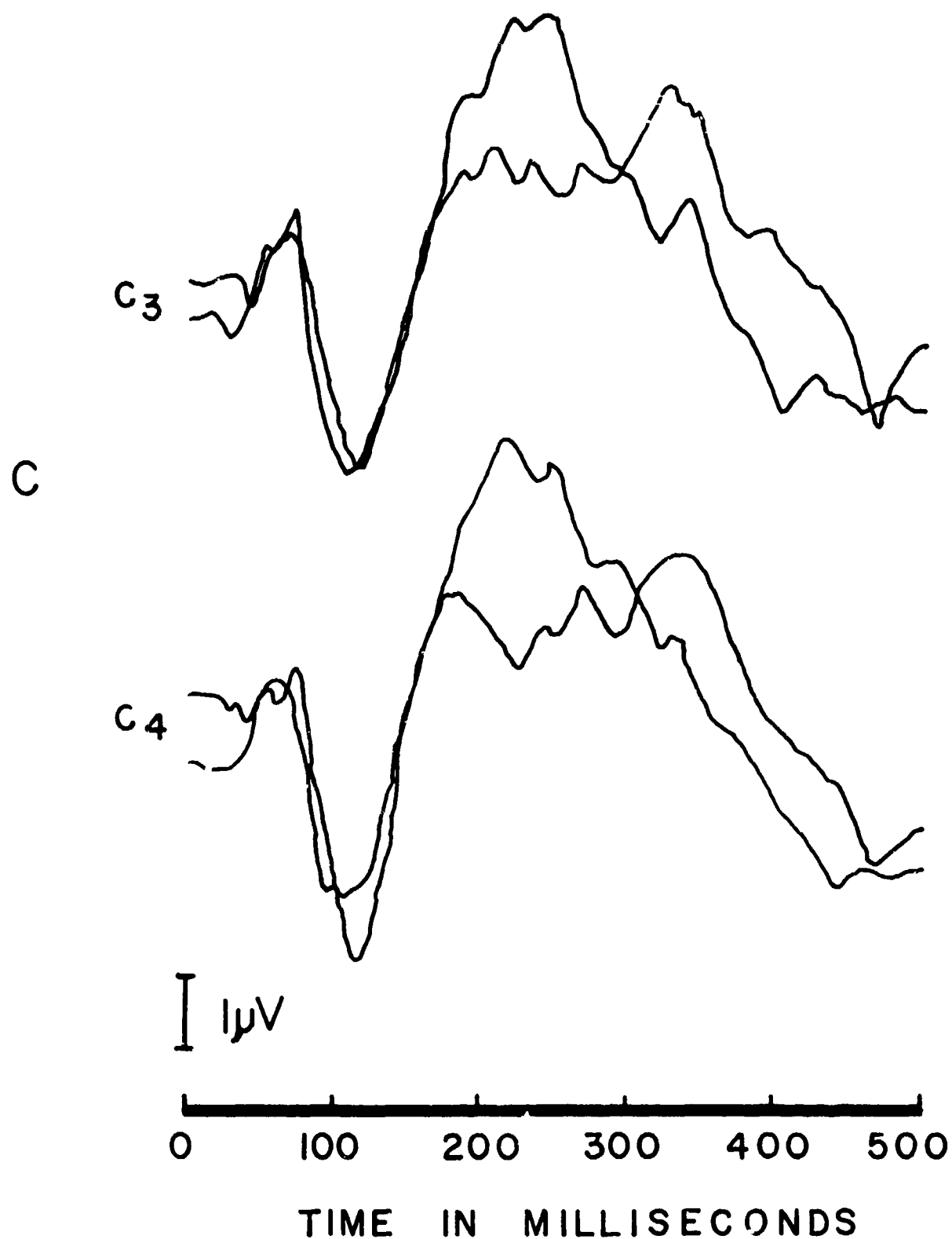


Figure 2 - continued

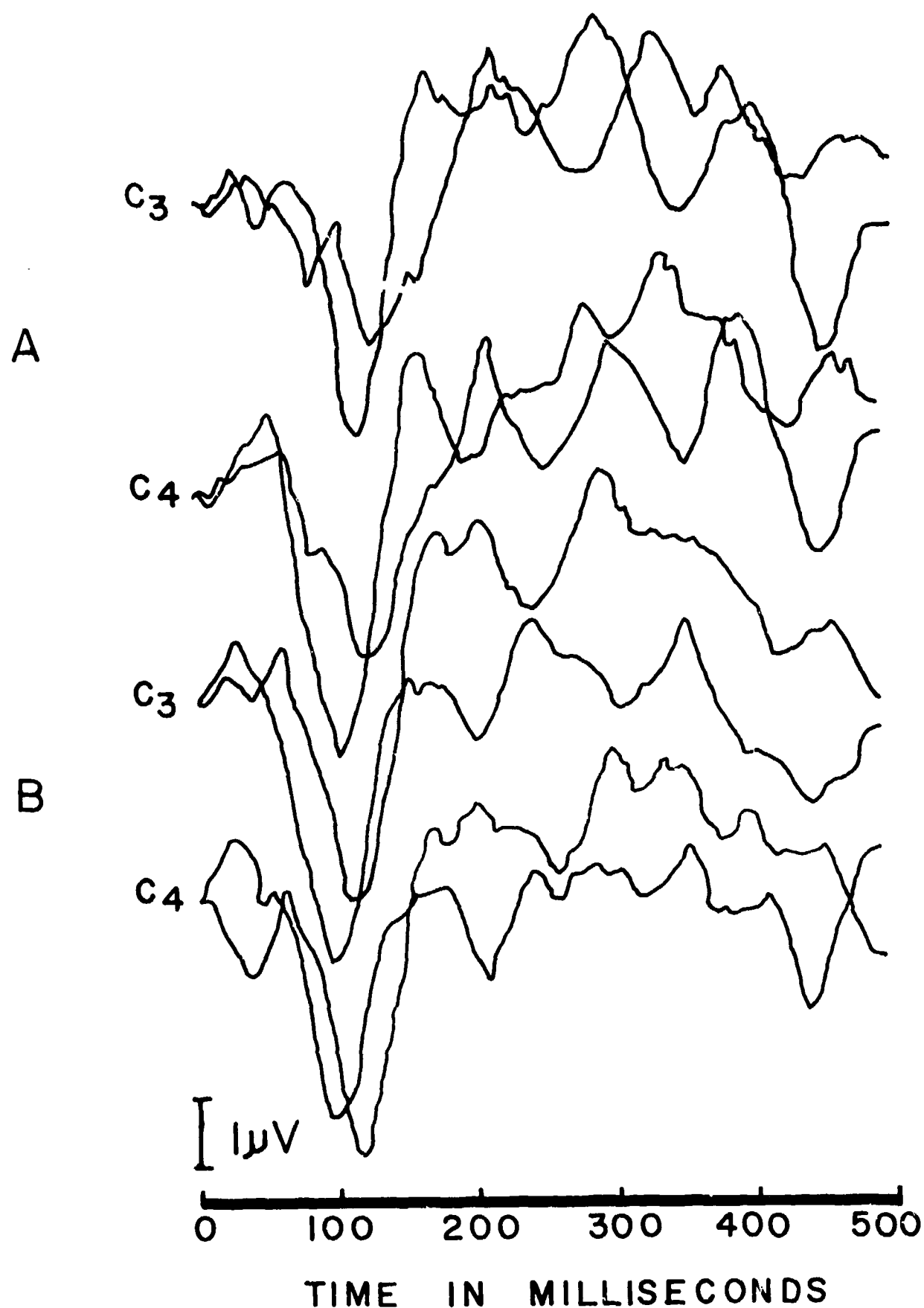


Figure 3 - Raw AEP traces for one subject (M.A.) under conditions A (left ear), B (right ear) and C (both ears). Traces are based on 150 presentations. Negativity is downward.

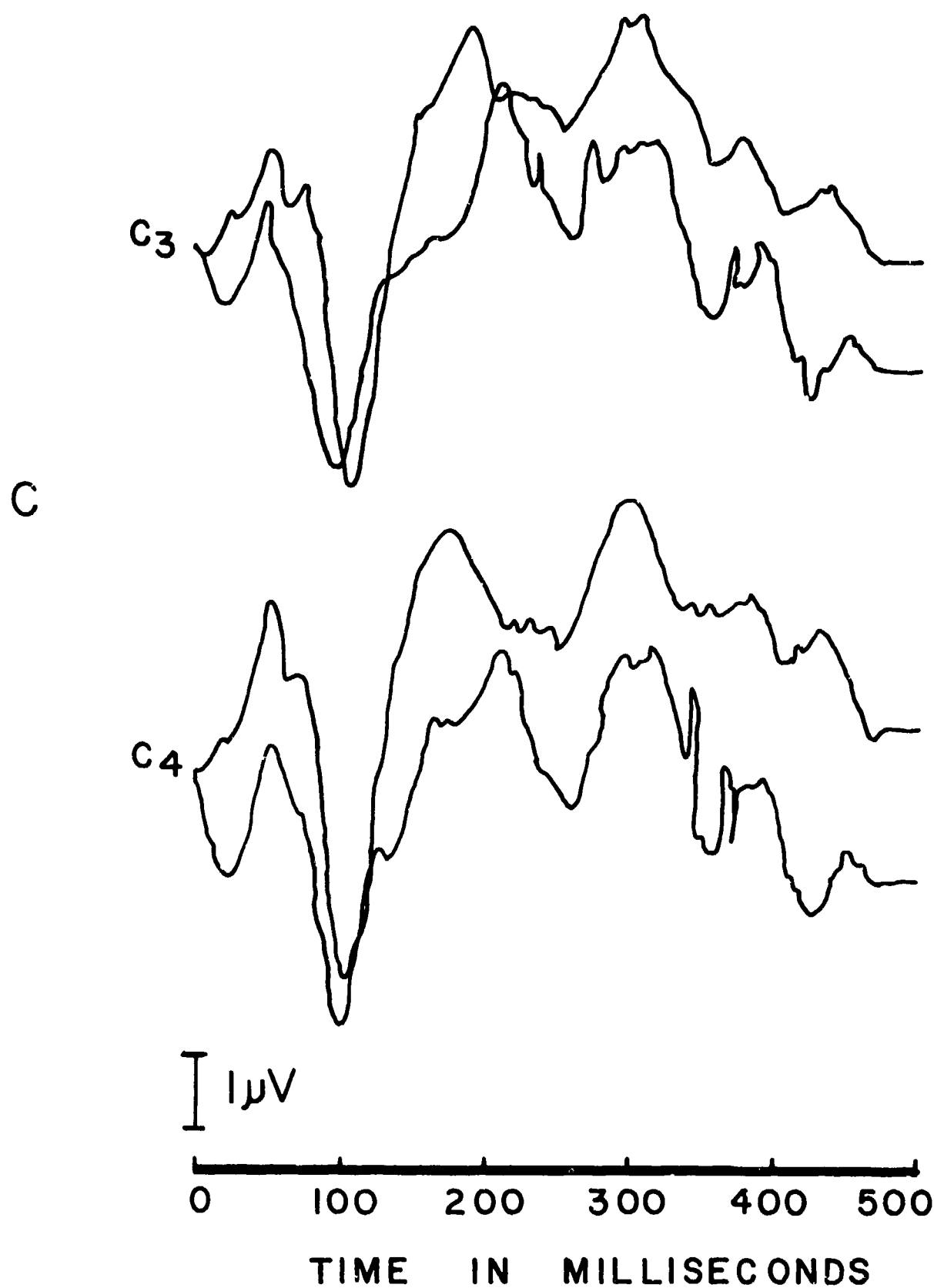


Figure 3 - continued

Experiment II: A Further Inquiry Into Hemispheric Latency  
Asymmetries in the Visual Evoked Potential  
As a Function of Stimulus Location

Introduction

In a previous study by Andreassi et al (1973) it was reported that latencies of the Visual Evoked Potential (VEP) recorded from the right and left occipital hemispheres varied as a function of stimulus location. Three stimulus locations were used: 1) a single X was presented at the center of the visual field; 2) one X was presented to the left of center; 3) a single X was presented to the right of center. The centrally located X produced no differences in the latencies of VEPs recorded from the two hemispheres. However, when the X was at left of center, the VEP major components recorded from the right hemisphere were shorter in latency than those recorded from the left hemisphere. On the other hand, when the X was at right of center, latencies from the left hemisphere were shorter than those recorded from the right. These results were explained in terms of the angles at which the stimuli impinged on the retinas of the two eyes from the locations used. For example, under the condition in which the X was on the right, the stimulus impinged most directly on the temporal retina of the left eye and nasal retina of the right eye, resulting in shorter latency of response as recorded from over the left hemisphere. The opposite occurred when the X was on the left. Previous investigators have reported hemispheric asymmetries in amplitude of VEPs as a function of stimulus location (Eason and White, 1967; Eason, Groves, White

and Oden, 1967), amplitude asymmetries of the Auditory Evoked Potential (AEP) to speech stimuli (Morrell and Salamy, 1971), and asymmetries in the stability of VEPs to verbal (word) stimuli vs. non-verbal (designs and random dot) stimuli (Buchsbaum and Fedio, 1969). Thus, asymmetries in amplitudes and stability had been found previously, but not in latency.

