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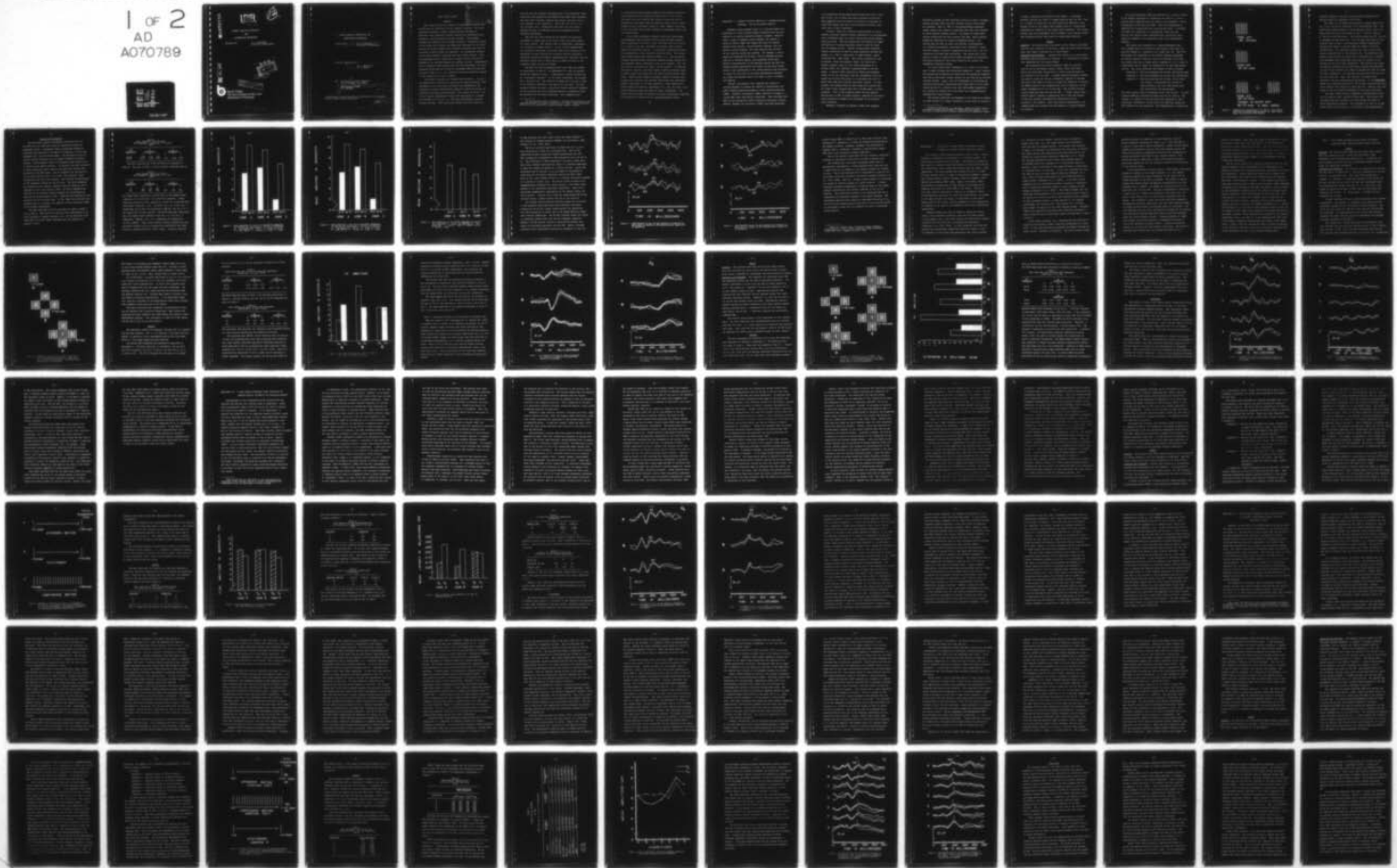
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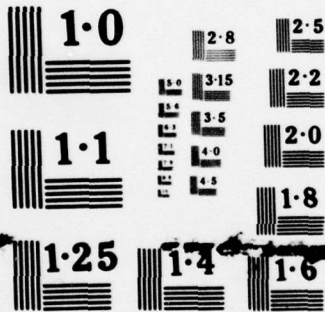
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EVOKED CORTICAL POTENTIALS  
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INFORMATION PROCESSING

Prepared by:

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Principal Investigator

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6 EVOKED CORTICAL POTENTIALS AND  
INFORMATION PROCESSING

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Sixth Annual Report

ABSTRACT

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This report details the results of experimental studies conducted over the sixth year of this research contract. The first experiment employed a visual backward masking paradigm in which the first appearing (target) stimulus was completely overlapped by a later-appearing masking stimulus. This masking stimulus was identical to the target stimulus. Perceptual masking of the target was achieved and significant decreases in the amplitude of the target-related brain potential recorded from over the occipital (visual) cortex was observed. No attenuation occurred in the brain potential recorded from over central cortex. Thus, the perceptual result showed that a target stimulus need not be bounded on its external borders for masking to occur. Additionally, as in a previous study originating from this laboratory, the brain potential attenuation was limited to recordings obtained from over occipital cortex, i.e., that region of the brain primarily engaged in the processing of visual stimuli.

The second experiment was divided into two parts. In Part A the object was to examine the visual event related potential (ERP) correlates of the mask alone and Part B was addressed to the question of various interstimulus intervals (ISIs) and effects on perceptual masking and related ERPs. The results of Parts A and B again clearly demonstrated visual ERP attenuation at a target-mask interval of 40 msec., an ISI which consistently produced backward masking. Both experiments showed that this effect was

specific for the occipital recording site, since amplitude reductions were not observed at the central site under this condition. The mask alone condition produced the largest amplitude ERPs in both segments of the experiment. Again this was specific for the occipital area. Target-mask ISIs which did not produce masking (10 msec and 100 msec) were not accompanied by ERP amplitude reductions.

The fact that ERP attenuation was specific to occipital recordings is likely due to the role of this area with respect to visual stimuli. The central area is polysensory, responding to a variety of sensory stimuli. It may also be hypothesized that amplitude reductions associated with visual masking are not observable in areas outside the occipital because excitatory-inhibitory interactions require topographically organized cortical receptive fields such as those which are known to exist in the occipital cortex for visual stimuli.

The topic of motion perception and visual ERPs was studied in Experiments III and IV. In Experiment III, beta or apparent motion was compared to both a "continuously" moving stimulus and to a stationary stimulus.<sup>1</sup> In all three conditions, the stimulus was a vertical line. The velocity of motion was the same in both of the movement conditions (9.26 deg of arc per sec). The most important result was that a significant latency delay was observed at the occipital area with continuous motion as compared to both the apparent and no motion conditions. This suggested that:

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<sup>1</sup>In the apparent motion condition a vertical line seemed to jump from one location to another adjacent to it, while under continuous motion the line appeared to streak quickly across a screen.

1) continuously moving stimuli might be processed by different brain mechanisms than apparently moving ones, 2) the latency difference may mean that greater cortical processing time is required for continuous than for apparent motion and no motion; perhaps because continuous motion is a more complex perception, 3) the occipital area is more involved in processing motion than the central area.

In the final experiment velocity effects of continuously and apparently moving stimuli on the visual ERP were studied. Three conditions of velocity 3 deg, 13.08 deg and 19.19 deg/sec. of a vertical line were presented to subjects under apparent motion and continuous motion. An additional condition involved the presentation of two stationary vertical lines. The results again showed significant latency results, i.e., the two higher velocity apparent motion conditions produced longer latency ERPs than apparent motion conditions of the same velocity. This was true for the occipital site only, not the central. In addition, the highest velocity continuous motion condition produced significantly larger amplitudes than the three apparent motion conditions. These results suggest a greater amount of cortical processing time (latency) and activity (amplitude) with continuous motion, especially at the high velocities. Also suggested by these results and those of Experiment III is that the human visual system processes these two types of motion differently. The results were discussed in relation to recent formulations regarding the perception of motion and its neurophysiological bases.

Experiment I - Complete Stimulus Overlap in a Backward Masking  
Paradigm: VEP and Perceptual Effects

Backward visual masking refers to a situation where presentation of a later stimulus (mask) interferes with the perception of an earlier presented stimulus (target). Metacontrast, a type of backward visual masking, was studied in detail by Werner (1935) who showed that when two equally intense visual stimuli, having adjacent contours, were presented in rapid sequence, the first stimulus was not seen at all, only the second was reported. For example, a solid square was presented for 20 msec, and was followed 150 msec later by an outlined square, also presented for 20 msec. Werner's interpretation of the obtained results was that the outlined square appropriated the contour of the solid square before it was established in the visual system of the perceiver. It should be noted that in the usual metacontrast paradigm the target and masking stimuli are equal in area, intensity, and duration.

Several investigators have reported the results of studies designed to examine the effects of metacontrast and other backward masking paradigms on event-related potentials (ERPs). Schiller and Chorover (1966) reported no changes in visual ERPs under metacontrast conditions. They concluded that ERPs do not necessarily reflect subjective perceptual effects. However, Vaughan and Silverstein (1968) found ERP amplitudes



to be attenuated during metacontrast suppression when stimuli were foveal, but not when they were presented parafoveally. They suggested that the failure of Schiller and Chorover to obtain ERP changes was due to the parafoveal stimulus conditions used in their experiment.

Schiller (1969) has referred to metacontrast as visual masking involving complete contour interaction, as distinguished from a situation where no contour interaction occurs between target and mask. This may happen when the contours of target and mask fall on widely separated retinal areas (in which case no masking occurs). Another instance which minimizes contour interaction is when the mask completely overlaps the target, e.g., when a large patch of light follows a small, relatively dim, light flash. This latter paradigm was used by Donchin, Wicke and Lindsley (1963), who found that a second, brighter flash not only masked perception of an initial flash, but completely suppressed ERPs to the dim flash. A similar result obtained by Donchin and Lindsley (1965) led to the conclusion that the interference with the target by the mask took place at or preceding the point at which these ERPs were recorded (occipital cortex). In both studies, the masking flash was many times more intense than the target flash (ranging from 100 to 10,000 times, in millilamberts). This is the probable reason for the complete obliteration of ERPs to target flashes, compared to the attenuation observed by Vaughan and Silverstein in the metacontrast situation.

Andreassi, DeSimone and Mellers (1976) have reported

perceptual masking and ERP amplitude attenuation under a backward masking paradigm where less than complete contour interaction<sup>1</sup> was produced. That is, ERPs to two simultaneously presented target stimuli were reduced in amplitude when they were followed by three adjacent masking stimuli. The degree of target-mask contour interaction was never greater than 50%. Total luminant energy was identical for target and masking stimuli. All stimuli were the same in shape and duration of presentation. In a follow-up experiment, when mask stimuli differed in shape from the targets, perceptual suppression did not occur, nor did significant ERP amplitude attenuation. The results were interpreted in terms of interactions between excitatory and inhibitory activities produced at the visual cortex by the earlier and subsequently presented stimuli.

In a more recent study (Andreassi et al. 1977) it was found that a target stimulus was effectively masked by a "noise" pattern. The masking was accompanied by significant VEP amplitude reduction from the O<sub>2</sub> derivation (visual cortex) but not from the C<sub>2</sub> location (central cortex). Again, this was interpreted as reflecting the excitatory-inhibitory interaction which takes place at the visual cortex and not at a cortical area (C<sub>2</sub>) which shows responsivity to a variety of stimuli and is not known to be topographically organized for visual stimuli.

The present study will be addressed to the question of effects of total overlap of a target stimulus by a mask which is identical

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<sup>1</sup>Contour interaction, as used here, refers to direct spatial contiguity between the borders of target and mask stimuli. In the case of metacontrast, contour interaction is complete, or 100%.

in shape, intensity and duration to the target. A subsidiary question concerns the effect of target duration upon the VEP. That is, it might be argued that the VEP attenuation observed in past studies is due to the longer total display time of a target-mask combination as compared to the target alone condition. This longer display time could presumably lead to greater visual system fatigue thus producing smaller VEPs under the target-mask condition.

#### Method

Subjects: The subjects were four males and two females associated with the City University of New York. None had visual system defects other than myopia (corrected to at least 20/25).

Apparatus and Procedure: Subjects were seated in an electrically shielded sound-attenuated (IAC Chamber). All experimental sessions were conducted with the lights dimmed.

The averaged event-related potential (ERP) was obtained from O<sub>2</sub> and C<sub>2</sub> (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to a silver clip electrode on the subject's left ear lobe. A Beckman Type RM Dynograph recorder was used to record the EEG and a Mnemotron Computer of Averaged Transients (CAT 1000) was used to average the responses to stimuli. The 9806A coupler of the Dynograph was used to condition the EEG signal (bandpass set at 0.5 to 32.0 Hz). The filtered and amplified signal was then fed into the CAT. A "start" signal from a PDP-8/E digital computer triggered the CAT to take EEG samples of 500 msec duration following the presentation of each stimulus to the subject. After 100 stimulus presentations, the summated ERPs were plotted from CAT memory on a Hewlett-Packard X-Y plotter.

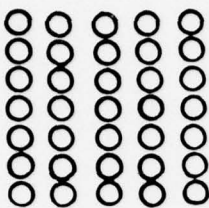
The electrooculogram (EOG) was measured by a separate channel of the Beckman Dynograph and averaged by the CAT as a check on possible ERP contamination by eye blink or eye movements. Trials contaminated by EOG were discarded. This was accomplished by comparing the averaged EOG trace with the ERP trace. A straight line EOG trace indicated no contamination, while one with positive and negative peaks indicated that a particular trial should be repeated at an appropriate time in the experimental sequence.