The purpose of the present experiment will be to extend the previous study of Andreassi et al. (1973) to determine whether a systematic relation exists between latency asymmetries and stimulus location when stimuli are extended farther out into the right and left visual fields. Since the central location does not produce latency asymmetries, this can be regarded as the control condition. The method will involve testing VEPs in conditions where there are three stimuli, spaced equally, to the left of center and three stimuli to the right of center. Thus, there will be seven locations, and we will designate them as A, B, C, D, E, F and G. The left-most location will be designated A, the middle stimulus D, and the right-most G. Our hypotheses with respect to latencies are that latency differences from right and left hemisphere recordings will occur at all of the stimulus locations except D (center). To summarize our hypotheses:

- 1) Condition A latencies: right hemisphere shorter than left
- 2) Condition B latencies: right hemisphere shorter than left
- 3) Condition C latencies: right hemisphere shorter than left
- 4) Condition D latencies: right hemisphere equals left
- 5) Condition E latencies: left hemisphere shorter than right

- 6) Condition F latencies: left hemisphere shorter than right
- 7) Condition G latencies: left hemisphere shorter than right

The expected results with respect to amplitudes are in the direction previously reported by Eason and White (1967), Eason et al. (1967) and Andreassi et al. (1973). That is, the central location will produce the largest amplitude VEPs and amplitude will drop as a function of distance from the center of the visual field.

#### METHOD

Subjects: The subjects (Ss) were seven males ranging in age from 25 to 36. None had visual system defects other than myopia (corrected to 20/30). All Ss were right-handed.

Apparatus and Procedure: Ss were seated in an electrically shielded, sound-attenuated room (IAC Chamber). All experimental sessions were conducted with the lights out, with Ss dark adapting for 15 minutes at the beginning of each session.

In order to obtain the averaged cortical evoked potential, the electroencephalogram (EEG) of each S was recorded from  $O_1$  and  $O_2$  ("Ten-twenty" system, Jasper, 1958) with silver cup electrodes referenced to a silver clip electrode on the S's left ear lobe. Electrode resistance was 5,000 ohms or less. The S was grounded by means of an electrode attached to his left wrist leading to "patient ground" of a Beckman RM Dynograph. The 9806A coupler of the Dynograph was used to condition the EEG signal (bandpass set at 0.5 to 32.0 Hz). The filtered and amplified signal was fed into a Mnemotron Computer of Average Transients (CAT 1000). A "start" signal from a PDP-8/E digital computer triggered the CAT

to take EEG samples every 0.5 msec. duration following the presentation of each stimulus to S. After 100 stimulus presentations, the summated VEP responses from CAT memory were plotted by a Hewlett-Packard X-Y plotter. The electro-oculogram (EOG) was recorded from above S's left eye and summed by the CAT to monitor for possible interference with the VEPs. Any records suspected of being contaminated by eye movement were discarded.

The stimuli were displayed to Ss on a VR-14 CRT display driven by a PDP-8E digital computer. The stimuli were single Xs presented individually at adjacent locations on the CRT screen. The stimulus conditions were:

Condition A - Single X located 3.0" to left of center on CRT

Condition B - Single X located 2.0" to left of center on CRT

Condition C - Single X located 1.0" to left of center on CRT

Condition D - Single X located at center of CRT

Condition E - Single X located 1.0" to right of center on CRT

Condition F - Single X located 2.0" to right of center on CRT

Condition G - Single X located 3.0" to right of center on CRT

The Conditions A through G were counterbalanced across the seven Ss. Each S was given 100 presentations at each location during an experimental session, a total of seven trials and 700 presentations within a session. The S was tested in the same order of conditions on a second day, no longer than one week after the first session, at the same time of day. Thus, there were two averaged VEPs for each condition for each S.

During each trial, Ss were instructed to fixate a small

(1/8" diameter) dim (.001 mL) red light located 1/4" above the central stimulus on the CRT. Fixation of the light was maintained under Conditions A through G. A Bausch and Lomb chin rest was used to keep Ss head in a fixed position. The S's nasion was 45" from the center of the CRT screen. Ss were instructed not to blink their eyes during presentations, to count silently, and to say "100" aloud when this number was reached. Each stimulus X was presented for 180 msec, with two seconds between presentations. The height of each X was 1/2", and the intensity of a single, steady-state, X was .13 mL, as measured by a Photometer, from inside the chamber to the CRT screen outside. At a distance of 45", the 1/2" high X produced a visual angle of 39 minutes at the eye.

#### RESULTS AND DISCUSSION

The mean amplitudes ( $\mu$ V) and latencies (msec) were computed for each of the Ss from the primary X-Y tracings. The N1 components were considered to be the first negative dip in the plot which occurred 50 msec after the stimulus. The amplitude of the N1 component was measured as the vertical distance from the X-Y trace baseline to the trough of the first depression in the wave. The P1 component was measured as the vertical distance from N1 to the peak of the first positive component, while N2 was measured as the vertical distance from the peak of P1 to the trough of the second major depression, and so on for P2 and N3. Latencies (or time after stimulus presentation) were measured to the midpoints of each positive and negative peak. If the "peak" was flat, and appeared more as a plateau, the midpoint of the plateau was taken



as the latency measurement. The mean amplitudes for each condition across the seven Ss are shown in Table 1 for  $O_1$  and  $O_2$ .

Table 1  
Mean Amplitudes ( $\mu v$ ) for Major VEP  
Components, Conditions A - G (7Ss)

Scalp Location	VEP Component	Condition						
		A	B	C	D	E	F	G
$O_1$ (Left Hemisphere)	P1	2.16	1.84	1.88	2.41	1.95	2.03	2.20
	N2	3.49	3.35	4.39	5.99	5.16	4.77	4.77
	P2	5.16	4.73	6.52	9.13	7.03	6.73	6.24
$O_2$ (Right Hemisphere)	P1	2.37	2.05	2.24	2.75	2.68	2.30	2.23
	N2	4.05	4.18	5.16	6.17	5.12	4.49	4.39
	P2	6.45	7.00	8.75	10.59	7.14	6.72	6.03

The mean latencies for the various VEP components for each condition across the seven Ss are shown in Table 2 for  $O_1$  and  $O_2$ . The major trends for these data are depicted in Figure 1. The average

Table 2  
Mean Latency (msec) for Major VEP  
Components, Conditions A - G (7Ss)

Scalp Location	VEP Component	Condition						
		A	B	C	D	E	F	G
$O_1$ (Left Hemisphere)	P1	133	135	137	118	115	119	129
	N2	187	193	192	171	168	171	177
	P2	266	277	266	251	254	262	268
$O_2$ (Right Hemisphere)	P1	108	110	114	109	134	132	140
	N2	164	164	165	165	183	184	188
	P2	258	248	251	246	275	264	261

data in Tables 1 and 2 were used in constructing the VEPs shown in Figure 1. The plots in Figure 1 enable a comparison of  $O_1$  and  $O_2$  amplitudes and latencies, averaged across the seven Ss, for Conditions A through G. The plotted composite amplitude and latency measures in Figure 1 suggest support for the hypotheses outlined in the introductory section. That is, the latencies of the major VEP components\* (P1, N2 and P2) are shorter as measured from the right hemisphere ( $O_2$ ) compared to the left ( $O_1$ ) when the stimulus is left of center. However, this changes as the stimulus is presented to the right of center, i.e., now latencies as measured from the left hemisphere are shorter than those from the right.

The raw latency and amplitude data were subjected to analyses of variance (ANOVA). A three-way fixed model (Winer, 1962) was used in which stimulus location (7 levels), hemisphere (2 levels) and subject (7 levels) and their interactions were analyzed. The Ss were considered as a fixed factor since they were not chosen at random, but were selected from undergraduate and graduate students working in the laboratories. A log transformation of all the raw latency and amplitude scores was conducted to ensure that the data would conform to the assumptions of normality of distribution and homogeneity of variance required by the ANOVA. Analyses of N2 and P2 latencies and N2 and P2 amplitudes were performed, since these were the most reliable of all components. Table 3 shows the latency data for N2 as subjected to ANOVA. All of the main effects and interactions were significant at beyond the .01 level. Table 4 shows the ANOVA for N2 amplitudes

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\*Considered "major" because of the consistency and reliability of occurrence in the VEPs of all Ss tested.

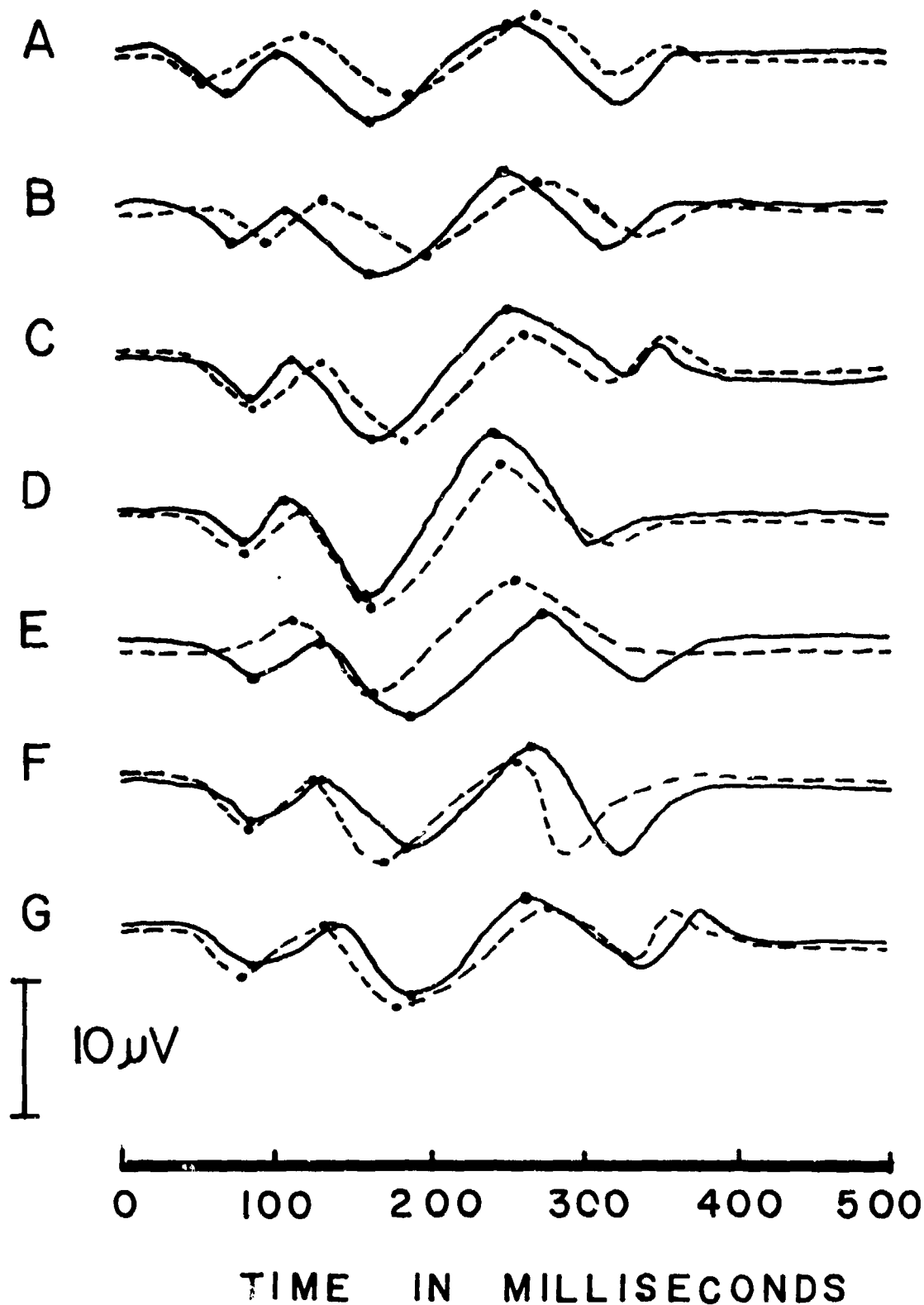


Figure 1 - VEP amplitudes and latencies averaged across 7 Ss for conditions A - G for locations  $O_1$  and  $O_2$ . Negativity is downward.

and indicates that two main effects and several interactions were significant at the .05 and .01 levels. Further statistical tests were performed to determine which of the comparisons of main interest in this experiment were significantly different from one another. The multiple comparison technique used was the Newman-Keuls (Winer, 1962).

Table 3  
ANOVA for N2 Latency Data  
(Log Transformed) for Stimulus  
Location, Hemisphere and Subjects

Source	S.S.	d.f.	M.S.	F	p
A (Stimulus Location)	.089	6	.015	4.29	<.01
B (Hemisphere)	.079	1	.078	22.29	<.01
C (Subjects)	1.195	6	.199	56.86	<.01
AB	.513	6	.085	24.29	<.01
AC	.374	36	.010	2.86	<.01
BC	.167	6	.028	8.00	<.01
ABC	.305	36	.008	2.29	<.01
E (ABC)*	.341	98	.0035		
TOTAL	3.063	195			

\*Error term used throughout is within-cell variance (M.S.)

Since similar results were obtained for the P2 ANOVAs, the discussion to follow will refer to the N2 analyses.

From the ANOVA in Table 3, it is known that stimulus locations produce significantly different latencies, and so do

hemispheres (left and right occipital). The seven Ss also had significantly different N2 latencies. The multiple comparisons are relied upon to test our hypotheses regarding latencies. The most meaningful multiple comparisons are those which test the interactions between stimulus location (A through G) and hemisphere ( $O_1$  and  $O_2$ ). All of the hypotheses regarding latencies are confirmed at the .01 level of significance except that for Condition G (X at the right-most location). With regard to Condition G, it was noted that three of the seven Ss did not have as well-defined

Table 4  
ANOVA for N2 Amplitude Data  
(Log Transformed) for Stimulus  
Location, Hemisphere and Subjects

Source	S.S.	d.f.	M.S.	F	p
A (Stimulus Location)	4.960	6	.827	16.57	<.01
B (Hemisphere)	.196	1	.196	3.93	>.05
C (Subjects)	18.600	6	3.100	62.12	<.01
AB	.535	6	.089	1.78	>.05
AC	6.659	36	.185	3.71	<.01
BC	.931	6	.155	3.11	<.01
ABC	2.886	36	.080	1.60	<.05
E (ABC)*	4.894	98	.0499		
TOTAL	39.661	195			

\*Error term used throughout is within-cell variance (M.S.)

VEP components for Condition G as they did for Condition A (the left-most X). This probably contributed to the lack of significance of latency data between  $O_1$  and  $O_2$  under Condition G. There is some support for the hypotheses regarding amplitudes. Considering the left visual field, Condition D results in larger N2 amplitudes than C ( $p < .01$ ) and C produces higher amplitudes than B ( $p < .025$ ). However, A and B amplitudes do not differ. In the right visual field, Condition D results in higher amplitude N2 components than E ( $P < .025$ ) but E does not produce significantly greater amplitude responses than F ( $p > .05$ ). There is no difference between the amplitudes produced by Conditions F and G, the most extreme locations of the right visual field.

The results of the present experiment confirm and expand those of the original study (Andreassi et al, 1973) regarding the relationship between stimulus location and hemispheric latency asymmetries in the VEP. Our explanation for the VEP asymmetries is in terms of the angle at which the visual stimulus enters the retinas of the two eyes under the various conditions. That is, under conditions in which the X is to the left of center of the visual field, the stimulus impinges most directly on the temporal retina of the right eye and nasal retina of the left eye, resulting in shorter latency responses as recorded from over the right occipital hemisphere ( $O_2$ ). The neurons from these retinal locations have projections back to the area approximately at  $O_2$ . On the other hand, when the stimuli are to the right of the center of the visual field, they impinge most directly on the temporal retina of the left eye and the nasal retina of the right eye, and,

thus, produce shorter latency VEPs from the left occipital hemisphere ( $O_1$ ). When the stimulus is directly ahead (Condition D), there are no differences in latencies of the VEP components since the angle of stimulation for both retinas is now similar.

The raw traces for two of our Ss (S.S. and M.S.) are presented in Figures 2 and 3, and are illustrative of the main findings of the present experiment. For both Ss it can be seen how the latency advantage shifts gradually from the right hemisphere, when stimuli are in the left visual field, to the left hemisphere when stimuli are in the right visual field. The raw traces also show clearly the lack of a latency difference between right and left hemispheres when the stimulus is at the center of the visual field. It would appear that researchers must be certain that stimulus location is controlled, and that the stimulus is fixated in a similar manner by all Ss before forming conclusions about the relationship between hemispheric VEP latency asymmetries and complex behavioral functioning.

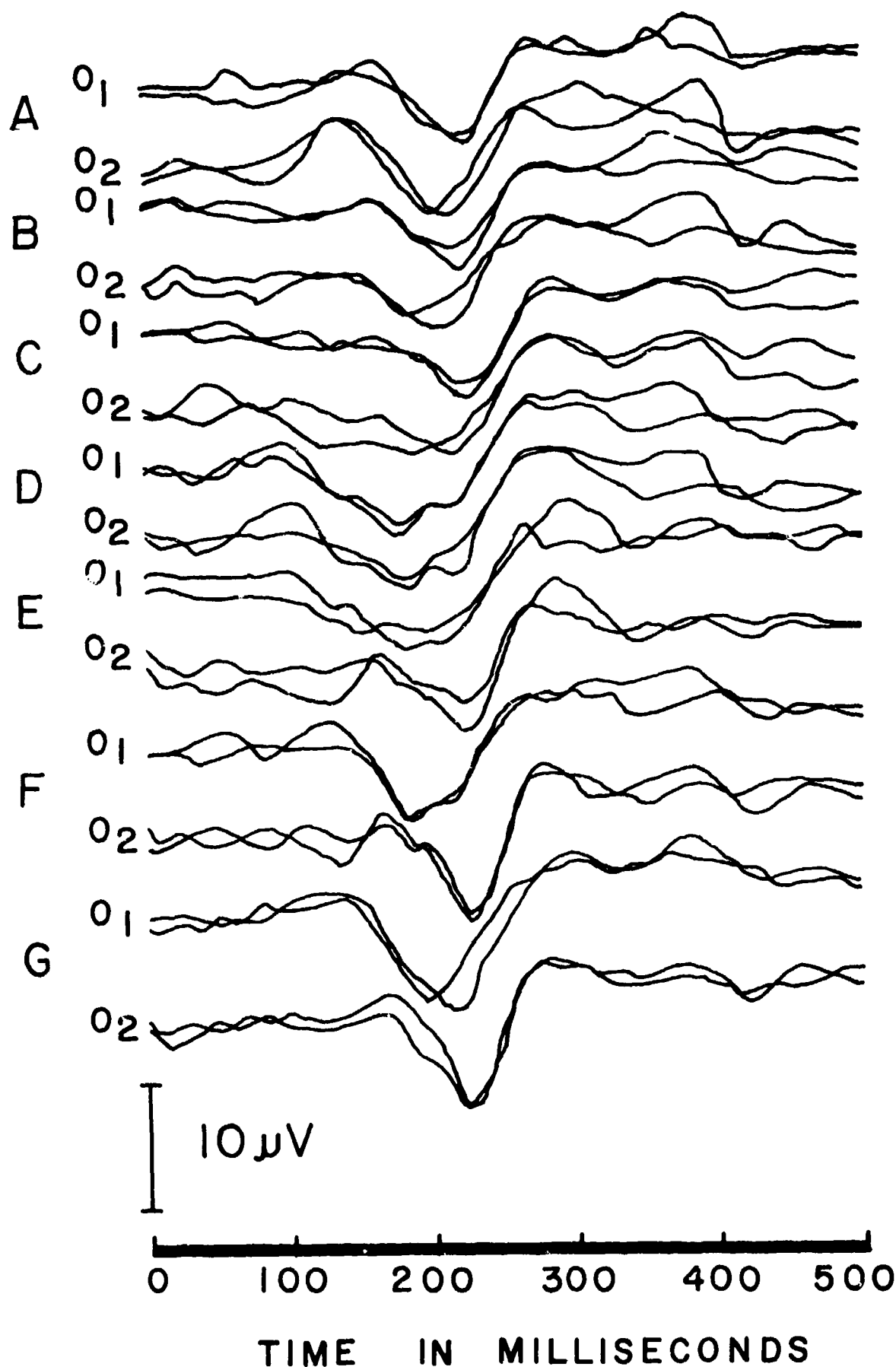


Figure 2 - Raw VEP traces for one subject (S.S.) under conditions A - G. Each trace is based on 100 presentations. Negativity is downward.



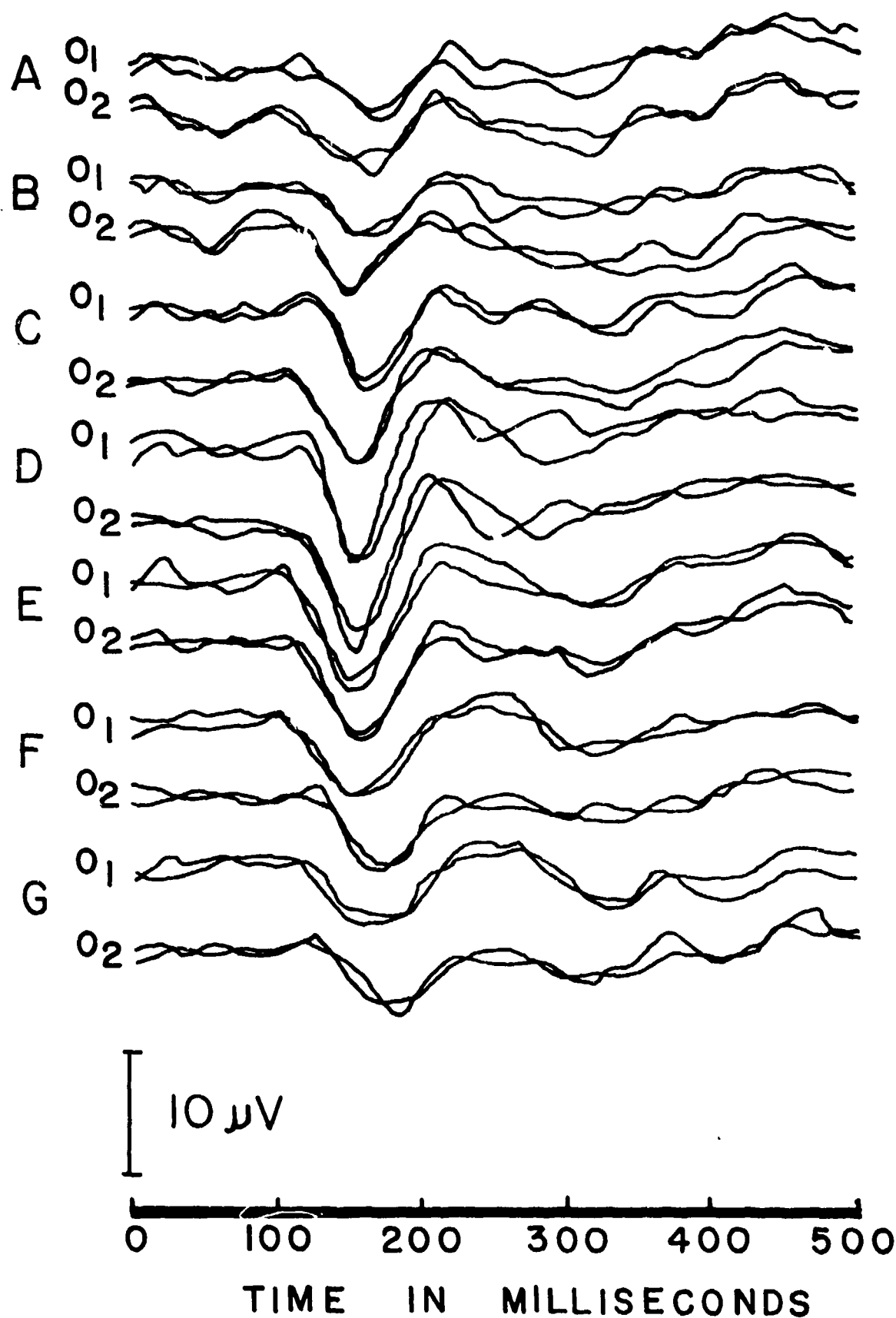


Figure 3 - Raw VEP traces for one subject (M.S.) under conditions A - G. Each trace is based on 100 presentations. Negativity is downward.

### Experiment III: Effects of Cigarette Smoking Upon the Visual Evoked Potential and Perception Span for Digits

Results of past studies seem to indicate that the effect of cigarette smoking, or nicotine, upon the central nervous system is one of arousal or activation. These results have been obtained in studies using raw electroencephalographic (EEG) data and averaged EEG responses (the averaged cortical evoked potential). For example, Ulett and Itil (1969) investigated the effects of cessation of smoking on EEGs of heavy smokers. The Ss were deprived of cigarettes for 24 hours during which time the EEG showed a slowing of activity (slow frequencies of the EEG increased in occurrence). This slowing of EEG activity was reversed when two cigarettes were smoked after the deprivation period. A similar result was obtained by Phillips (1971). Six moderate smokers were tested after smoking for five minutes or engaging in conversation for five minutes. After smoking, the EEG showed an activation pattern in the form of decreased amplitude and desynchrony in the record. The EEG arousal pattern observed after smoking was accompanied by increases in heart rate and skin conductance, two autonomic measures of arousal. Domino (1967) experimented with cats and found that small doses of intravenous nicotine administered during sleep produced a transient "wake-up" effect. That is, the EEG changed from a sleep to a waking pattern, indicating that nicotine is a central nervous system stimulant.

Hall, Rappaport, Hopkins and Griffin (1973) studied the neurophysiological effects of smoking withdrawal and resumption

by using the visual evoked potential (VEP). They measured the vertex VEPs of six male and three female smokers (3/4 to three packs a day, and one inhaling pipe smoker) to four different intensity light flashes. The VEPs were taken during three separate baseline periods before abstinence from smoking, then after 12 and 36 hours of abstinence from smoking, and finally after the resumption of smoking (one cigarette or one pipeful). The results showed a decrease of the VEP amplitude envelope during withdrawal and an increase with the resumption of smoking. The authors suggest that the increased VEPs with smoking indicate that this activity may change the manner in which the brains of the smokers process sensory stimuli. Also, smoking may selectively enhance the perception of weak stimuli. Prior studies have indicated that poor vigilance was associated with decreases in VEP amplitudes and increases in latencies (Haider, Spong and Lindsley, 1964). Increased attention and arousal have been related to increased amplitudes of the VEP associated with avoiding an electric shock (Groves and Eason, 1969). Thus, it might be expected that smoking will produce an excitatory effect on brain activity as measured by VEPs and also result in improved performance in a visual detection task. The present experiment was designed to explore these possibilities. More specifically, the VEPs of smokers and non-smokers were measured after smoking and after a control condition, while they performed a visual task (perception span for digits). The research questions were: 1) Do VEP changes occur under conditions of smoking vs. no smoking? 2) Does smoking result in superior

performance in perception span for digits? 3) Are different VEP and performance results obtained for smokers and non-smokers?

#### METHOD

Subjects: The subjects (Ss) for this experiment were 14 males and two females. The mean age was 25 years, with a range of 19 to 40. None of the Ss had visual system defects other than myopia (corrected to at least 20/30).