The stimuli were displayed on a Digital Equipment Corp. VR-14 display which was mounted at the subject's eye level outside the Chamber at a distance of 54 inches (137 cm). The VR-14 CRT display was controlled by the PDP-8/E computer programmed to deliver stimuli at specific times and locations on the CRT. The stimuli were one cm square grids, composed of a 5 X 7 array of yellow-green dots of light and displayed on the dark CRT display surface. The three conditions (see Figure 1) were as follows:

- Condition A - One grid presented for 20 msec (ON time-20 msec)
- Condition B - One grid presented for 80 msec (ON time-80 msec)
- Condition C - One grid presented for 20 msec, blank screen for 40 msec, a second grid for 20 msec at same location as the first (ON time-20 msec, OFF time-40 msec, ON time-20 msec)

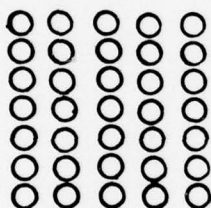
The total display time of conditions B and C was 80 msec. In every instance 1000 msec intervened between such set of stimuli. For example, in Condition C the two grids were presented in rapid succession, followed by a blank screen for 1000 msec before the next stimulus set was presented. The disappearance of stimuli was

**A**



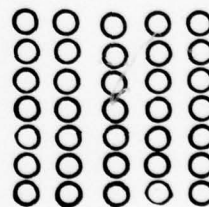
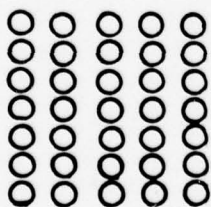
Single grid  
ON - 20 msec.

**B**



Single grid  
ON - 80 msec.

**C**



Single grid  
ON - 20 msec.  
followed by second grid  
ON - 20 msec. at same location

Figure 1 - Schematic of Conditions A, B, and C. All circles were solid greenish-yellow points of light (equal size) in the actual CRT display.

virtually immediate (50 usec) with the brief persistence P24 phosphor specially installed in the VR-14.

The single 1.0 cm square grid produced a visual angle of 25 min. of arc and had an intensity of 2.2 millilamberts (mL). The instructions asked subjects to focus directly below a small fixation point located at the center of the 7" (17.8 cm) high by 9" (22.9 cm) wide CRT screen. The fixation point was 1/8" (.32 cm) in diameter and was placed 1/4" (.64 cm) above the center of the stimulus array to give a focusing point between presentations. Subjects were asked to silently count the number of stimulus presentations. The counting procedure was used to help insure subject concentration in this tedious task. The recordings from central areas ( $O_z$  and  $C_z$ ) should not be influenced by a possible left hemisphere task (counting) since they are located at the juncture of left and right hemispheres. The subjects were asked to avoid eye movements and blinks during stimulus presentations. In pilot trials subjects were asked to diagram what they saw under the three conditions. All drawings indicated that only one grid was ever perceived. Thus, the existence of masking under condition C was pre-experimentally determined. In the **experiment** proper each condition consisted of 100 stimulus presentations after which subjects drew diagrams of what they saw. Subjects were also asked to rate the relative brightness of the three conditions.

The three conditions were completely counterbalanced across the six subjects over a period of three days. Each subject was presented with each condition six times during the course of three experimental sessions. This resulted in a total of 18 ERP traces from  $O_z$  and 18 from  $C_z$ , each based on 100 presentations.

Results and Discussion

The perceptual reports and diagrams indicated that only one grid was ever perceived under all conditions during the experiment proper. Perceptual reports concerning brightness indicated that condition B (80 msec) as brightest, C was second brightest and A was the least bright. The perceptual effect of precise overlap therefore, was to produce complete perceptual masking. The perceptual effect of increased target duration was to make the grid appear brighter. To ascertain the ERP correlates of these perceptual events latency and amplitude analyses were performed on the ERP traces. The N1 component was considered to be the first negative dip in the trace, from baseline, which occurred 50 msec after the stimulus. The baseline was determined by the horizontal portion of the X-Y plot. The N1-P1 component was measured as the vertical distance from the trough of the N1 component to the first positive peak. The N2-P2 component was measured as the vertical distance between the second negative peak and the second positive peak. Latencies were measured to the midpoints of each positive peak. If the "peak" was flattened and appeared more as a plateau, the midpoint of the plateau was taken as the latency measurement.

The mean amplitude of N1-P1 and N2-P2 are shown in Table 1 for O<sub>2</sub> and C<sub>2</sub>. Note that N1-P1 did not occur sufficiently at C<sub>2</sub> to be included in further analyses, i.e., it did not occur in at least 50% of the ERP traces. Amplitude data are depicted in Figures 2 and 3.

Table 1  
Mean Amplitude (uV) for Major  
VEP Components, Conditions A, B, and C  
(N=6)

VEP Components	O <sub>z</sub> Conditions			C <sub>z</sub> Conditions		
	A	B	C	A	B	C
N1-P1	7.64	8.18	5.05	-	-	-
N2-P2	10.35	9.80	8.50	7.30	6.90	6.33

The mean latencies for N1-P1 and N2-P2 are presented in Table 2. The data in Table 1 indicate greater amplitude ERPs to

Table 2  
Mean Latency (msec) for Major  
VEP Components, Conditions A, B, and C  
(N=6)

VEP Components	O <sub>z</sub> Conditions			C <sub>z</sub> Conditions		
	A	B	C	A	B	C
P1	141	140	136	-	-	-
P2	224	225	231	265	265	262

the target alone (conditions A and B) than to the masked target (condition C) for both the N1-P1 and N2-P2 components. These amplitude differences were compared by t-tests for correlated data (two-tailed criterion, 5 df). For N1-P1 the A vs. B and A vs. C comparisons for O<sub>z</sub> were not significant ( $p > .05$ ), but the B vs. C was significant ( $t=3.88, p < .02$ ). The N2-P2 amplitude comparisons were not significantly different from the A vs. B or B vs. C conditions. However, the A vs. C comparison was significant ( $t=3.12, p < .05$ ). Thus, total stimulus overlap produced not only perceptual masking but was accompanied by significant ERP attenuation as recorded from over visual cortex. Activity reflected



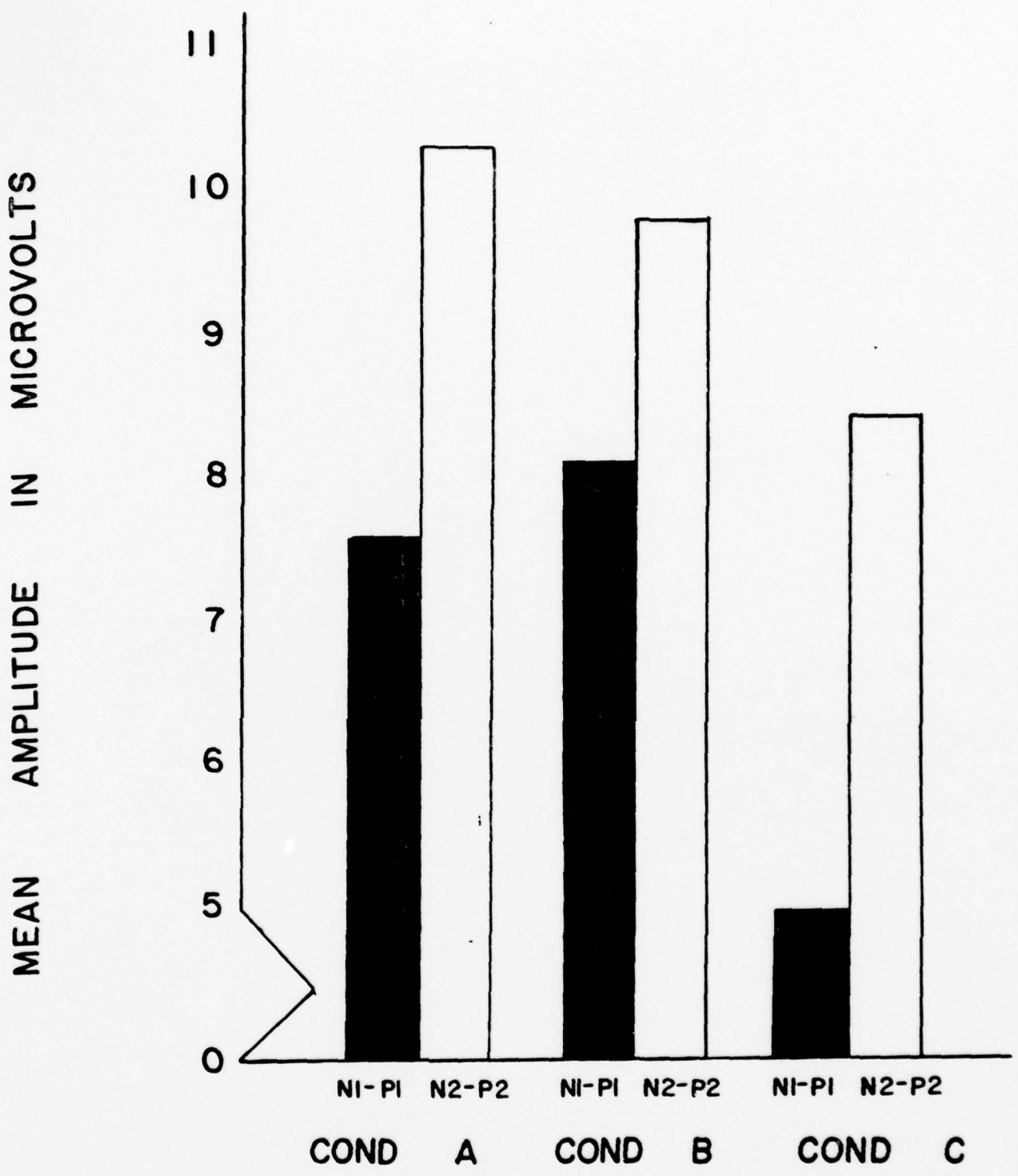


Figure 2 - Mean amplitude of the N1-P1 and N2-P2 components of the VEP for Conditions A, B and C at location O<sub>z</sub>. The means are: N1-P1 - A = 7.64, B = 8.18, C = 5.05; N2-P2 - A = 10.35, B = 9.80, C = 8.50.

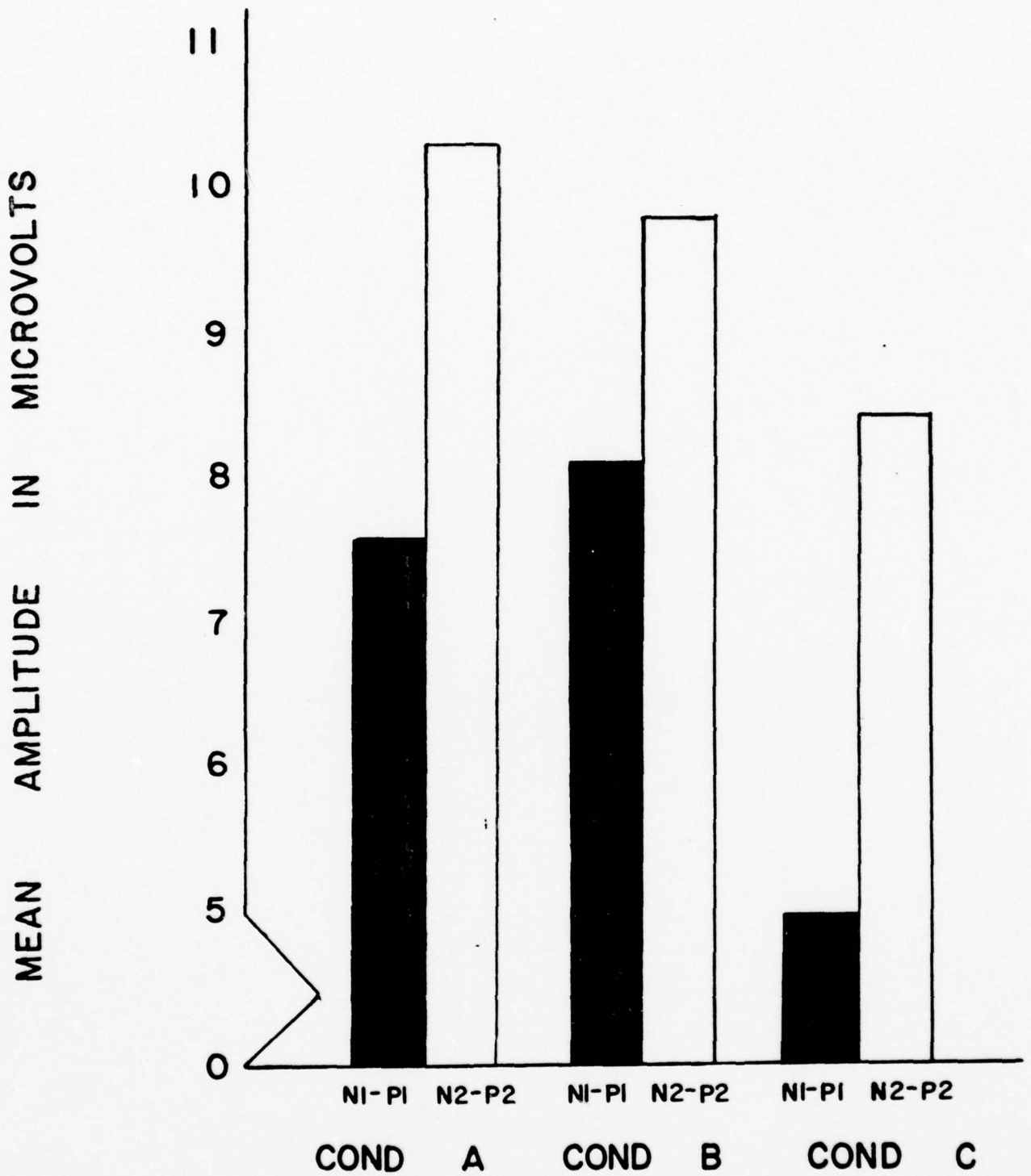


Figure 2 - Mean amplitude of the N1-P1 and N2-P2 components of the VEP for Conditions A, B and C at location O<sub>z</sub>. The means are: N1-P1 - A = 7.64, B = 8.18, C = 5.05; N2-P2 - A = 10.35, B = 9.80, C = 8.50.

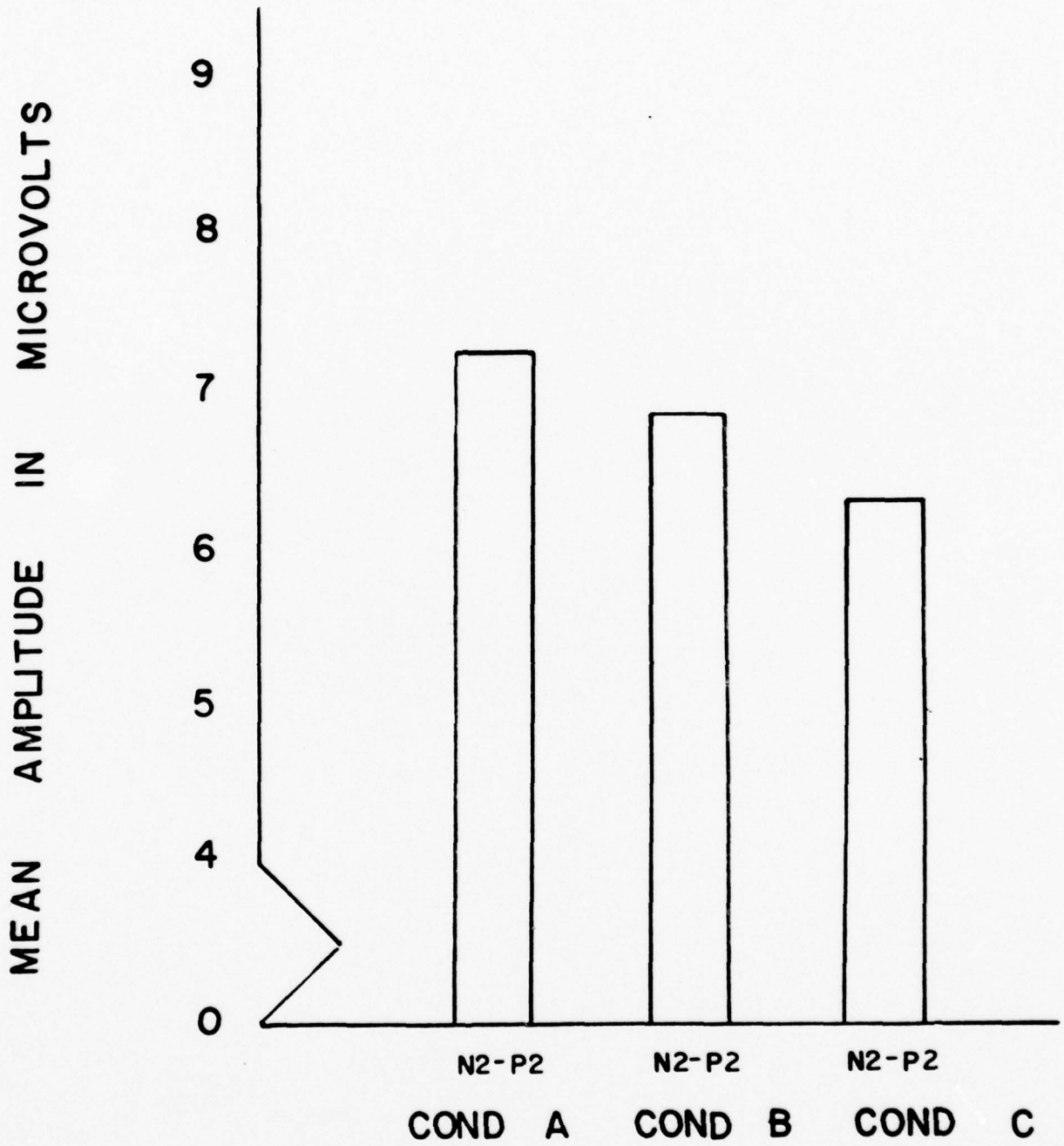


Figure 3 - Mean amplitude of the N2-P2 component of the VEP for Conditions A, B and C at location Cz. The means are: A - N2-P2 = 7.30; B - N2-P2 = 6.90; C - N2-P2 = 6.33.

by ERPs obtained from over visual cortex has shown changes in past studies of backward masking (Vaughan and Silverstein, 1968, Andreassi et al., 1976, 1977).

The N1-P1 and N2-P2 amplitudes recorded from over  $C_z$  were also subjected to t-tests for correlated data. None of the comparisons between conditions yielded significance ( $p > .05$ ). Thus, masking was accompanied by ERP attenuation at  $O_z$  but not at  $C_z$ . This difference in ERP attenuation at  $O_z$  and  $C_z$  under backward visual masking conditions was found in a previous experiment in which the target was masked by a "noise" pattern. Visual ERP attenuation may be specific to  $O_z$  and might be interpreted as reflecting the excitatory-inhibitory interaction which takes place at the visual cortex and not in a cortical area which responds to a variety of stimuli ( $C_z$ ). The visual cortex is known to be topographically organized for visual stimuli, a fact which lends support to the excitatory-inhibitory explanation. There is no such known topographical organization at the central cortex for visual stimuli. Figures 4 and 5 show the superimposed ERP traces obtained during a single session from one of our subjects.

The finding that the 80 msec duration target did not result in ERP component amplitudes which were different from those produced by the 20 msec target argues against the possibility that ERP attenuation is merely due to the longer duration target-mask stimulus combination. The 80 msec duration target did result in perceptual reports that this was the brightest condition. However, the ERP results indicate a dissociation between this aspect of perceptual experience and the ERP. Namely, although condition B was consistently perceived as brightest, it did not

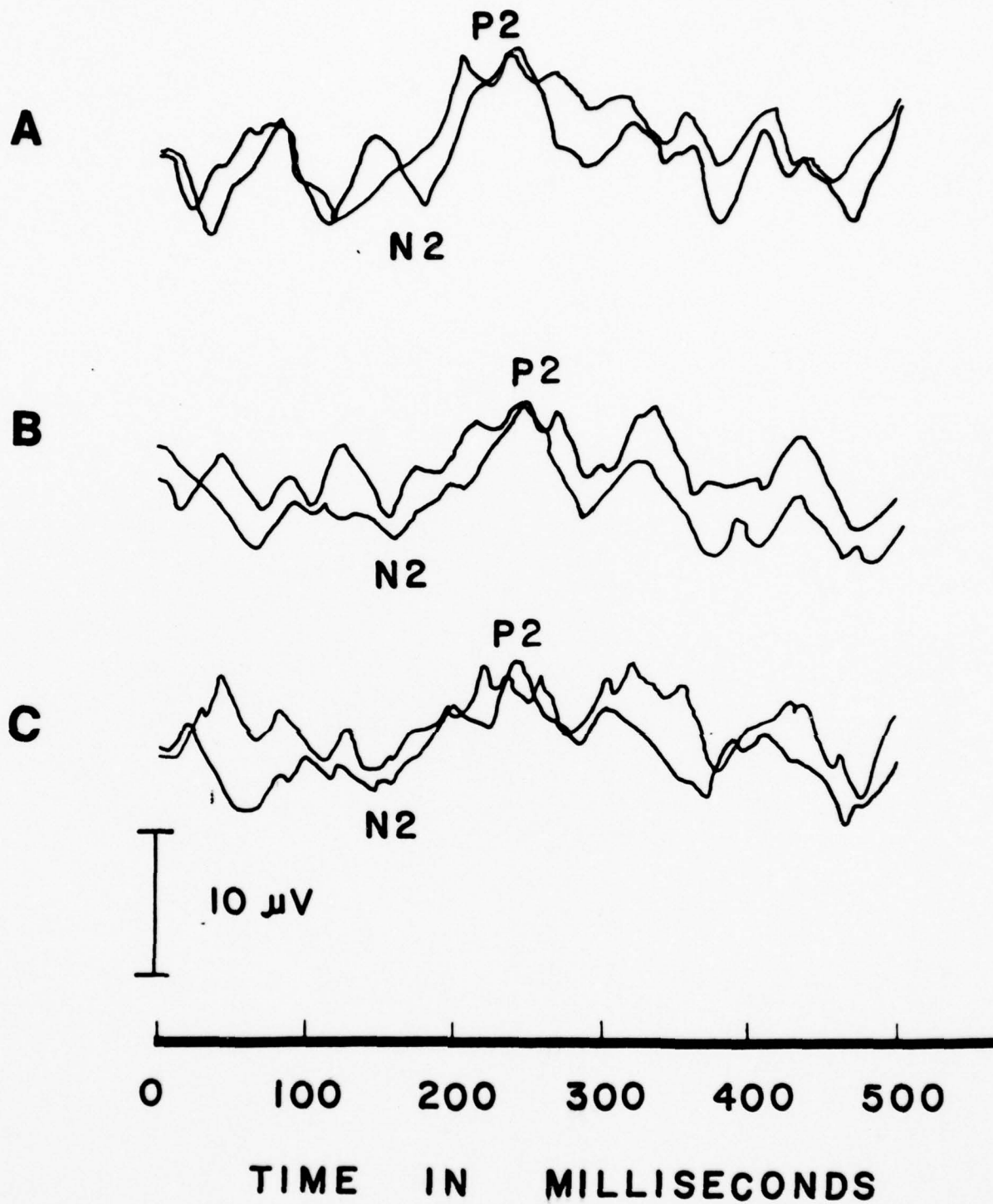


Figure 4 - Superimposed traces for one subject at location  $O_z$ . Each trace is based on 100 presentations (negativity is downward).

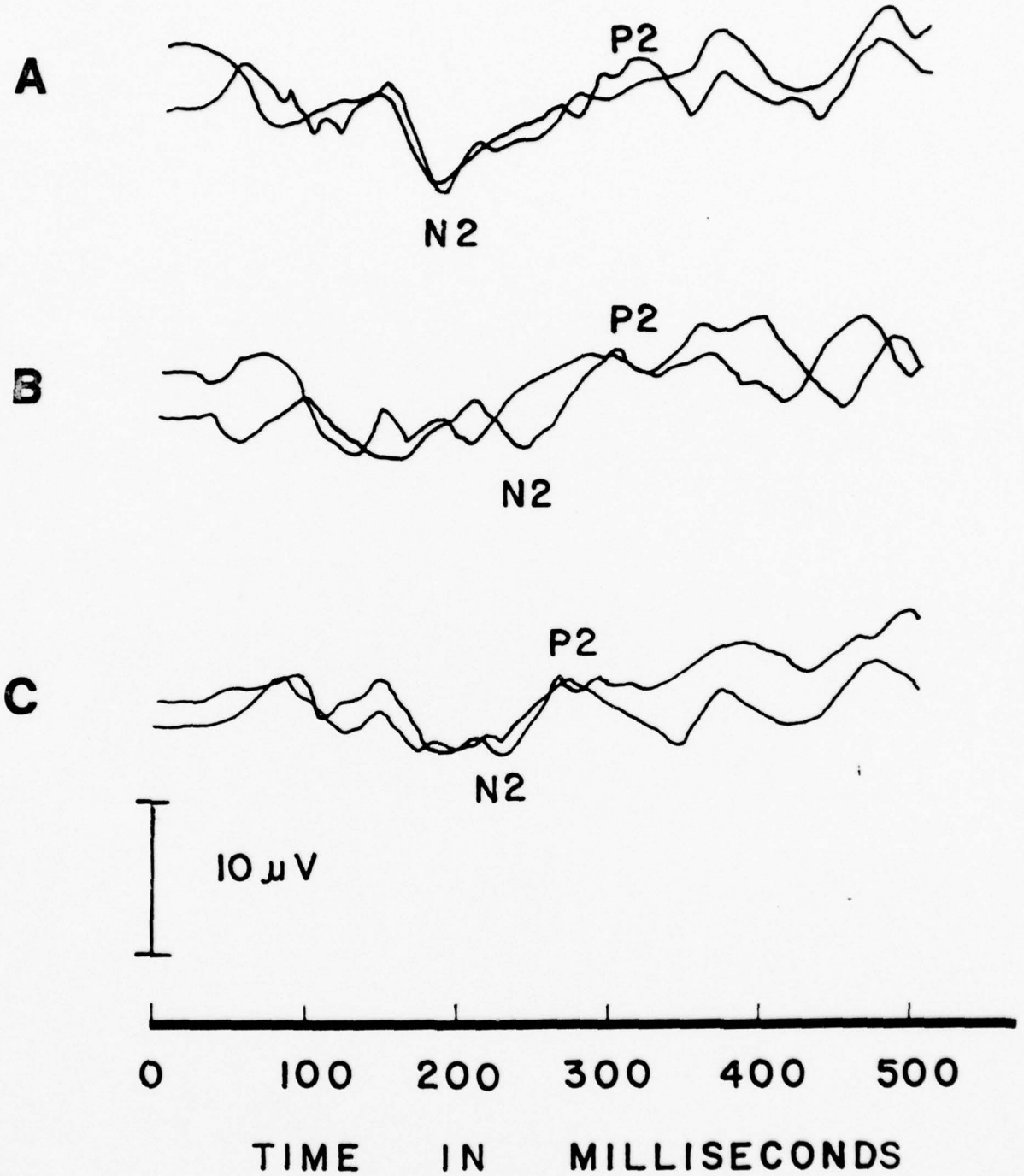


Figure 5 - Superimposed traces for one subject at location C<sub>2</sub>. Each trace is based on 100 presentations (negativity is downward).

produce larger ERPs at either  $O_z$  or  $C_z$  than those observed under condition A.<sup>2</sup> Condition A, it will be recalled was perceived as the dimmest stimulus. Likewise, although C was perceived as brighter than A, condition A resulted in significantly higher ERPs than C (the perceptual masking condition).

None of the latency comparisons for the different conditions resulted in significant differences at either recording site.

The finding that a precisely overlapped target will be perceptually suppressed by a later-presented mask indicates that a target need not be bounded on its external borders for masking to occur. The result obtained can be interpreted in terms of the excitatory-inhibitory hypothesis previously proposed (Andreassi et al., 1971, 1976). That is, a target stimulus results in excitation of a group of cortical neurons at a given location. A second stimulus, presented contiguously in time and space to the target, produces interference with neuronal response to the initial stimulus. The interference results in an attenuated ERP and is associated with perceptual masking of the target stimulus. The differences observed with respect to amplitude attenuation at  $O_z$  but not  $C_z$  with masking point up the role of the occipital cortex as the primary visual area and reflects its role in processing visual stimuli.