Apparatus and Procedure: The experiment took place in a room which was lit just sufficiently for the S to see a teletype keyboard. The keyboard was linked to a PDP/8E computer such that when a horizontal string of simultaneous digits was presented on a VR-14 CRT, the S could type in the digits observed and the computer would store the S's responses for later scoring. The remaining apparatus was the same as that used in Experiment II, i.e. a Beckman Dynograph, a computer of average transients and X-Y Plotter to record the VEP. The only difference was that the S now sat outside of the IAC Chamber and viewed the CRT from a distance of 45" without a window between him and the CRT screen. The intensity of a single, steady-state digit was 1.3 mL. A small lamp was placed so that 10 foot candles of illumination fell upon the teletype keys, and 3 foot candles upon the CRT screen. The EEG was measured from O<sub>1</sub> ("Ten-Twenty" system, Jasper, 1958). An additional electrode was placed over the S's left eye to measure EOG and average it, to insure against eye movement contamination of VEPs.

The Ss were designated as smokers if they regularly

smoked more than 1/2 pack of cigarettes daily. There were eight smokers and eight non-smokers. There were two conditions: Condition A (performing digit span task after six minutes of smoking) and Condition B (digit span after six minutes of "sham" smoking, which consisted of dragging upon an unlit cigarette over a six minute period). Four smokers were tested in an A, B sequence and four in a B, A order. The same was done for the non-smokers so that the two conditions were counterbalanced over Ss. The two conditions were given on separate days at the same time of day, with two to seven days between sessions. On a given day, S was tested twice under one of the conditions.

The instructions to S were the following:

You will be presented with a series of digits on the screen directly in front of you. The number of digits will vary. Your task is to press the space bar of the teletype when you are ready and then to type the numbers you see-IN THE CORRECT ORDER. If you are not sure, type what you thought you saw. When the bell rings, it means that the computer is ready to present the next string of digits as soon as you press the space bar. In one of your sessions we will measure brain activity and your performance on this task (Perception Span for Digits) after you have smoked a cigarette. In another session you will be tested after dragging on an unlit cigarette an equal number of times (12). Please do not blink your eyes when the digits appear, since this will interfere with our recordings. The digits will be presented very quickly (200 msec or 1/5th of a second). Therefore, you must pay careful attention to each presentation. The task is a difficult one, and you are not expected to perform without error. Therefore, do not hesitate to type in digits you thought you saw, and do not take too much time since this will not increase your accuracy. If you make a mistake, press the letter 'M' and begin to type the digit string from the beginning. Typing the letter 'M' will erase your error and allow you to start again. There will be two trials of 100 presentations each in today's session. Do you have any questions?

Thus, the task was a self-paced one in which S could control the presentation of the string of digits. However, S was encouraged to work quickly and total trial length did not vary much between Ss.

When a trial was ready to begin, each S was handed a Tareyton King filter tip cigarette (either lit or unlit, depending on the condition). Tareyton was chosen because it is at the median level for both tar (19 mg/cigarette) and nicotine (1.3 mg/cigarette) content ("Tar and Nicotine Content of Cigarettes", Federal Trade Commission, March, 1972). Each smoker S smoked a Tareyton regardless of their regular brand. In some cases, non-smokers had to be instructed in how to inhale cigarette smoke before the actual trial began.

In the smoking condition (A), the S dragged on the lit cigarette every 30 seconds until 12 drags and inhalations had been performed. In the control condition, each S sham-smoked by inhaling on the unlit cigarette every 30 seconds. The sham smoking was done to cancel any possible effects of deep breathing in the smoking vs. non-smoking conditions. The reason for giving Conditions A and B on separate days was to prevent any possible carry-over effects from a smoking to a non-smoking condition.

The digits were produced by a random number generator program for the 8E computer. The span of digits ranged from 5 to 8. During a trial 100 strings of digits were presented. The length of the digit string and the digits in the string were random, with the only restriction being that an equal number of 5, 6, 7 and 8 digit strings be presented, i.e., 25- 5's, 25- 6's, 25- 7's

and 25- 8's. A press of the space bar resulted in a digit string being presented on the CRT screen after a delay of 100 msec. The S attempted to reproduce the string in the original order after the 200 msec presentation period. When the S typed in the proper number of digits for a given presentation, a bell rang to indicate that the computer was ready to present a new string. As the S typed the numbers, his performance was automatically scored by the computer. After the S typed his response for the 100 digit strings, a rest period was given. Then he smoked another cigarette over a six minute period and was tested on 100 additional presentations. After two trials of the condition for that day, testing was concluded, and then resumed on a second day using the other condition. Thus, the VEPs were obtained by averaging the EEG changes which occurred each time a string of digits was presented on the CRT. The computer of average transients was triggered by a pulse from the 8E computer each time a digit string was presented to S. At the end of each test session, the computer printed out the number of correct responses for the various strings of 5, 6, 7 and 8 digits. (S was not given knowledge of results.) The S was given partial credit if the correct digit was typed in the proper location of the particular digit string (this was automatically done by the program used with the 8E). For example, for 25 strings of five digits each, there were 125 potential correct responses which S could make. If he correctly identified digits one, three and five, he would get a score of three correct out of a possible five points.

## RESULTS AND DISCUSSION

The VEP components were analyzed with regard to latencies (milliseconds) and amplitudes (microvolts) in the same manner as described in Experiment II. The most consistent and reliable components for this experiment (N2 and P2) were utilized in testing for significant differences between smokers and non-smokers (t-tests for uncorrelated data,  $p > .05$ .) (The two-tailed criterion was used in all tests of significance.) Performance scores were also subjected to similar t-tests and no significant differences were found ( $p > .05$ ). Thus, the data for smokers and non-smokers were pooled and treated as coming from a single population in further statistical tests. Table 1 shows the mean latencies of the P1, N2 and P2 components across the 16 Ss for Conditions A and B. Table 2 presents the mean amplitude data for all Ss under the two conditions.

Table 1  
Mean Latencies (in msec) of P1, N2 and P2 Components  
of the VEP Under Conditions A (Smoking) and B  
(Sham Smoking) Across 16 Subjects

	VEP Component	Msec
Condition A (Smoking)	P1	107
	N2	149
	P2	208
Condition B (Sham Smoking)	P1	105
	N2	153
	P2	214



A cursory examination of Table 1 indicates that the N2 and P2 latency scores are shorter under Condition A than Condition B. The data from Tables 1 and 2 are used to plot an averaged VEP across 16 Ss (see Figure 1) under Conditions A and B.

Table 2

Mean Amplitudes (in  $\mu\text{V}$ ) of P1, N2 and P2 Components of the VEP Under Conditions A (Smoking) and B (Sham Smoking) Across 16 Subjects

	VEP Component	$\mu\text{V}$
Condition A (Smoking)	P1	6.16
	N2	10.50
	P2	11.10
Condition B (Sham Smoking)	P1	5.90
	N2	10.40
	P2	10.90

The mean amplitudes for N2 and P2 under Condition A seem slightly higher than the same values for Condition B. To test whether these differences in latencies and amplitudes for Conditions A and B were significantly different, t-tests for correlated data were performed. With respect to latency, the t-ratio for N2 (Condition A vs. B) was 2.54, significant at the .05 level, two-tailed criterion for 15 d.f. The t-value for P2 is 1.64, not significant at the .05 level. For amplitude, t-ratios of .30 and .15 for N2 and P2 amplitudes respectively (A vs. B) were not significant at the .05 level, for 15 d.f. The mean number of correct responses under Condition A was 820 digits (out of a possible 1300) while under Condition B the mean was 849 correct.

A t-ratio of 2.02 is not significant at the .05 level (two-tailed criterion, 15 d.f.) and indicates that performance was similar after sham smoking and after smoking. The performance data for the perception span task was presented in Table 3. The mean number and the percent correct responses for the various digit spans are shown. For the 5, 6 and 8 span digit series, the Ss performed slightly better after sham smoking. Performance for the 7 digit string was the same under Conditions A and B. While the total number of correct identifications varied little as a function of increased digit span, it decreased drastically with respect to percent correct as the digit strings increased in length (see Table 3).

Table 3

Mean Number and Percent of Correct Responses  
For Various Length Digit Strings, Condition A  
(Smoking) and Condition B (Sham Smoking) N = 16

	<u>Digit String Length</u>			
	<u>Five</u>	<u>Six</u>	<u>Seven</u>	<u>Eight</u>
Condition A				
Number Correct	106/125	105/150	103/175	100/200
Percent Correct	80	70	59	50
Condition B				
Number Correct	108/125	110/150	103/175	103/200
Percent Correct	81	73	59	52

It is interesting to note that the total number of correctly identified digits did not increase with an increase in number of digits presented. Thus, for the 200 msec presentation time, there seemed to be a limit to the number of digits processed

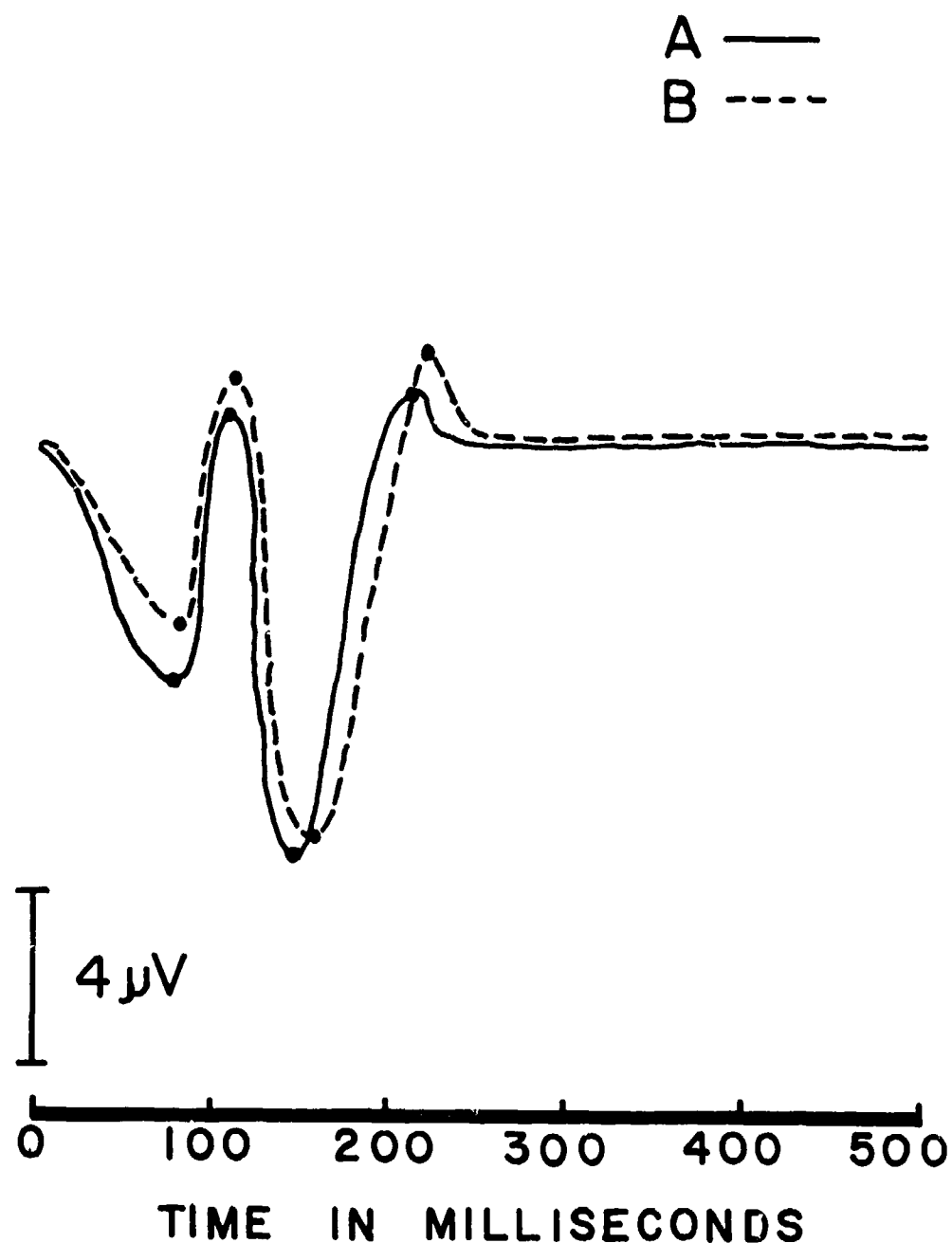


Figure 1 - Averaged and smoothed VEP amplitude and latency scores for  $O_1$  (left hemisphere) across 16 Ss for conditions A (smoking) and B (sham-smoking). Negativity is downward.

i.e., perception span is approximately constant at four digits regardless of number of digits presented (5, 6, 7 or 8).

The statistical tests indicate that N2 latencies are shorter when Ss smoke than under the sham smoking condition. There are no other significant differences. Our research question may now be answered. The only significant VEP change was the shorter N2 latency after smoking vs. non-smoking. Performance on digit span was similar under the two conditions. The results were the same for smokers and non-smokers.

Our results for amplitude do not agree with those of Hall et al. (1973), who found greater amplitude VEPs for smokers after they smoked one cigarette subsequent to 36 hours of deprivation. Our smoker groups of Ss were asked to abstain from smoking for only one hour prior to reporting to the laboratory for testing, and this may be a factor in the difference in results between our study and that of Hall et al. (1973). However, the latency results for N2 are consistent with prior findings indicating the arousing effects of cigarette smoking or nicotine on brain activity (Domino, 1967; Ulett and Itil, 1969; and Phillips, 1971).