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<sup>2</sup>There is evidence that increasing visual stimulus intensity will, up to a point, result in larger amplitude visual ERPs (eg., Vaughan and Hull, 1965)

Experiment II - Interactions Between Target and Masking Stimuli:  
Perceptual and Event Related Potential Effects

The backward visual masking paradigm is one in which a target stimulus is followed by presentation of a masking stimulus. The mask prevents perception of the target. This general paradigm has been used in a variety of ways and related to visual event related brain potentials (visual ERPs) which result from the target - mask combination. One such paradigm has involved the use of a large and very intense flash as a mask to perceptually suppress a smaller, less intense target stimulus (Donchin, Wicke and Lindsley, 1963; Donchin and Lindsley, 1965; Fehmi, Adkins and Lindsley, 1969). The perceptual suppression in these studies was accompanied by complete elimination of visual ERPs to the target. Results of this type could be explained in terms of an integration theory of masking which says that the first and second stimuli are summed as the Mask overtakes the Target, at some point in the visual system prior to the cortex, and the response to their presentation in sequence is the same as that evoked by their joint simultaneous presentation.

Another approach has been to present a series of stimuli, singly, and in adjacent locations, such that the later stimuli in the sequence (e.g., the third, fourth and fifth) were of greater intensity than the first two, and bounded them spatially (Andreassi et al, 1971, 1974). In this situation, the first two stimuli were perceptually masked and there was a delay in time of appearance of the visual ERP generated by the initial stimuli.



In a variation of this approach, multiple sets of sequential stimuli were used, i.e., two target stimuli were followed by three and then six masking stimuli. All stimuli were identical in shape, and luminance was equated for the three sets of stimuli. The target stimuli were masked and visual ERP amplitude to the targets was significantly attenuated (Andreassi et al., 1976a). The findings produced by these latter two paradigms might be interpreted within the framework of an interruption theory of masking in which processing of the target stimulus is terminated, or interfered with, by the mask. It has been contended that this may take the form of either delayed latencies (Andreassi et al., 1971, 1974) or reduced amplitudes of visual ERPs generated by target stimuli (Andreassi et al., 1976a). It has been further suggested that the interruption theory of masking is compatible with an excitatory-inhibitory model of visual masking and ERP changes (Andreassi et al., 1976a). This model proposes that the excitatory fields produced in the visual cortex by early stimuli are decreased in their activity by the inhibitory action produced by later presented stimuli in areas adjacent to, or slightly overlapping, the excited areas. This applies to a situation where target and mask are of the same luminant energy. Weisstein (1968) also appealed to excitatory and inhibitory processes to explain masking which occurred when target and mask were of equal intensity.

Still another paradigm (i.e., metacontrast) was employed by Vaughan and Silverstein (1968) along with measurements of visual ERPs. In the usual metacontrast paradigm the Target and Mask are equal in area, intensity and duration. Two visual stimuli having

adjacent contours are presented in rapid sequence, with the second completely enclosing the first, e.g., a disc followed by a ring or a solid small square followed by a larger outline square. Vaughan and Silverstein used the disc-ring stimulus pairing and found that perceptual suppression of the disc was accompanied by reduced amplitude visual ERPs to this target stimulus. This result may also be explained in terms of excitatory-inhibitory mechanisms produced by the two successive stimuli and taking place at the cortical level.

In the metacontrast situation there is 100% contour interaction between the borders of the target and mask, i.e., the spatial contiguity between the outside perimeter of the target and the inside perimeter of the mask is complete. The amount of contour interaction between Target and Mask was systematically varied by Andreassi et al. (1976b). The degree of interaction was 0% (no mask) 25%, 50%, 75% and 100%. This was accomplished by presenting a square grid as a target and following it with zero, one, two, three or four other grids in close spatial contiguity with the Target. The condition in which four grids were used resembled a metacontrast situation, especially since the total luminous energy of target and mask stimuli was equated under all conditions. The only departure from the usual metacontrast paradigm was the greater area occupied by the mask when more than one grid was presented after the initial target stimulus. Increased amounts of target-mask contour interaction resulted in progressive decreases in visual ERP amplitude to target stimuli. Effective perceptual masking was achieved with 50% contour interaction. The effect of possible areal effects upon the results was ruled out in a

follow-up experiment. This time the target was followed by single line stimuli, whose total area was only 68% of the Target while maintaining contour interaction at 100%. Both ERP attenuation and perceptual masking were observed. The results lend support to the excitatory-inhibitory model since varying the degree of contour interaction produced varying amounts of VEP attenuation with the target-mask combination.

The use of the single grid (Target) followed by the four grid (Mask) paradigm has been established in this laboratory as an effective technique for producing perceptual suppression and visual ERP attenuation. Several questions remain to be answered, ones which especially lend themselves to examination by the technique described. These questions concern: 1) the relative activity at some other recording site as well as the occipital, under conditions of masking and no masking; 2) the ERP correlates of the mask alone in the experimental paradigm and 3) the effects of varying inter-stimulus intervals (ISIs) upon masking and the visual ERP. This last question is of particular interest since it had been previously found that stimulus situations which preclude perceptual masking also fail to produce ERP changes (Andreassi et al., 1976a). The strategy was to find ISIs at which masking failed to occur and to compare the ERPs under these conditions with those obtained with perceptual masking. These questions were examined in two separate experiments, Part A and Part B. It was predicted that ISIs which do not produce perceptual masking would not result in ERP attenuation. Further, when ERP attenuation occurs it would be observed at the occipital site since that area is primarily concerned with visual processing, but not at the central recording area.

Part A - Visual ERPs Recorded From Occipital and Central  
Locations Under Masking and Mask Alone Conditions

Method

Subjects: The subjects were three male and three female adults. They were tested for visual acuity with the Bausch & Lomb Orthorater and all demonstrated 20/20 acuity. In addition, all were screened to ensure that they experienced backward masking under the appropriate conditions.

Apparatus and Procedure: The apparatus for presenting the stimuli was the same as in Experiment I. The only difference was the addition of a C<sub>z</sub> recording site. There were three conditions as follows: A: Masking - a single grid appeared on the screen for 20 msec and after an off time of 40 msec four surrounding grids were presented for 20 msec (see Fig. 1). B: Mask Alone - The screen was blank for 60 msec at which time the four grids were presented for 20 msec. C: Target Alone - A single grid was presented for 20 msec.

In every condition 1000 msec intervened between each stimulus presentation. For example, in condition A the single grid was presented, followed by the four grids in rapid succession. The screen was then blank for 1000 msec until the next stimulus set was presented. The disappearance of the stimuli was virtually immediate (50 usec) with the very brief persistence P24 phosphor specially installed in the VR-14.

The intensity of a single grid was 5.5 millilamberts (mL). This differed from the four grid condition since in that situation each grid was 1.4 mL. Thus, the total liminance under the one grid and four grid presentations was 5.5 mL and 5.6 mL, respectively.

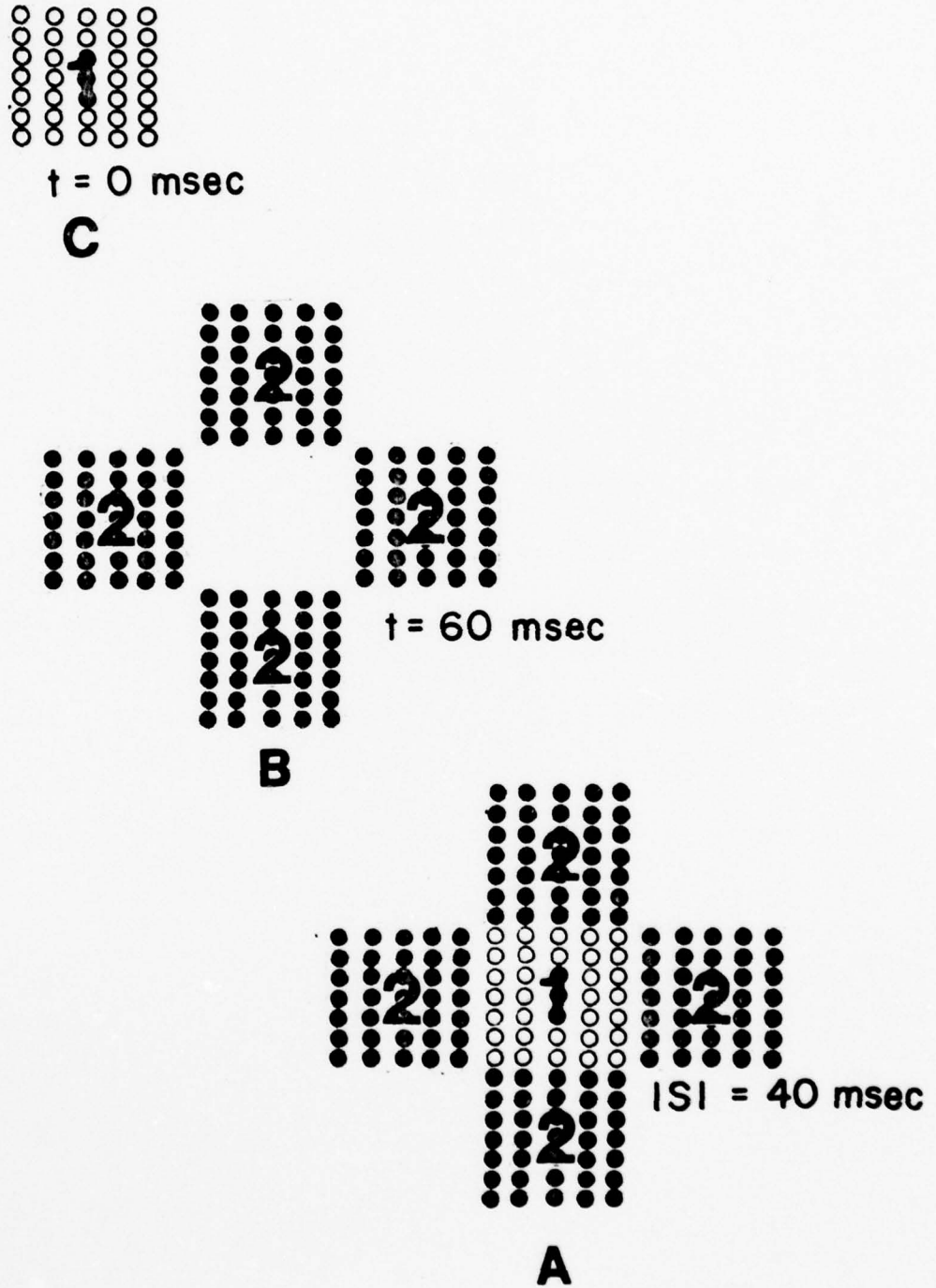


Figure 1 - Schematic of Conditions A, B, and C. All circles were solid greenish-yellow points of light (equal size) in the actual CRT display. The numbers merely indicate order of presentation.

The single 1.0 cm square grid produced a visual angle of 25 min. of arc at the viewing distance used (137 cm). An array of three adjacent grids (the greatest extent used) produced a visual angle of 1 deg. 18 min. of arc. Thus, stimuli were in foveal vision.

As in Experiment I subjects were asked to focus on the fixation point during presentations and to avoid eye movements and blinks especially during presentations. In pilot trials subjects were asked to diagram what they saw under the three conditions. All drawings indicated that the target grid was not perceived under the masking condition (A). Subjects were asked to silently count the number of stimulus presentations. In the experiment proper each condition consisted of 100 presentations after which subjects drew diagrams of what they saw on the screen.

The three conditions were completely counterbalanced across the six subjects over a period of three days. Each subject was presented with each condition six times during the course of three experimental sessions. This resulted in a total of 18 ERP traces from  $O_z$  and 18 from  $C_z$  for each subject.

### Results

The perceptual reports and diagrams indicated that all subjects saw what was expected. That is, in condition A the first grid was masked, in condition B they consistently saw the four grid mask, while in C the single target grid was observed.

The various ERP components were measured as described in Experiment I. The mean amplitude, in microvolts, for the N1-P1 and N2-P2 components are given in Table 1 for both the  $O_z$  and  $C_z$  recording sites. The N1-P1 component did not occur in at least

50% of the trials at C<sub>z</sub> and was therefore excluded from further analyses.

Table 1  
Mean Amplitude (uV) for Major Visual ERP Components  
Conditions A, B and C (N=6)

VEP Components	O <sub>z</sub> Conditions			C <sub>z</sub> Conditions		
	A	B	C	A	B	C
N1-P1	5.82	5.32	5.21	-	-	-
N2-P2	5.10	11.70	7.40	8.18	7.50	7.40

The N2-P2 amplitude data of Table 1 are depicted graphically in Figure 2. The mean latency data for the P1 and P2 components are given in Table 2.

Table 2  
Mean Latency for Major Visual ERP Components  
Conditions A, B, and C (N=6)

VEP Components	O <sub>z</sub> Conditions			C <sub>z</sub> Conditions		
	A	B	C	A	B	C
P1	142	177	132	-	-	-
P2	221	267	217	253	289	258

The relatively long latencies for condition B were expected because the time stimulus presentation was delayed for 60 msec.