The performance results are not in the direction suggested by Hall et al. (1973). They had suggested that smoking may alter the manner in which the brains of smokers process sensory stimuli. Further, they suggested that smoking may selectively enhance perception of weak stimuli. However, we did not find support for these suggestions in our data, with the perception span task used. One possibility is that the activation produced by smoking caused the

Ss to make more errors. This is feasible since the perception span task used required a great deal of attention and accuracy in detecting and keying in the correct response. A possible difficulty in any study of this type, which depends upon the inhalation of nicotine, is that different individuals do not inhale to the same extent. Thus, different persons may be inhaling different amounts of nicotine. Further, it is difficult to control amount of intake according to the body weights of the Ss, except if intravenous injections of nicotine are given according to body weight. In any event, it would seem that our study, and others, indicate that evoked potential researchers should control the smoking of their Ss prior to their reporting to the laboratory session for testing.

The raw VEP traces for two of our Ss are shown in Figures 2 and 3. Figure 2 shows the VEPs for a smoker and it is plain that this S had larger amplitude VEPs after smoking than after sham smoking. The VEPs for the non-smoker indicate the opposite, i.e., larger VEPs for the sham-smoking condition. However, these results were not consistent across all Ss because no statistical differences for smokers vs. non-smokers were found when t-tests were conducted.

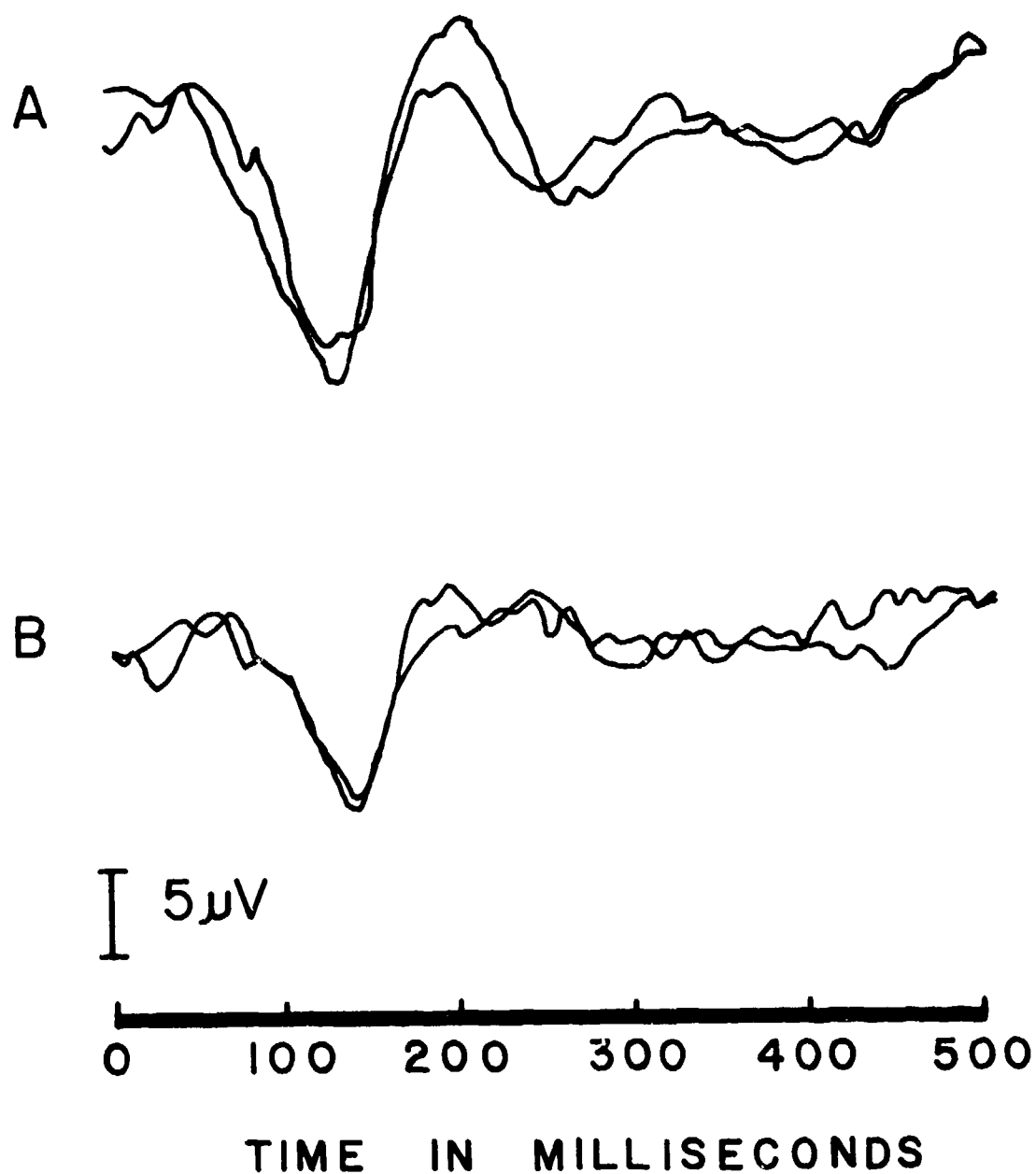


Figure 2 - Raw VEP traces for a smoker (R.N.) under conditions A (smoking) and B (sham-smoking). Traces based upon 100 presentations of digit strings. Negativity is downward.

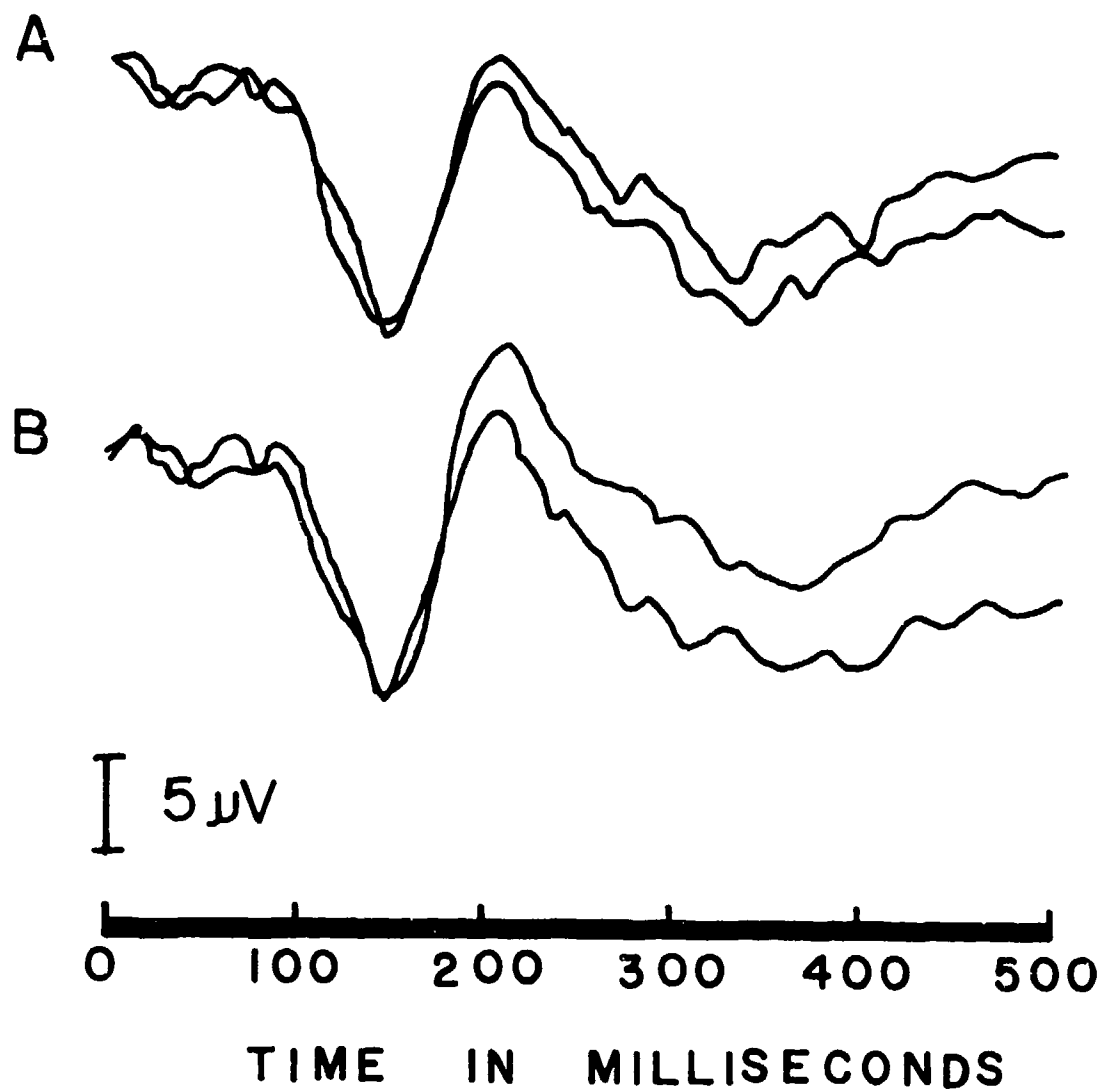


Figure 3 - Raw VEP traces for a non-smoker (J.A.) under conditions A (smoking) and B (sham-smoking). Traces based upon 100 presentations of digit strings. Negativity is downward.

## Experiment IV: Visual Evoked Potentials and Visual Masking:

### 1. Effects of Sequential Sets of Stimuli

Previous studies (e.g., Andreassi, Mayzner, Beyda, and Davidovics, 1971) indicate that when a string of five successive (single) stimuli are presented in certain orders and at certain input rates, the first two were not seen by subjects. The third, fourth and fifth items in the sequence were clearly seen. The visual evoked potentials (VEPs), however, indicated that a cortical response occurred to the very first of these stimuli, thus indicating a disassociation between the VEP and psychological experience, i.e., a VEP occurred but there was no perception of the stimulus. Further investigation revealed that if the third, fourth and fifth stimuli were of greater luminant intensity than the first two, then, not only does perceptual suppression occur, but a partial physiological suppression occurs in the form of a delayed VEP to the first stimulus in the series. In addition, the amount of physiological suppression is related to the ratio of the intensity differences between the first two stimuli and the next three, i.e., the greater the difference the longer the delay in the appearance of the VEP to the first stimulus in the string (Andreassi, Stern and Okamura, 1974). This type of interference, in which later stimuli interfere with perception of earlier ones, is a type of "backward masking" effect (see Kahneman, 1968 and Turvey, 1973 for thorough discussion of visual masking).

To explain the results of these earlier studies, it was



suggested that when blanking stimuli (i.e., the later appearing ones) are more intense than the blanked stimuli (the early stimuli in the string) the action of visual cortical inhibitory fields of the blanking stimuli on the excitatory fields of the cortical areas responding to the blanked stimuli is of sufficient magnitude to interfere with the VEP to the first two stimuli. However, when all stimuli are of equal intensity, the inhibitory action is correspondingly less and only a perceptual response difference occurs. The neural mechanisms proposed in the concepts of lateral inhibition (Hartline and Ratliff, 1957) and receptive cortical fields (Hubel and Wiesel, 1968) have been advanced to explain this type of visual masking with equally intense stimuli (See Mayzner & Tresselt, 1970).

The present experiment was conducted to determine the effects of later sets of stimuli upon earlier sets with regard to perceptual reports and the VEP. Thus, instead of single stimuli presented in sequence upon a CRT screen the plan was to present two stimuli simultaneously in one condition, two followed by three in another, and two, three and six stimuli in a third condition. In no case would the later stimuli temporally overlap the first although there could be slight spatial overlap in the vertical dimension. The research questions posed were: 1) Will later presented sets of stimuli interfere with perception of the earlier ones? i.e., Does backward masking occur? 2) If backward masking occurs, is it reflected in the VEP?

## METHOD

Subjects: The subjects (Ss) were six males and two females, students and faculty, associated with Baruch College of the City University of New York. None had visual defects other than myopia (corrected to at least 20/30).

Apparatus and Procedure: The Ss were seated in an electrically shielded and sound-attenuated room (IAC chamber). All experimental sessions were conducted with the lights dimmed. The remaining apparatus and recording techniques were the same as in the preceding experiments of this report. The averaged evoked potential was recorded from  $O_z$  ("Ten-Twenty" system, Jasper, 1958). The electro-oculogram (EOG) was measured by a separate channel of the Beckman Dynograph and averaged by the CAT to check on possible distortion of the VEP due to excessive eye movement or eye blink. Inspection for eye movement contamination involves a comparison of the averaged EOG trace with the VEP trace. A straight line EOG trace indicates very little or no eye movement. A rise then a dip in the EOG trace would indicate consistent eye movement, and if the EOG trace is superimposed over the VEP trace, the effect is noticeable by rises and dips in the VEP at the same temporal positions. The effect of eye movement on the VEP can be serious because of the high amplitude EOG (millivolts) relative to VEP (microvolts) and distortions are more severe the closer the EEG electrode is to the source of the eye generated potentials. None of our trials had to be repeated because of excessive eye movement.

The stimuli were displayed on a Digital Equipment Corp.