The amplitude data (N2-P2) and P2 latencies were analyzed by t-tests for correlated data after log transforms were conducted. The t-test results indicated significant amplitude reduction in N2-P2 amplitude at the O<sub>z</sub> recording site under Condition A when compared to B (t=4.11, p<.01) and C, (t=3.03, p<.05). The B vs C comparison was significant (t=3.57, p<.02) with B resulting in larger responses. The latency results for the O<sub>z</sub> site reveal no

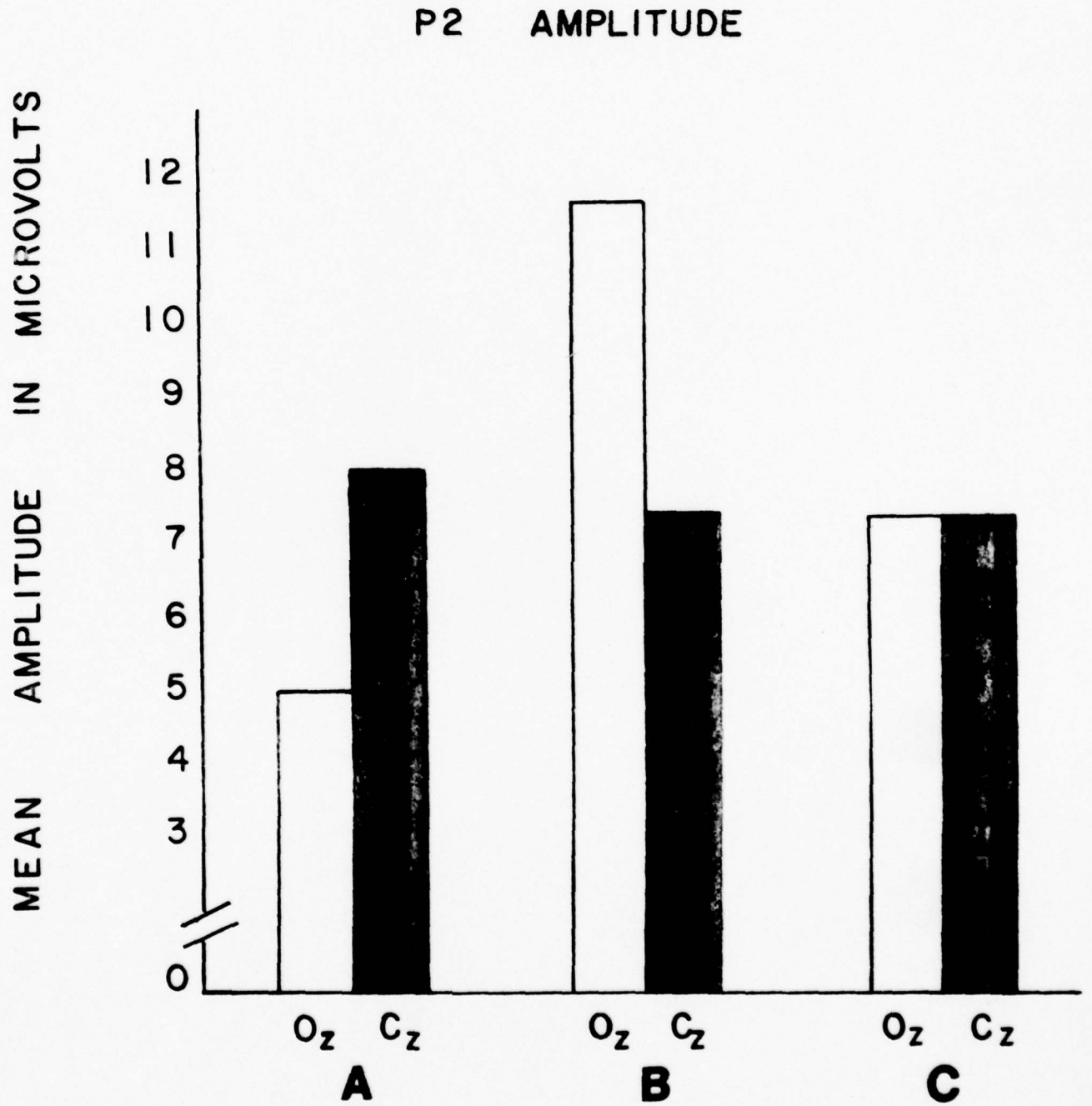


Figure 2 - Mean N2-P2 amplitude of the VEP for Conditions A, B, and C at locations O<sub>2</sub> and C<sub>z</sub>.



significant difference between Conditions A and C ( $p > .05$ ). However significant differences were found for both A vs B ( $t = 3.92$ ,  $p < .02$ ) and B vs C ( $t = 11.90$ ,  $p < .001$ ) comparisons. The amplitude and latency analyses for  $C_z$  comparisons did not yield significant differences ( $p > .05$  for all).

The results show that the perceptual masking in Condition A was accompanied by significant ERP amplitude reduction at  $O_z$  but not at  $C_z$ . The mask alone condition produced significantly larger amplitudes at  $O_z$  than any other condition, i.e., greater amplitudes than the target alone (C) and target and mask (A) conditions.

The superimposed ERP traces for one subject are presented in Figures 3 ( $O_z$ ) and 4 ( $C_z$ ). This subject had mean N2-P2 amplitudes (at  $O_z$ ) of 7.16  $\mu V$  for Condition A, 17.25  $\mu V$  for B, and 11.60  $\mu V$  for C. The same conditions at  $C_z$  produced amplitudes of 11.10  $\mu V$  (A), 7.20  $\mu V$  (B), and 7.75  $\mu V$  (C).

#### Part B - Perceptual Masking and Visual ERPs at Different ISIs

The main object of this experiment was to compare ERPs under a condition which is known to be effective for masking (an ISI of 40 msec. between target and mask) with those obtained at ISIs determined in pilot runs not to be effective for backward masking. Pilot trials with several naive subjects determined that at an ISI of 10 msec between target and mask stimuli they were perceived as simultaneous presentations, i.e., subjects reported seeing five grids. When an ISI of 100 msec. was used the target and mask stimuli were perceived as successive presentations (again, five grids were seen). It was predicted that ERP amplitude reduction would not occur under conditions in which perceptual masking was absent.

O<sub>z</sub>

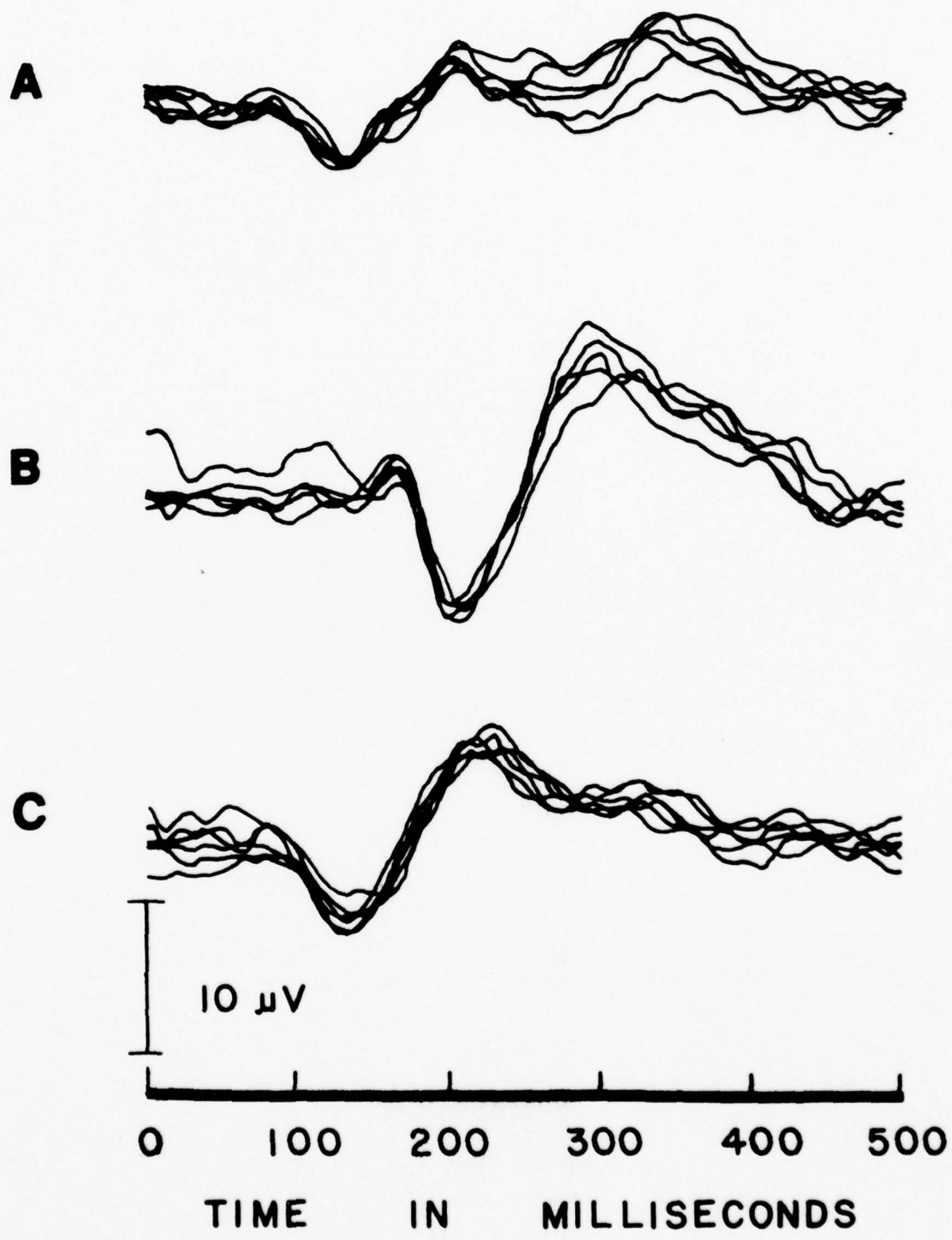


Figure 3 - Superimposed traces for one subject at location O<sub>z</sub>. Each trace is based on 100 presentations (negativity is downward).

C<sub>z</sub>

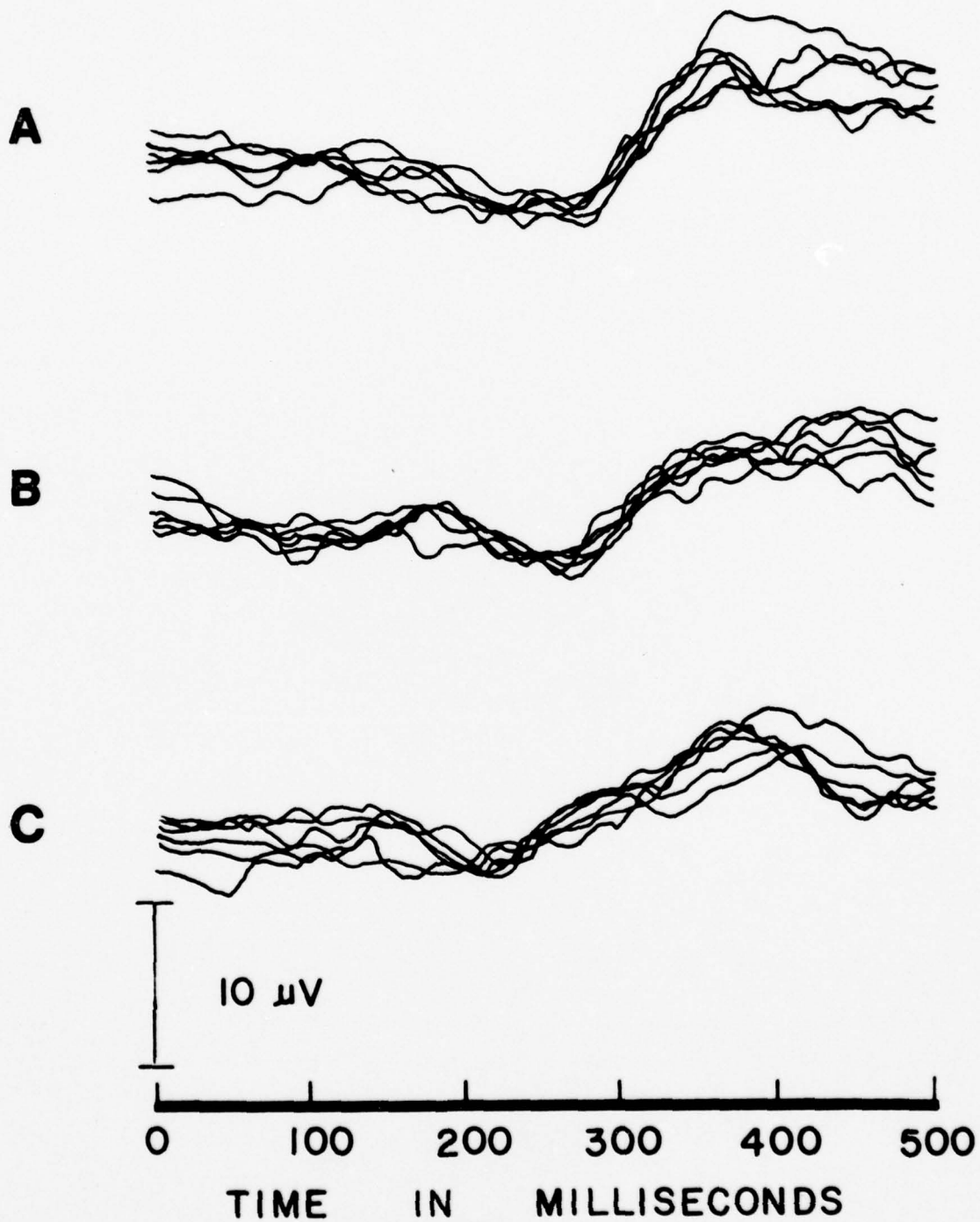


Figure 4 - Superimposed traces for one subject at location C<sub>z</sub>. Each trace is based on 100 presentations (negativity is downward).

### Method

Subjects: The subjects were three male and two female adults. They were screened for visual acuity and found to have at least 20/20 vision, corrected or uncorrected (two wore corrective lenses).

Apparatus and Procedure: The apparatus for obtaining visual ERPs and presenting stimuli was the same as described previously. The display conditions A, B and C are the same as those employed in Part A (see Figure 5). Condition D is new and involved an ISI of 10 msec between target and mask. Experimental subjects were screened with this condition and all reported seeing five simultaneously presented squares. Condition E is also new and used an ISI of 100 msec between target and mask. Experimental subjects reported seeing one square followed by four other similar squares during screening trials. Presentation time for all target and mask stimuli was 20 msec. A 1000 msec interval was used between presentations.

All subjects participated in this experiment on five separate days. The five conditions were counterbalanced over all subjects over the five days. In a given session each condition was presented two times. Thus, over the five day period a total of 10 ERP traces was obtained for both  $O_z$  and  $C_z$  recording sites for each subject.

### Results

The mean amplitudes and latencies of the major ERP components were obtained as outlined in Experiment I. The amplitude data are shown in Table 1. These data are plotted in Figure 6. Examination of the tabulated data reveals that, for N2-P2 amplitude at the  $O_z$  site, there were considerable amplitude differences with the five conditions used. On the other hand, the amplitudes recorded

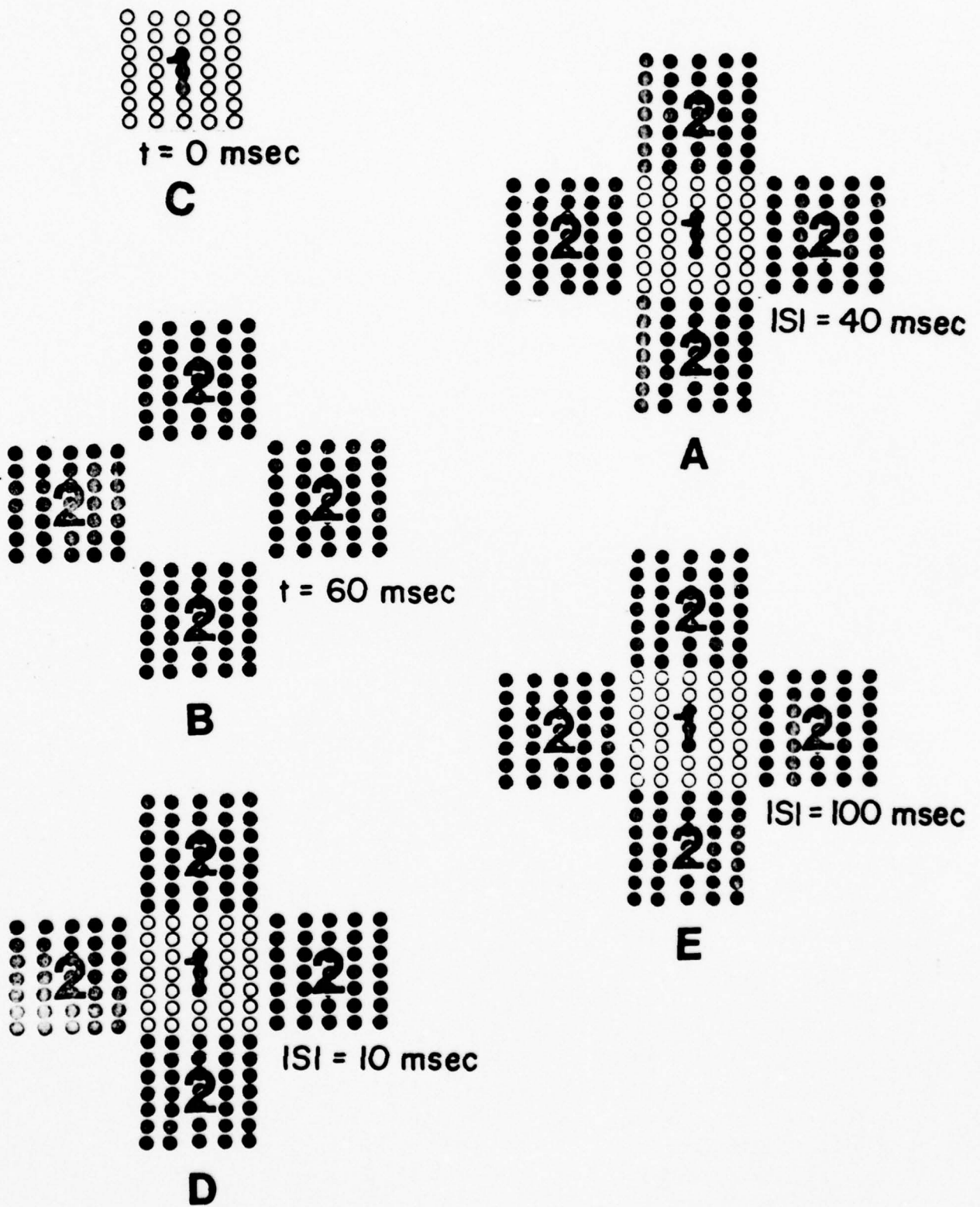


Figure 5 - Schematic of Conditions A, B, C, D, and E. All circles were solid greenish-yellow points of light (equal size) in the actual CRT display. The numbers merely indicate order of presentation.

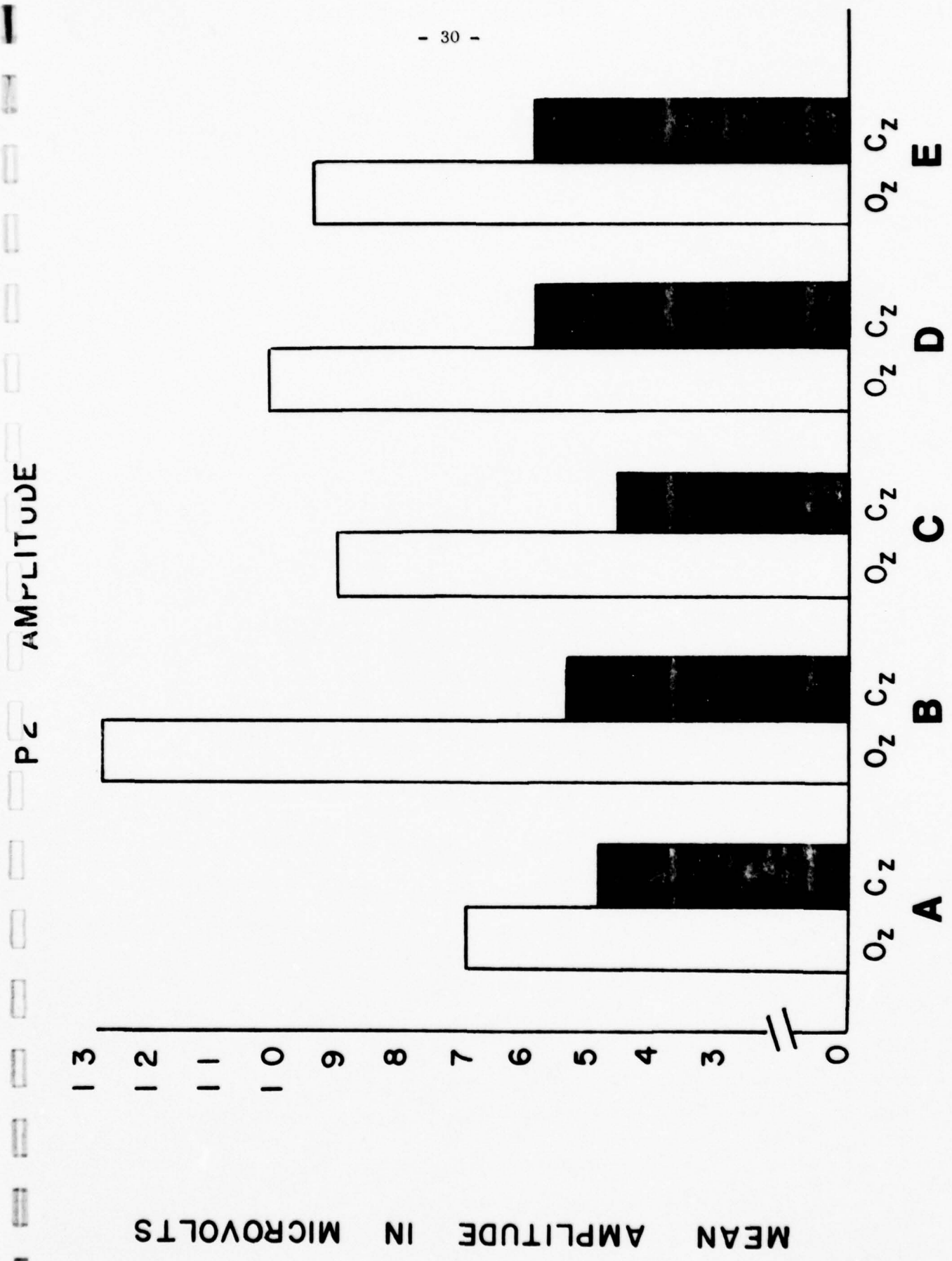


Figure 6 - Mean N2-P2 amplitude of the VEP for Conditions A, B, C, D, and E at locations Oz and Cz.

from  $C_z$  showed little difference as a function of condition. The N2-P2 amplitudes were subjected to analysis of variance (ANOVA).

Table 1  
Mean Amplitude (uV) for Major ERP Components,  
Conditions A - E, N=5

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<u>VEP</u> <u>Components</u>	<u>O<sub>z</sub></u> <u>Conditions</u>				
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>
N1-P1	4.30	4.90	3.90	4.80	6.30
N2-P2	7.10	13.00	9.20	10.30	9.60

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	<u>C<sub>z</sub></u> <u>Conditions</u>				
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>
N1-P1	2.40	4.40	3.30	3.60	4.00
N2-P2	5.00	5.50	4.70	6.00	6.00

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Separate ANOVAs were performed for  $O_z$  and  $C_z$ . A two-way (Subjects X Conditions) fixed model (Winer, 1971) was used. A log transformation of all the raw data was conducted to insure that they conformed to the assumptions of ANOVA. The ANOVA for N2-P2 amplitude at  $O_z$  indicated that both main effects were significant: Subjects,  $F(4/49)=14.33$  ( $p<.01$ ) and Conditions,  $F(4/49)=11.66$  ( $p<.01$ ). The Subjects X Conditions interaction was also significant:  $F(25/49)=5.11$  ( $p<.01$ ). The Newman-Keuls multiple comparison technique (Winer, 1971) was used to further examine the significance of specific amplitude differences. The Newman-Keuls results indicate that condition A (target and mask) produced significantly smaller ERP amplitudes than any of the conditions. Condition B (mask alone) resulted in significantly larger amplitude ERPs than all other conditions except D (10 msec ISI). A similar ANOVA for N2-P2 amplitudes for the  $C_z$  site did not yield any significant differences

between the various conditions. Thus, the effects for amplitude seem specific for the occipital site.

The latency data for the P2 component were subjected to ANOVA. The only significant latency difference was for the P2 response under condition B (mask alone) at the  $O_z$  recording site. This difference was expected because of the delay in presenting the mask alone (60 msec). The latency data will not be presented or analyzed further. Figures 7 and 8 are superimposed VEP traces ( $O_z$  and  $C_z$ , respectively) for one subject under all conditions. Each trace is based on 100 presentations.

#### Discussion

The results of Parts A and B again clearly demonstrated visual ERP attenuation at a target-mask ISI of 40 msec., an ISI which consistently produced backward masking. Both experiments showed that this effect was specific for the occipital recording site since amplitude reductions were not observed at the central area under this condition. The mask alone condition produced the largest amplitude ERPs in both experiments. Again this was specific for  $O_z$ . As predicted, the target-mask conditions which did not produce masking (10 msec. and 100 msec. ISIs) were not accompanied by ERP amplitude reductions.

The results again may be explained by a cortical excitatory-inhibitory model. That is, when successive stimuli are presented to the visual system, the visual cortical excitation produced by the initial stimuli is inhibited by the presentation of subsequent stimuli. This occurs when stimuli are presented at the appropriate temporal and spatial intervals. Part B of this experiment has shown that 100 and 10 msec. ISIs did not produce either perceptual masking



O<sub>z</sub>

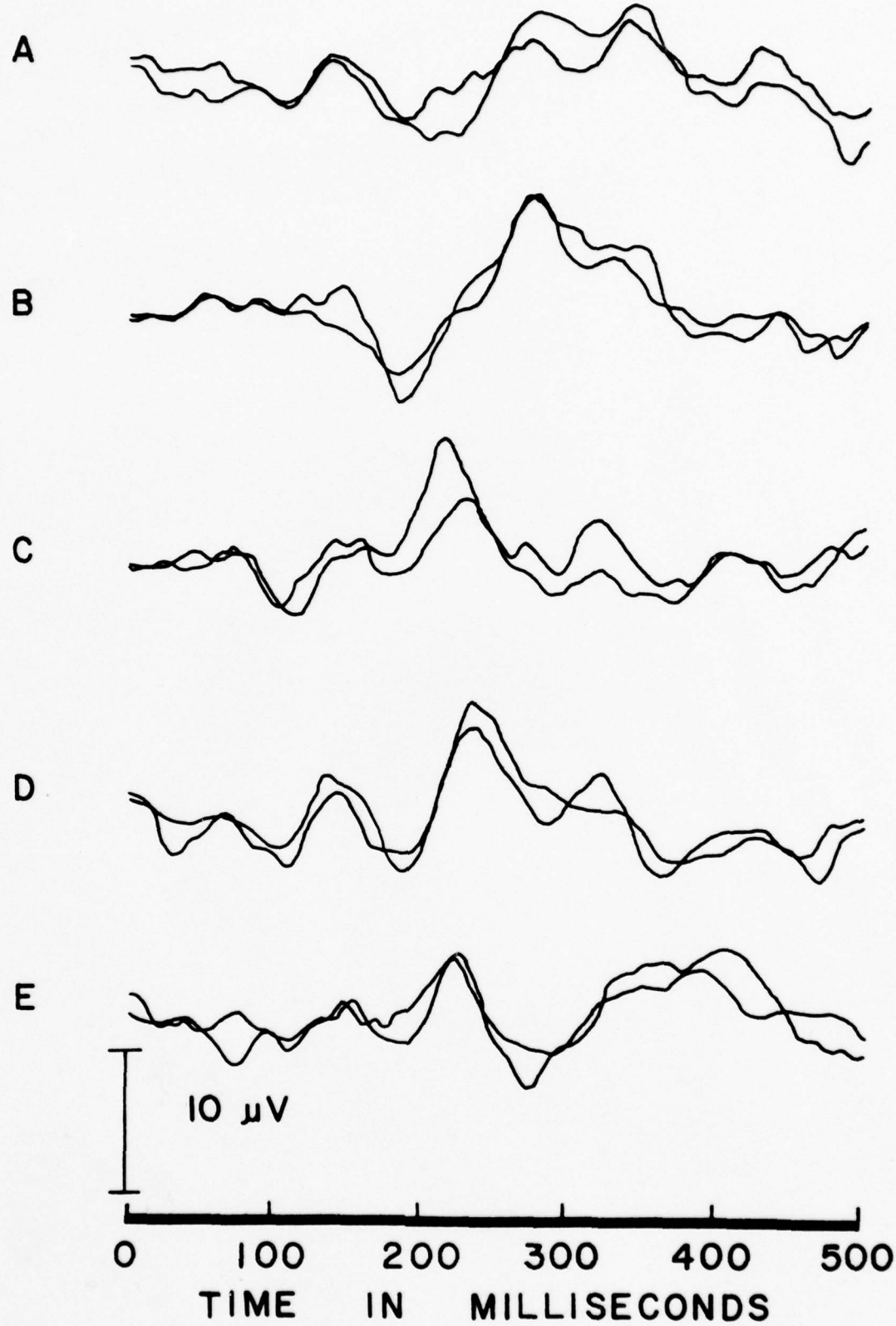


Figure 7 - Superimposed traces for one subject at location O<sub>z</sub>. Each trace is based on 100 presentations (negativity is downward).