VR-14 which was mounted at the S's eye level outside the chamber at a distance of 39 inches. The VR-14 CRT was controlled by a PDP-8E digital computer which was programmed to deliver stimuli at specific times and locations upon the CRT. There were four conditions:

Condition A - 2 B's appearing on the screen for 20 milliseconds (msec) (ON time of 20 msec)

Condition B - 2 B's for 20 msec, followed by 3 additional B's 40 msec later (ON time of 20 msec, OFF time of 40 msec)

Condition C - 2 B's, followed by 3 B's 40 msec later, followed by 6 B's 40 msec later (ON time of 20 msec, OFF time of 40 msec)

Condition D - 6 B's presented for 20 msec at time 120 msec (i.e., at the same time as the 6 B's in Condition C)

In every instance there was always 1000 msec between each set of stimuli. For example, 2, 3 and 6 B's were presented in rapid succession, followed by a pause of 1000 msec before the next set of 2, 3 and 6 B's.

The spatial arrangement in which the stimuli appeared upon the screen is represented schematically in Table 1. The numbers indicate the order in which the successive sets of B's appeared, and the location of the numbers depicts the actual location of stimuli as they appeared on the CRT screen. Note that there is slight spatial overlap of stimuli in the vertical dimension, although in no case was there temporal overlap.

The stimuli were 1/2 inch high and 3/8 inch wide and at a distance of 39 inches produced a visual angle at the eye of 43 minutes of arc for the vertical dimension (1/2 inch). The characteristics of the VR-14 are such that the total luminous intensity is equally distributed among all simultaneously presented stimuli. For example the 2 B's produce the same total intensity on the CRT as the 3 B's, and the 3 B's have the same intensity as the 6 B's. This means that the intensity of the individual

Table 1

Schematic of Spatial Arrangement of Stimuli Appearing on CRT Screen, Numbers Indicate Order of Presentation

<u>Condition A</u>	<u>Condition B</u>	<u>Condition C</u>	<u>Condition D</u>
1 1	2 1 2 1 2	$\frac{3}{2} \ 1 \ \frac{3}{2} \ 1 \ \frac{3}{2}$	3 3 3 3 3 3

character decreases as the number of elements displayed simultaneously on the screen increases. The intensity of a single B was .45 millilamberts (mL) as measured from inside the room to the outside by a Gamma Scientific Photometer. The stimuli appeared in locations at and around the center of the 7" (high) by 9" (wide) CRT screen. A small luminous fixation .1/8" in diameter, placed 1/2" above the set of stimuli, was used to give S a place upon which to focus his eyes between presentations.

The instructions asked S to focus upon the fixation point between and prior to the start of presentations. He was asked to silently count the number of presentations. The counting procedure was used to help insure S's concentration in this tedious

task. The recording from  $O_z$  would seem to minimize the possible influence of language functions (counting) upon the VEP since it is over the juncture of left and right hemispheres. The Ss were asked to avoid excessive movement or eye blink during presentations of stimuli. After the presentation of each condition, S was asked to report the number of B's seen in any single presentation, and these responses were recorded by the experimenter.

The four conditions were counterbalanced across the 8 Ss. Each S was presented with each condition 2 times in the experimental session, for a total of 8 trials and 8 VEP traces from  $O_z$ .

#### RESULTS AND DISCUSSION

The first result which we will examine in this section concerns data which will enable us to answer our first research question, i.e., Will later presented stimuli interfere with perception of the earlier ones? Questioning of each S indicated the following number of B's seen for each condition:

- A - All 8 Ss saw 2 B's (2 B's presented)
- B - 5 Ss saw 3 B's, 3 Ss saw 3 B's and fragments of other stimuli between them (5 B's presented)
- C - All 8 Ss saw only the last 6 B's (11 B's were presented)
- D - All Ss saw 6 B's ( 6 B's presented)

Thus, in Condition B there is an indication of complete masking for 5 of 8 Ss and partial masking for 3 Ss, while under C, there was complete masking of the first two sets of stimuli for all 8 Ss.

The second research question was: If perceptual masking occurs, is it reflected in the VEP? The best data for answering this question emerge from Conditions A and D vs. C, since only under C did complete masking of earlier stimuli occur, while A and D did not involve masking effects.

The VEP components were analyzed in the same manner as the preceding studies of the present report (viz., latencies and amplitudes of major VEP components). Table 2 shows the mean amplitudes for the various components, across Ss, for Conditions A, B, C and D. Where a value is omitted in the table, it indicates

Table 2  
Mean Amplitudes ( $\mu$ v) for Major VEP  
Components, Conditions A - D (8 Ss)

VEP Component	A	Condition		D
		B	C	
N2	5.75	5.14	5.59	8.47
P2	9.44	8.19	7.53	14.06
N2	-	3.80	4.75	-
P3	-	3.25	4.33	-

that the particular component did not occur in at least 50 percent of the traces across all Ss. The mean latencies for the various VEP components for each condition across the 6 Ss are shown in Table 3.

The data in Tables 2 and 3 show the occurrence of additional VEP components (viz., N3 and P3) under the two conditions in which more than one set of stimuli were presented (B and C). This

indicates that Ss were able to respond physiologically when more than one set of stimuli were presented, but not perceptually, since they did not report more than one set.

Table 3  
Mean Latencies (msec) for Major VEP  
Components, Conditions A - D (8 Ss)

VEP Component	A	Condition		D
		B	C	
N2	147	148	148	256
P2	211	214	208	327
N3	-	260	255	-
P3	-	297	296	-

The data from Tables 1 and 2 were plotted in Figures 1 and 2. As can be seen by inspection of the tabulated data, and the figures, there appear to be amplitude differences between conditions, but little in the way of latency differences, except for Condition D as compared to the other three. However, this longer latency for Condition D was expected since it was the condition in which the 6 B's were presented at time 120 msec compared to the time 0 msec at which the first stimuli in the three other conditions were presented. Figure 1 shows an amplitude hierarchy in which Condition D produces the highest amplitudes, A is next, and B is closely followed by C.

To determine the significance of the observed differences, t-tests for correlated data were computed between the various conditions. A two-tailed criterion with 7 d.f. was used for deter-

mining  $p$  values. All of the N2 and P2 amplitudes were significantly higher for Condition D as compared to all others. For example,  $t = 4.68$  and  $t = 5.93$  for D vs. A for N2 and P2, respectively, ( $p < .01$  in both cases);  $t = 2.76$  and  $t = 3.90$  for D vs. B, for N2 and P2, respectively, ( $p < .05$  in both cases); and  $t = 2.70$  and  $t = 4.80$  for D vs. C, N2 and P2, respectively, ( $p < .05$  and  $p < .01$ ). The only other significant comparison was a higher amplitude P2 component for Condition A vs. C ( $t = 2.61$ ,  $p < .05$ ). The  $t$ -tests for latency data yielded no significant differences other than the previously mentioned D vs. all other conditions.

The important VEP findings concern amplitude. Why should Condition D have resulted in higher amplitude responses than the other three conditions? Condition D was the one in which 6 B's were presented alone, with no stimuli following. Conditions B and C had other stimuli following the primary ones, and, thus, there was interference by the later occurring stimuli with the earlier ones; an interference which manifested itself in the slightly decreased amplitudes of the major VEP components (P2 and N2). The question remains as to why Condition D produced larger amplitude responses than A since A was not a masking condition and the total stimulus energy in A was the same as D. It is hypothesized that the pattern of 6 B's was more compelling than the 2 B's and commanded Ss' attention more effectively. Under the monotonous conditions of the present type of experiment, Ss' seem to attend more intensively to any stimuli which are



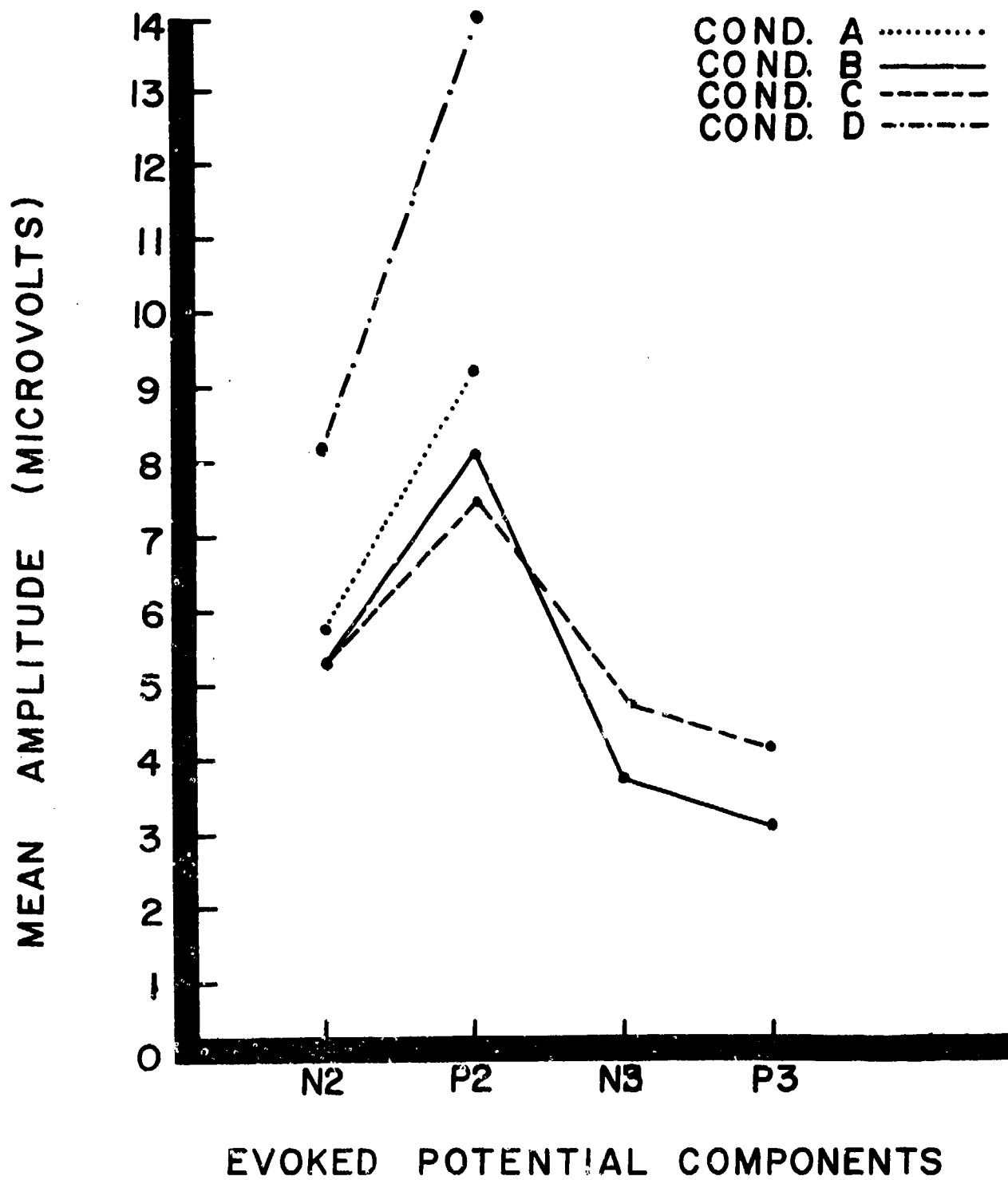


Figure 1 - Mean Amplitude of VEP (8 Ss) under Conditions A, B, C and D.

COND.	A	.....
COND.	B	————
COND.	C	-----
COND.	D	-.-.-.-

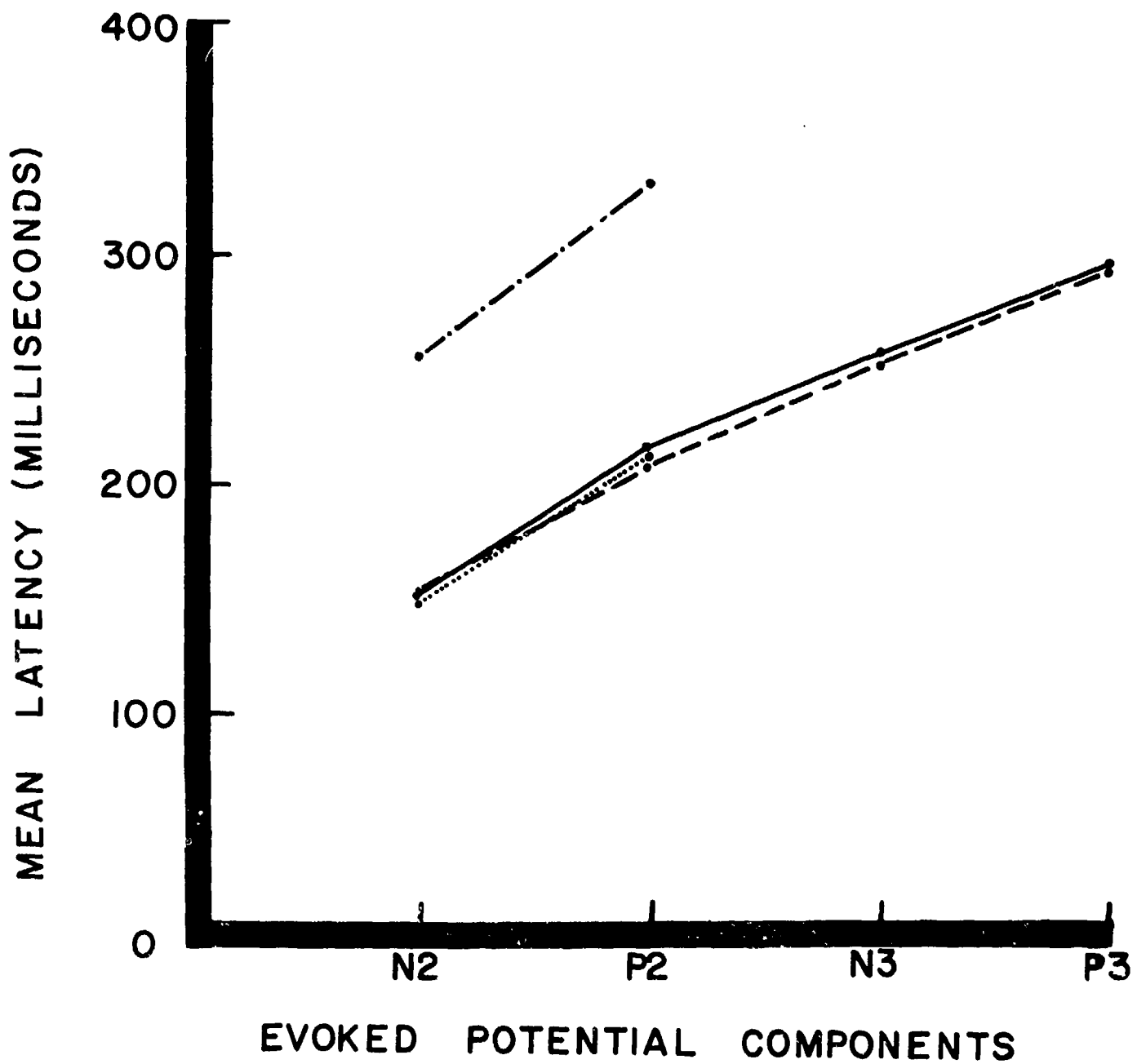


Figure 2 - Mean Latency of VEP (8 Ss) under Conditions A, B, C and D.

slightly more complex. It is possible that they were also interested by Conditions B and C, but the interference by later stimuli with the earlier ones may have negated any slight advantage which may have accrued due to attentional value of the stimuli. It is well documented that attentional factors play a role in determining the amplitude of the VEP (see, for example, Donchin and Cohen, 1967; Eason, Harter and White, 1969; and Groves and Eason, 1969).