C<sub>Z</sub>

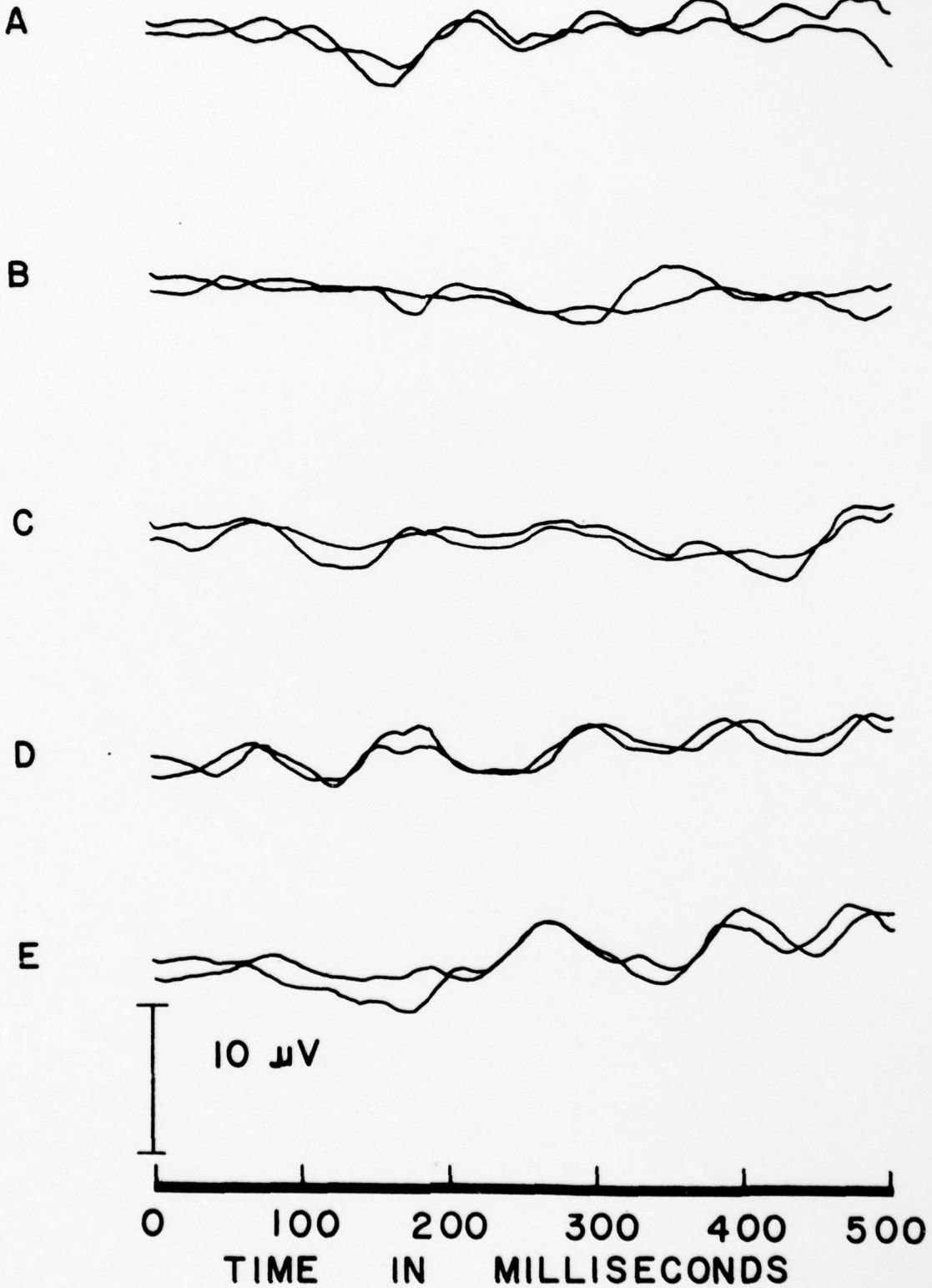


Figure 8 - Superimposed traces for one subject at location C<sub>Z</sub>. Each trace is based on 100 presentations (negativity is downward).

or ERP attenuation. The results emphasize that initial stimuli must be followed closely enough in time by the Mask in order for the inhibitory effect to occur. However, if the Mask is presented too close in time, the effect is lost because Target and Mask are perceived as one unit. The 100 msec. ISI results in a situation where the Mask is too far removed temporally from the Target to interfere with its perception and thus is processed as a separate stimulus. In both cases the mask did not appear at the appropriate temporal interval to inhibit excitatory activity created by the initial stimulus.

The excitatory-inhibitory model draws some support from studies which have tested the feasibility of visual cortical prostheses with blind patients (Brindley & Lewin, 1968; Dobbelle & Mladejovsky, 1974). In work of this type direct electrical stimulation of discrete portions of visual cortex has been used to produce electrical phosphenes, or sensations of light, in patients with peripherally caused blindness (e.g., eye damage). These electrically produced phosphenes interacted when two adjacent areas of visual cortex were stimulated (Dobbelle, Mladejovsky and Girvin, 1974; Hambrecht & Frank, 1975). Simultaneous or sequential stimulation of two adjacent cortical areas resulted in reports by patients of "seeing" one phosphene instead of two. The possibility that inhibitory effects can take place at the level of the visual cortex is directly suggested by these observations.

The larger amplitude ERPs for the mask alone versus the target alone condition may be due to the greater degree of perceived contour for the mask (16 sides) compared to target (4 sides). Angles and contour breaks may also be a factor. Namely, the target

has only four right angles and contour breaks, while the mask has 16 of each. Moskowitz et al. (1974) have shown that sharply angled 90 deg. corners produce larger amplitude visual ERPs than rounded corners of 90 deg. Perhaps the greater number of right angles in the mask caused the amplitude differences observed. Hypotheses regarding area, amount of contour, and number of sharp 90 deg. angles can be experimentally tested.

The fact that ERP attenuation under masking conditions was specific to occipital recordings is most likely due to the role of occipital cortex as the area primarily concerned with processing visual stimuli. The central area, represented by  $C_z$ , is polysensory, responding to a variety of sensory stimuli. It may also be hypothesized that amplitude reductions associated with visual masking would not be observed in areas outside the occipital because excitatory-inhibitory interactions require topographically organized cortical receptive fields such as those which are known to exist in the occipital cortex for visual stimuli.

Experiment III - Visual Evoked Potentials Under Conditions of  
Apparent Motion, No Motion and Continuous Motion<sup>1</sup>

Psychologists of the nineteenth-century believed that perceptions were derived from elements known as sensations. Among these psychologists, Exner (1875) was one of the first to explore this notion with regard to movement. In his experiment, an observer was presented with two spatially separate electric sparks and had to determine the order in which these sparks were flashed. Exner found that if the two sparks were placed adjacent to each other, whether the time between flashes was 14 or 45 msec., the observer perceived apparent motion in that flash A appeared to move to the location of flash B. From these results, Exner concluded that movement must be a special process or sensation and not a perception derived from the senses of time or space. Exner's conclusion was further supported by an experiment by Wertheimer (1912). In this classic experiment, Wertheimer presented two adjacent lines in rapid succession. When the time interval between the two flashes was just right, the observer reported seeing movement between the two lines. This perception of motion in relation to the two stationary lines is referred to as the phi phenomenon. Like Exner, Wertheimer concluded that movement was a sensation, one which could be produced by simply providing enough stimulation to the brain to mimic the actual stimulation which occurs during real motion.

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<sup>1</sup>This experiment was conducted in the Psychophysiology laboratory by Ms. Barbara Boland to fulfill requirements for independent study in psychology at Baruch College.

In Wertheimer's study, the interstimulus interval, or ISI, was the main variable defining apparent motion. However, if we review the studies of Korte (1915) we find that factors other than stimulus spacing have an important influence on movement perception. Korte studied the relationships between stimulus intensity and stimulus separation in space and time and established laws concerning the roles of these variables in apparent motion. These laws are more or less guidelines which explain how the different variables (space between two stimuli, duration of the ISI, the intensity of the stimuli, and the length of presentation time of each stimulus) may be manipulated to maintain the perception of apparent motion. For example, when intensity of the two stimuli is held constant, and space between them is increased, the time intervals between the two must also be increased in order to obtain apparent motion.

Schouten (1967) attempted to explain the perception of movement through a model of retinal velocity. According to this model, two receptors must be stimulated within a certain time interval before a signal to a movement detector can be transmitted. A particular movement detector will fire only if the velocity of an image crossing the retina has certain temporal and spatial characteristics. Schouten's work, though it is considered logical, is not recognized as the basis for movement perception because of certain research findings. Rock and Ebenholtz (1962) were the main challengers of Schouten's model. In their work, they studied whether stroboscopic movement (or apparent motion) depends on the successive stimulation of separate retinal areas or of separate areas or points located in "phenomenal" space. In order to do this, conditions were created so that separate phenomenal points could be experienced when only

one area of the retina was stimulated. The subjects were asked to view two alternating flashing lights through separate apertures. When the subject's eye movements were synchronized with the two flashing lights, apparent motion was perceived. These results show that it is not necessary to stimulate two retinal locations in order for apparent motion to occur, instead such motion can occur even when the same retinal point is stimulated. Thus, the physiological mechanism for apparent motion lies at some point in the visual system beyond the retina.

Schouten's model of retinal velocity was also subject to revision by the conclusions drawn from the works of Kaplan (1972) and Barlow and Hill (1963). Though Kaplan basically agreed with Schouten's model, she pointed out that the two stimulated receptors which signal the motion detector must also be sensitive to the direction of movement in order for the correct movement detector to respond. Barlow and Hill have postulated that movement detectors respond differently depending on the direction of the movement. For example, there may be detectors whose rate of firing increases when movement occurs in one direction, and decreases when movement occurs in the opposite direction.

Unidirectional sensitivity of motion has been explored even further by Sekular and Ganz (1963). Their hypothesis was that if one viewed a unidirectional stimulus for a prolonged period of time, the luminance threshold will be increased for further stimuli moving in the same direction. This hypothesis was tested by having the subjects view a rectangle with bright vertical stripes (which moved either to the right or to the left) under three phases: 1) inspection, 2) interval, and 3) test. Under the test phase,

the subjects were to diminish the intensity of the stimulus when the stripes were not detected. The results showed that the subjects' luminance threshold would increase abruptly when the stripes continued to move unidirectionally as compared to when the movement occurred in the opposite direction. Thus, adaptation to movement in a particular direction occurred, indicating specific visual system mechanisms sensitive to direction.

Studies of frogs (Lettvin, Maturana, McCulloch and Pitts, 1959), rabbits (Barlow and Hill, 1963) and monkeys (Hubel and Wiesel, 1968) have further supported the assumption of specialized neuron cells in detecting motion. In addition, Bishop, Coombs and Henry (1971) found that most motion detectors were sensitive to stimulation in only one direction.

Specialization of neuron cells with regard to motion was also reported by Orban (1977) who studied the responses of neurons from area 18. The author used paralyzed, unanaesthetized cats to measure the influence of direction, angular velocity, and amplitude of movement on the neurons of area 18 by stimulating these neurons with different kinds of patterns. The results from this study revealed that the organization of the receptive field in area 18 consists of five types of receptor cells: simple, complex, hypercomplex, direction-independent, and amplitude specific cells. Among some other major findings of this study were: 1) direction-independent neurons respond to all directions of movement, 2) complex cells respond to all kinds of patterns tested, whereas the other cells were more specific, and 3) all three movement parameters influenced the firing of area 18 neurons, with all neurons being influenced by movement velocity, most by the movement direction and a few by



the length of movement. From this evidence, Orban finds support for the hypothesis that area 18 is involved in movement perception. In order to explain the roles each type of cell plays in the detection of motion, the author presents a cell chain which suggests that information entering area 18 is branched to particular cells which perform specific functions.

Noting that VEPs can be produced in humans by the reversal of direction, Clarke (1972) set out to find whether or not eye movements at the time of reversal could be the cause of VEPs. Using a noise slide pattern which projected the stimuli through a moving mirror onto a screen, Clarke studied VEPs under conditions of periodic and aperiodic stimulation. The pattern moved at a constant speed horizontally across a screen and would then suddenly reverse every 0.5 sec. Clarke found no significant differences in VEPs to periodic and aperiodic stimulation in the first 180 msec. and therefore concluded that eye movements do not account for VEP responses within the first 180 msec. of direction reversal.

Further experiments by Clarke indicate that perhaps neural mechanisms sensitive to pattern contrast and not motion direction can account for the VEPs obtained during motion reversal. However, a study by Clarke in 1973 concluded that motion-reversal VEPs are produced largely by direction-sensitive mechanisms in the brain.

In 1973, Clarke did a study comparing VEPs to stationary and moving patterns under the conditions of pattern appearance, motion onset, motion offset, and motion reversal. Clarke observed that the VEPs to motion reversal, motion offset and pattern appearance were very similar. Motion onset and pattern disappearance, though similar to each other, did produce significantly different VEPs.

Clarke hypothesized that the similarities between motion onset and pattern disappearance VEPs may be due to the fact that they both originate from the same neural mechanisms. He explains that motion, which causes a smearing of the image on the retina, may produce a decrease in the effective contrast of the pattern, causing the sudden onset of motion to elicit a response from pattern disappearance mechanisms. Another finding was that pattern appearance and pattern disappearance VEPs were very similar to each other and largest for stationary patterns, however, their amplitudes decreased as velocity (motion) increased. This difference in VEP response for stationary and moving patterns was seen by Clarke as evidence supporting his hypothesis. Clarke also suggested that the neural mechanisms producing pattern appearance and motion-offset VEPs lie in separate brain locations than the neural mechanisms for pattern disappearance and motion-onset VEPs.