The only other significant amplitude comparison, i.e., A vs. C for P2 amplitude is in the same direction for all the D comparisons; i.e., an indication of suppressed VEP in a situation where masking of earlier stimuli occurs as compared to a no-masking conditions. How do our results compare with those of earlier studies? The latency results are similar. However, the amplitude data show some differences in that now changes in VEP amplitude show up under masking conditions vs. no-masking, whereas before they did not (Andreassi, et al, 1971). The difference may be due to the fact that now there are multiple stimuli being presented on the screen at one time rather than only a single stimulus as occurred in the earlier used sequential blanking paradigm. Thus, the results of the present experiment indicate that attenuation of VEP amplitude occurs under some conditions in which backward masking is experienced. Figure 3 shows the superimposed raw VEP traces for one of the Ss (J.A.) under the four conditions of this experiment.

The question arose as to the nature of visual masking and associated VEPs under conditions in which the later presented stimuli were more complex than in the present experiment. This is the subject of Experiment V.

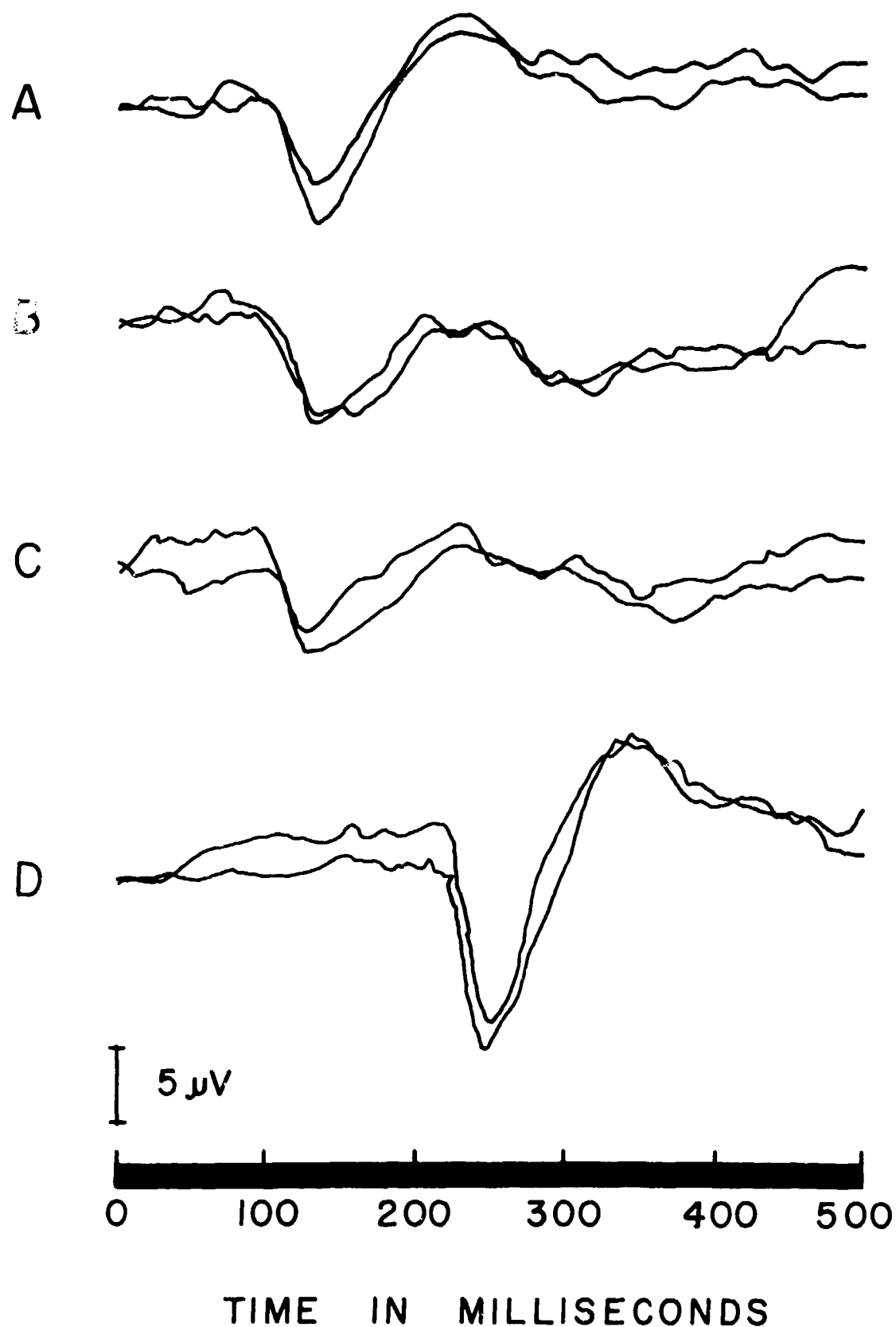


Figure 3 - Raw VEP traces (O<sub>2</sub>) for one subject (J.A.) under Conditions A, B, C and D. Each trace is based on 100 presentations. Negativity is downward.

## Experiment V: Visual Evoked Potentials and Visual Masking:

### 2. Effects of Complex Sequential Sets of Stimuli

The purpose of this experiment was to expand the techniques used in Experiment IV to determine the effects of more complicated strings of stimulus patterns upon the perception of, and VEPs to, the earliest stimuli in the sequence. Similar research questions were posed: 1) What perceptual effects will more complex sets of later stimuli have upon perception of early stimuli: (i.e. Will backward masking occur?); 2) If there are perceptual effects, i.e., if backward masking occurs, will these be reflected in the VEPs to the earliest stimuli?

### METHOD

Subjects: The Ss were 6 male and 2 female students and faculty at Baruch College of the City University of New York. None had visual defects other than myopia (corrected to at least 20/30).

Apparatus and Procedure: The apparatus and recording conditions were the same as in Experiment IV. The EEG was recorded from  $O_2$  and EOG from above the left eye. The general display conditions and instructions to S were the same as for Experiment IV. The major difference was the introduction of two new, and more complex, visual displays, i.e., Conditions E and F. Conditions A and C from Experiment IV were retained. Thus, the following conditions were used in this experiment:

Condition A - 2 B's presented at the center of  
the CRT screen

Condition C - 2 B's, followed by 3 B's, followed  
by 6 B's

Condition E - 2 R's, 3 B's, 6 B's and, finally,  
10 B's

Condition F - 2 B's, 3 B's, 6 B's, 10 B's and  
14 B's

The time of presentation of the first 2 B's was the same for each condition. The ON times and OFF times were the same for all conditions, i.e., 20 msec ON and 40 msec OFF for all sets of stimuli and conditions. Thus, for example, in Condition C, 2 B's were presented for 20 msec, then the screen was blank for 40 msec, and then 3 B's appeared for 20 msec, and another blank period of 40 msec occurred before the final set of 6 B's were presented. There was always 1000 msec between the end of each stimulus set and the beginning of the new sequence of 2, 3 and 6 B's. Table 1 summarizes the display order (by numerals 1, 2, etc.) and location (spatial position of the depicted numerals)

Table 1  
Display Order and Location of Stimuli  
Under Conditions A, C, E and F

<u>Condition</u>												
<u>A</u>		<u>C</u>			<u>E</u>				<u>F</u>			
1	1	3	1	3	3	1	4	1	5	5	1	5
		3	3	3	4	3	3	3	4	4	3	4
					4	4	4	4	5	5	5	5

of stimuli under each of the conditions of this experiment. Note that there was a slight spatial overlap of the successively presented stimuli. However, at no time was there temporal overlap. A simple count of the numbers indicates that the total number of B's presented in a single trial for the various conditions was as follows:

Condition A - 2 B's

Condition C - 11 B's

Condition E - 21 B's

Condition F - 35 B's

It should be pointed out that in each condition all of the stimuli labeled 1 appeared simultaneously and the same was true for those labeled 2, 3, 4 and 5 in Table 1. Therefore, with the ON-OFF times used, the total time of presentation for a single trial in each condition was as follows:

Condition A - 20 msec

Condition C - 140 msec

Condition E - 200 msec

Condition F - 260 msec

There was an interval of 1000 msec between each trial of each condition.

Prior to the start of each experimental session, S was presented with 10 trials of each condition to familiarize him with the displays to be used. After the sample trials, S was asked to focus upon the fixation point just above the center portion of the displayed stimuli. In the experiment proper, S was asked to count the number of presentations to himself and to say the number

aloud when 100 was reached. At the end of each 100 presentations, S was asked to describe what he saw and to estimate the number of B's he saw on the CRT screen during each presentation. The four conditions were counterbalanced across the 8 Ss using a Latin Square design. Each S was presented with each condition twice during the session, which resulted in 2 VEP traces under each condition. Each trace was based upon 100 samples of EEG activity to the particular display under consideration. Records which were suspected of being contaminated by excessive eye movement were discarded.

#### RESULTS AND DISCUSSION

The first research question was concerned with whether Ss would experience backward masking under Conditions C, E and F (Condition A is the Control in which no masking occurs). Seven of the 8 Ss experienced strong backward masking in that only the last set of B's was perceived in Conditions C, E and F. That is, the following occurred:

Condition A - All Ss reported two simultaneous  
B's (2 were actually presented)

Condition C - All 8 Ss reported seeing only six  
simultaneously occurring B's (11 were  
actually presented in a 2, 3 and 6  
sequence). Thus, Ss saw only the last  
6 B's in the sequence indicating a backward  
masking of the first 2 and the second 3  
B's in the series.



Condition E - 8 Ss reported seeing 10 B's simultaneously (no others) in this condition in which 21 B's were actually presented.

Condition F - 8 Ss reported seeing 14 B's simultaneously on the CRT screen, whereas 35 B's were actually presented

The Ss were able to give the correct number of stimuli seen in the last stimulus set of each string by counting on successive, separate presentations. It will be recalled that most Ss in Experiment IV also experienced backward masking.

The second research question asked whether, if masking occurred, the VEP would be effected. The answer appears to be that there is little effect on the VEP; at least under the conditions of the present experiment. The evidence for this statement comes from the VEP results. The VEP traces were analyzed with respect to amplitude and latencies of major components as in Experiment IV. The mean amplitude data are presented in Table 2 and the latency data in Table 3. The results in these tables are depicted in Figures 1 and 2.

A comparison of the VEP results with those of Experiment IV can be made directly for Conditions A and C, since these conditions were the same in both experiments. In Experiment IV, slightly larger VEP components occurred under Condition A as compared to C. One of the component differences (P2) was significantly larger for A ( $t = 2.61$ ,  $p < .05$ , 7 d.f.). The  $t$ -test for correlated data, two-tailed criterion, was used to test significance

Table 2  
Mean Amplitudes ( $\mu v$ ) for Major VEP Components  
Under Conditions A, C, E and F (N = 8)

VEP Components	Conditions			
	<u>A</u>	<u>C</u>	<u>E</u>	<u>F</u>
N1	3.17	2.82	3.21	--
P1	4.36	4.68	4.10	3.36
N2	5.88	6.34	5.91	5.37
P2	10.10	9.38	8.63	8.75

Table 3  
Mean Latencies (msec) for Major VEP Components  
Under Conditions A, C, E and F (N = 8)

VEP Components	Conditions			
	<u>A</u>	<u>C</u>	<u>E</u>	<u>F</u>
N1	97	93	95	--
P1	123	126	120	124
N2	157	162	160	158
P2	226	228	230	221

of results in both Experiment IV and the present one.

The VEP results for the present experiment are not clear since, for example, the N1 and P2 components for A are larger than C, but P1 and N2 are larger for C than A. None of these differences are significant, however. Under Conditions E and F, the amplitudes of the N2 components are not different than those for A and C (see Table 2 and Figure 1). However, the P2 components

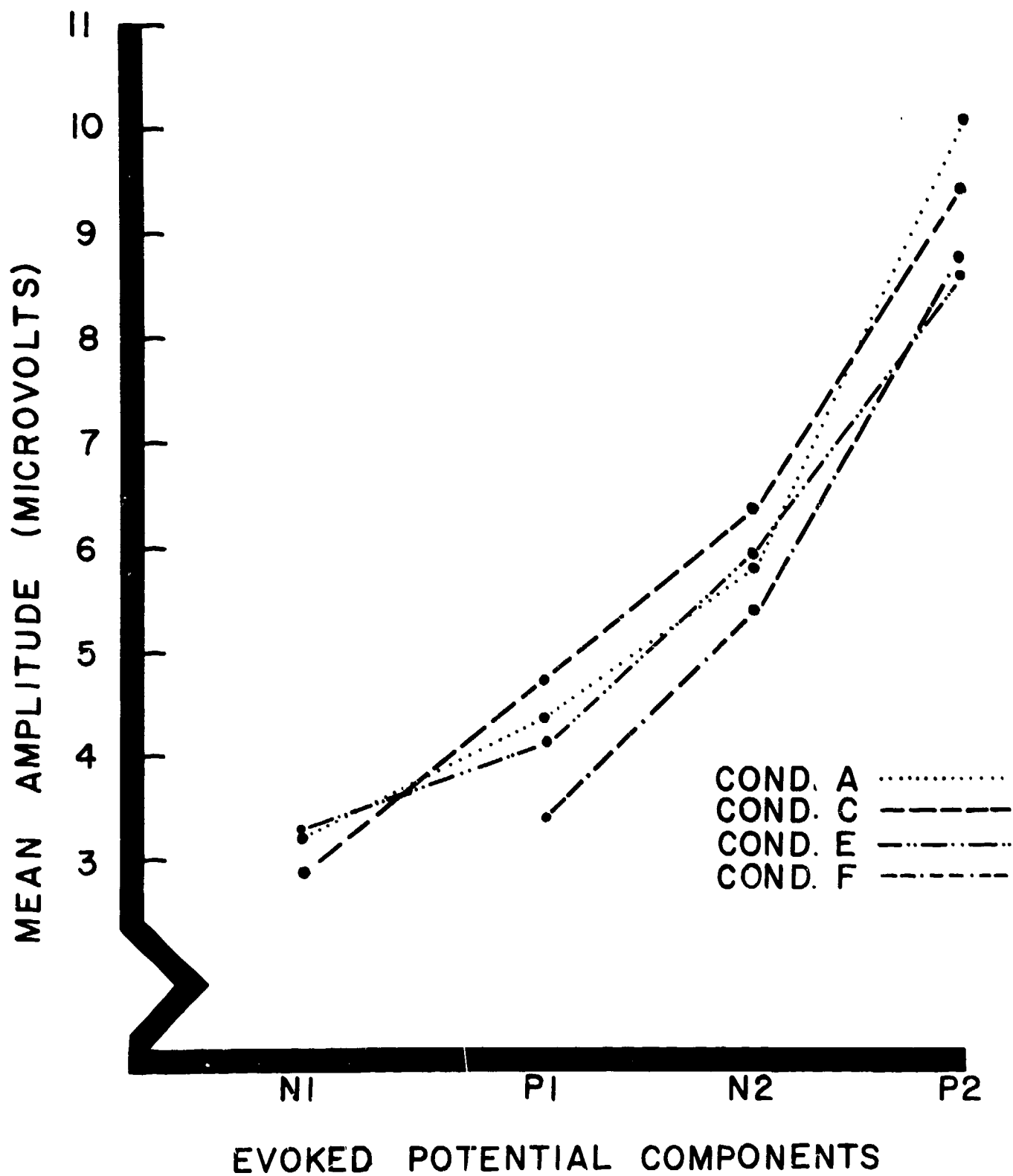


Figure 1 - Mean Amplitude of VEP (8 Ss) under Conditions A, C, E and F.

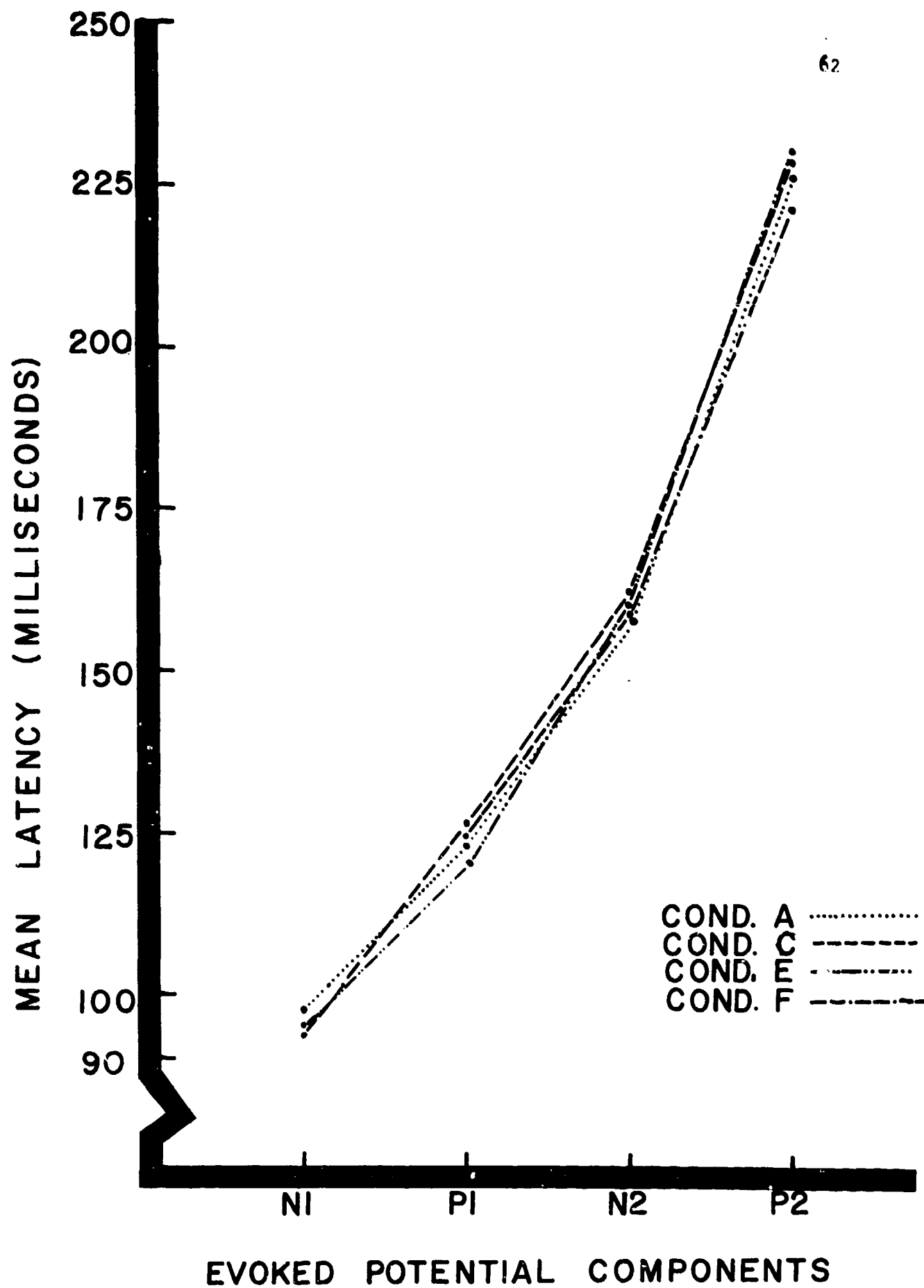


Figure 2 - Mean Latency of VEP (8 Ss) under Conditions A, C, E, and F.

of E and F are smaller in amplitude, but not significantly. Thus, there seems to be a dissociation between the VEP and visual masking in Experiment V, i.e., strong backward masking occurred for Ss, but their VEPs were not significantly affected.

In order for the trends observed in Experiment IV to have been confirmed, a hierarchy of significant amplitude differences where Condition  $A > C > E > F$  would have had to occur. Although there was a slight trend in this direction (see Figure 1) it was not significant. Some inconsistency between replications of VEPs on successive trials was observed and may have been a contributing factor to lack of statistical significance since the greater variance would result in a larger error term. The reason for the inconsistency may have been fatigue. Several Ss reported some fatigue and watering eyes as the experiment progressed. The large number of stimuli presented may have resulted in greater eye fatigue, a factor not experienced in Experiment IV, where the total number of stimuli presented was smaller. In order to reduce possible fatigue effects, future experiments using displays similar to the ones used here should have fewer replications on a given day and should take data on two or more days.

Figure 3 shows the superimposed, raw VEP traces for one of our Ss (P.G.) under the four conditions of the present experiment. The main trends of this experiment are shown in the raw VEP scores of this subject.

In conclusion, an examination of the results of Experiments IV and V indicates that for most Ss there was strong visual

masking of earlier stimuli by later sets of stimuli (backward masking). The predominant perception was that of the very last set of stimuli. This backward masking effect was accompanied by a non-significant tendency towards a decreased VEP amplitude to the initial stimulus in the series, as the number of later-presented sets of stimuli increased. Inconsistency of replicated VEPs may have contributed to the lack of statistical significance.

Preliminary results, utilizing a new experimental design, indicate that backward masking, of the type observed in Experiments IV and V, is accompanied by changes in the evoked cortical potential. That is to say, initial results indicate decreased VEP amplitudes under conditions in which backward masking occurs.

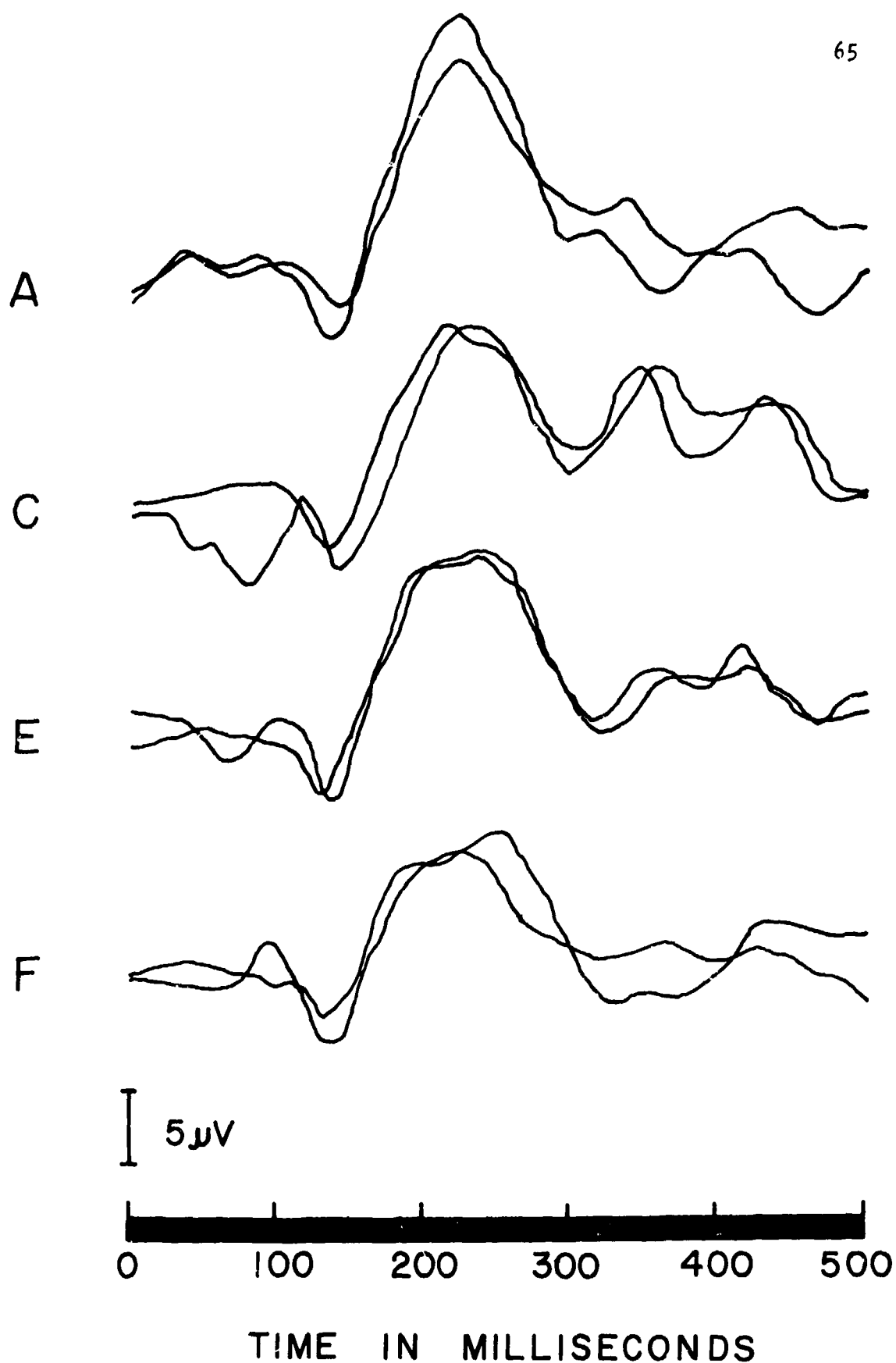


Figure 3 - Raw VEP traces ( $O_2$ ) for one subject (P.A.) under Conditions A, C, E, and F. Each trace is based on 100 presentations. Negativity is downward.

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