Whereas Clarke's works were studies of VEPs under various conditions of motion, the works of R.L. Gregory (1966) attempted to answer the underlying processes of movement perception in more general terms. According to Gregory, two systems are involved in the perception of movement: 1) the image-retina system and 2) the eye-head system. The image-retina system is believed to be capable of directly encoding retinal velocity, whereas the eye-head system instructs the extraocular muscles to track the retinal image. For example, if a stationary image is reflected onto the retina, and the individual's eye moves, then the person will perceive motion. Also, should the image move across the retina, while the eyes are being moved in the same direction, then the image will be perceived as stationary to the individual.

MacKay, (1976) also attempted to explain the underlying processes of motion perception with a theory involving the integration of two visual mechanisms - the image-drift and location-change mechanisms. Explaining the importance of the interaction of these two mechanisms in terms of an experiment conducted, the author presented a movable rectangular "window" to one group of subjects in which the background static noise field was locked so that it moved with the window. To another group of subjects, the background static noise field was synchronized to the overall CRT screen so that the window moved relative to the static field. MacKay found that when the window was moved smoothly under the first condition, motion was perceived normally. However, motion was perceived as discontinuous (jumping) in the second condition when the eye was fixated on the stimulus window. According to MacKay, the ability to perceive an object as moving depends on the integration of the image-drift and location-change systems. Since the window in the second condition was not perceived as moving smoothly across the screen, MacKay suggests that perhaps the synchronization of the static noise pattern in the second condition resulted in the functioning of only the location-detecting system. Since the noise pattern within the moving window was always stationary relative to the fixated retina, the image-drift system believed necessary for the detection of movement was not employed by subjects, thereby producing the perception of discontinuous motion.

Up until recently, there has been one question among psychologists regarding the perception of motion which has not been fully answered: What is the difference between "real" and "apparent" motion? Kaufman et al. (1971) compared real and apparent motion by

having their subjects view the luminous curve of a disc under three different conditions. Kaufman found that when a subject reported seeing the curve of the disc as stationary, the angular velocity of the disc was at a rate of  $27.9^{\circ}$  of arc/sec. The rate of velocity for apparent motion was only  $8.9^{\circ}$  of arc/sec., and that for real motion was  $10.6^{\circ}$  of arc/sec. Therefore, Kaufman concluded that since apparent movement began when an object in real motion began to blur, that these two categories of movement are complementary processes rather than parallel.

Cooper et al. (1977) studied the VEPs of subjects who were asked to scan a model landscape and detect and recognize any moving vehicles crossing this landscape. A total of 25 vehicle-moving events occurred during the testing sessions and responses to the detection of changes in the display were taken from the frontal, central, parietal and occipital areas. Cooper found that the responses of subjects occurring after entry of the vehicle onto the display were highest in amplitude at the central and parietal areas. The results also showed that the waveform from the occipital area was usually more prolonged than that from the frontal region. Cooper suggested that perhaps these VEPs have common origins with the P300 component of cortical evoked potentials which is most often associated with discrimination and decision-making tasks.

Andreassi et al. (1973) compared VEPs under two conditions of apparent motion and one condition of no motion. In all conditions 20 Xs were presented, each sequentially with ON and OFF times of 5 msec. In one condition, the X's appeared to converge toward the center of the screen, in another they appeared to diverge from the center, and in a third condition, the X's appeared

stationary. The different perceptual experiences were the result of display order of the Xs. The results showed no significant VEP differences under the three conditions. Since the responses given were unexpectedly similar for all three conditions, Andreassi and colleagues suggested that perhaps the mechanisms involved in the perception of apparent motion were not reflected in brain response changes to the objectively similar stimulus conditions.

Andreassi et al. (1978) compared apparent motion with no motion in a study in which the stimuli were presented at differing velocities under the two apparent motion conditions. Under all three conditions, the subject viewed one X on a screen for 20 msec. followed by a second X at a distance of 2.8 cm. to the right. The timing condition simulated velocities of  $7^{\circ}/\text{sec}$  and  $14^{\circ}/\text{sec}$ . A third condition involved the presentation of two Xs. The highest velocity condition resulted in significantly longer latency VEPs (i.e., as compared to slower and stationary stimuli). Also, the largest amplitude responses for these visual stimuli occurred at the occipital ( $O_z$ ) recording site as compared to the central ( $C_z$ ) and frontal ( $F_z$ ) areas sampled. Using the hypothesis of Kaufman (1974), Andreassi et al discussed the longer latency response for the faster apparent motion condition in terms of a "pre-set time constant" needed to transmit a signal to a motion detector. That is, perhaps the  $7^{\circ}/\text{sec}$  velocity apparent motion condition was not fast enough for motion detectors to be stimulated. Instead this slower velocity may have stimulated the visual system in a manner similar to that of stationary stimuli. The fact that there were no significant differences between the

slower apparent movement condition and the stationary one was similar to Clarke's results, suggesting that similar mechanisms in the visual system process both stationary and slow moving stimuli. The final conclusion of Andreassi et al in this study regarding the higher amplitudes at the occipital region is that it points out the role of this area as the primary processor of visual information. It may also be possible to state from these results that the central occipital cortex sampled has some role in detecting differences in motion velocities. No condition effects were observed at  $C_z$  and  $F_z$ .

The literature indicates that different kinds of VEPs occur in response to motion. The purpose of the present experiment was to find whether or not any significant differences exist between VEPs under conditions of continuous, apparent and no motion. The research questions asked were: 1) Will there be a difference in the latency and amplitudes of the VEPs under three conditions of motion? and 2) Will recordings from central and occipital areas differ as a function of the different stimulus conditions?

#### Method

Subjects: The subjects were three males and three females associated with Baruch College of the City University of New York. None had visual defects other than myopia (corrected to at least 20/25).

Apparatus and Procedure: Subjects were seated in an electrically shielded sound-attenuated room (IAC Chamber). All experimental sessions were conducted with the lights dimmed. The EEG recording equipment and stimulus display equipment were the same as previously discussed (see Experiment I).

In order to obtain the averaged cortical evoked potential, the electroencephalogram (EEG) of each subject was recorded from  $O_z$

and  $C_z$  (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to a silver clip electrode on the subject's left ear lobe.

The stimuli were displayed on a Digital Equipment Corp. VR-14 which mounted at the subject's eye level outside the chamber at a distance of 132 cm. The VR-14 CRT was controlled by the PDP-8/E digital computer which was programmed to deliver stimuli at specific times and locations upon the CRT. There were three conditions, each comprised of vertical lines, yellow-green in color (see Figure 1 schematic).

Condition A - One line on the screen for 6 msec. followed by a second line 108 msec. later. The second line was 2.3 cm. to the right of the first one and was on for 6 msec. (Apparent motion)

Condition B - One line on the screen for 6 msec. followed by a second line 1 msec. later. This second line was 2.3 cm. to the right of the first one and was on for 6 msec. (Stationary)

Condition C - One line on the screen for 6 msec. followed 6 msec. later by 18 successive lines, each on for 3 msec. and off for 3 msec. The lines appeared in order from left to right. (Continuous motion)

In Condition A, total stimulation time was 120 msec. and total radiant energy was 7.0 mL (3.5 mL for each vertical line). This condition consistently produced apparent motion of a line moving from left to right for three pilot subjects screened in a pre-experimental session. Condition B produced a total presentation

time of 13 msec. and total stimulus energy of 7.0 mL. The perception of pilot subjects was of two simultaneous vertical lines. For Condition C the total stimulation time was 120 msec. and total radiant energy was 7.0 mL. This was achieved by presenting the first line at an intensity of 3.5 mL. and each successive line following at an intensity of .2 mL radiant energy. The perceptual effect was of a vertical line moving continuously across the screen from left to right. Thus, in the three conditions, stimulus energy was equal in Condition A, the velocity of apparent movement was  $9.26^\circ$  of arc per sec. (based on a  $1^\circ$  stimulus separation and a presentation time of 120 msec.). For B, there was no movement perceived. In C, the velocity of motion was  $9.26^\circ$  of arc per sec (based on a  $1^\circ$  stimulus separation and a presentation time of 120 msec.).

In every instance, there was always 1500 msec. between each set of stimuli. For example, in condition C, the 19 lines were presented in rapid succession, followed by a pause of 1500 msec. before the next set of lines appeared. The spatial arrangement in which the stimuli appeared upon the screen is schematically represented in Figure 1.

The distance between the two vertical line stimuli used in the present experiment produced a visual angle at the eye of  $1^\circ$  of arc. Therefore, the stimuli were always presented foveally since foveal extent is considered to be  $2.5^\circ$  (Ruch et al., 1966).

Subjects were asked to silently count the number of presentations and to focus on a small fixation point  $1/2$  cm above the center of the displayed lines. The subjects were asked to avoid excessive movement or eye blink during the presentation of stimuli. In the experiment proper, 100 presentations were given at the end of which



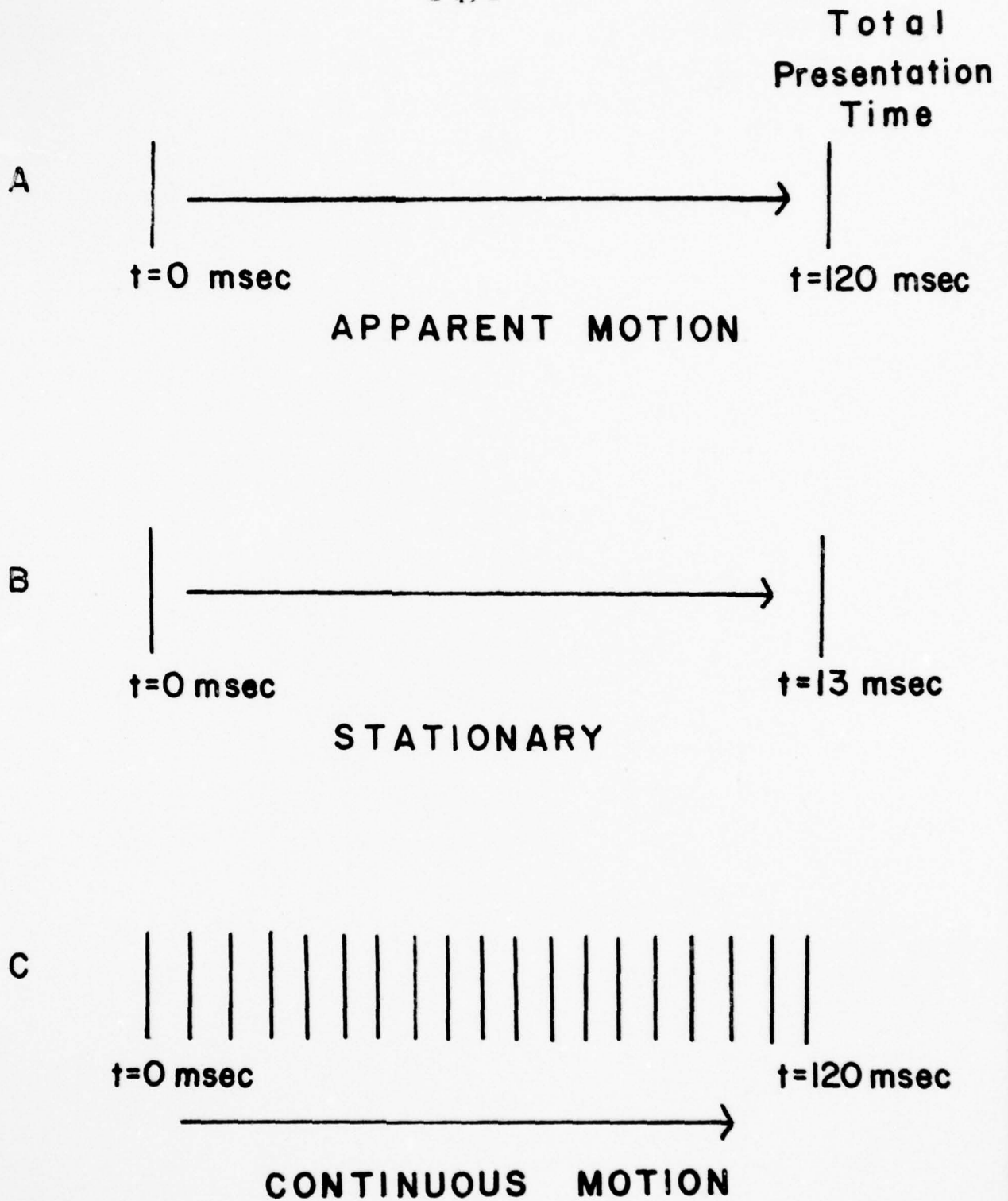


Figure 1 - Schematic of conditions A, B, and C. In condition B the vertical line appeared to the right one second after the first line disappeared. This produced a perception of two simultaneously presented vertical lines.

subjects were asked to draw what they observed in any single presentation.

The three conditions were counterbalanced across the six subjects over a period of three days using a Latin-square design. Each subject was presented with each condition six times during the course of the three experimental sessions, for a total of 18 trials and 18 VEP traces from  $O_z$  and  $C_z$ . This method proved useful in reducing fatigue while also increasing the amount of data collected on each subject.

The perceptual reports of experimental subjects corresponded with those of pilot subjects, i.e., condition A resulted in reports of one line jumping or flashing from left to right, B was perceived as two simultaneous lines, while C was reported as a vertical bar of light moving across the screen.

### Results

The mean amplitudes and latencies of VEPs were computed as previously described (Experiment I) for all subjects and conditions. Table 1 shows the mean amplitude data for the major VEP component N2-P2 for the two scalp locations as a function of condition. Figure 2 depicts the data of Table 1.

Table 1  
Mean Amplitude for the VEP Component N2-P2  
at  $O_z$  and  $C_z$  for Conditions A, B, and C

<u>Placement</u>	<u>Conditions</u>		
	<u>A</u>	<u>B</u>	<u>C</u>
$O_z$	8.0	7.9	7.7
$C_z$	8.8	8.0	6.4

Table 2 shows the mean latency for the P2 component at the

MEAN AMPLITUDE IN MICROVOLTS (P2)

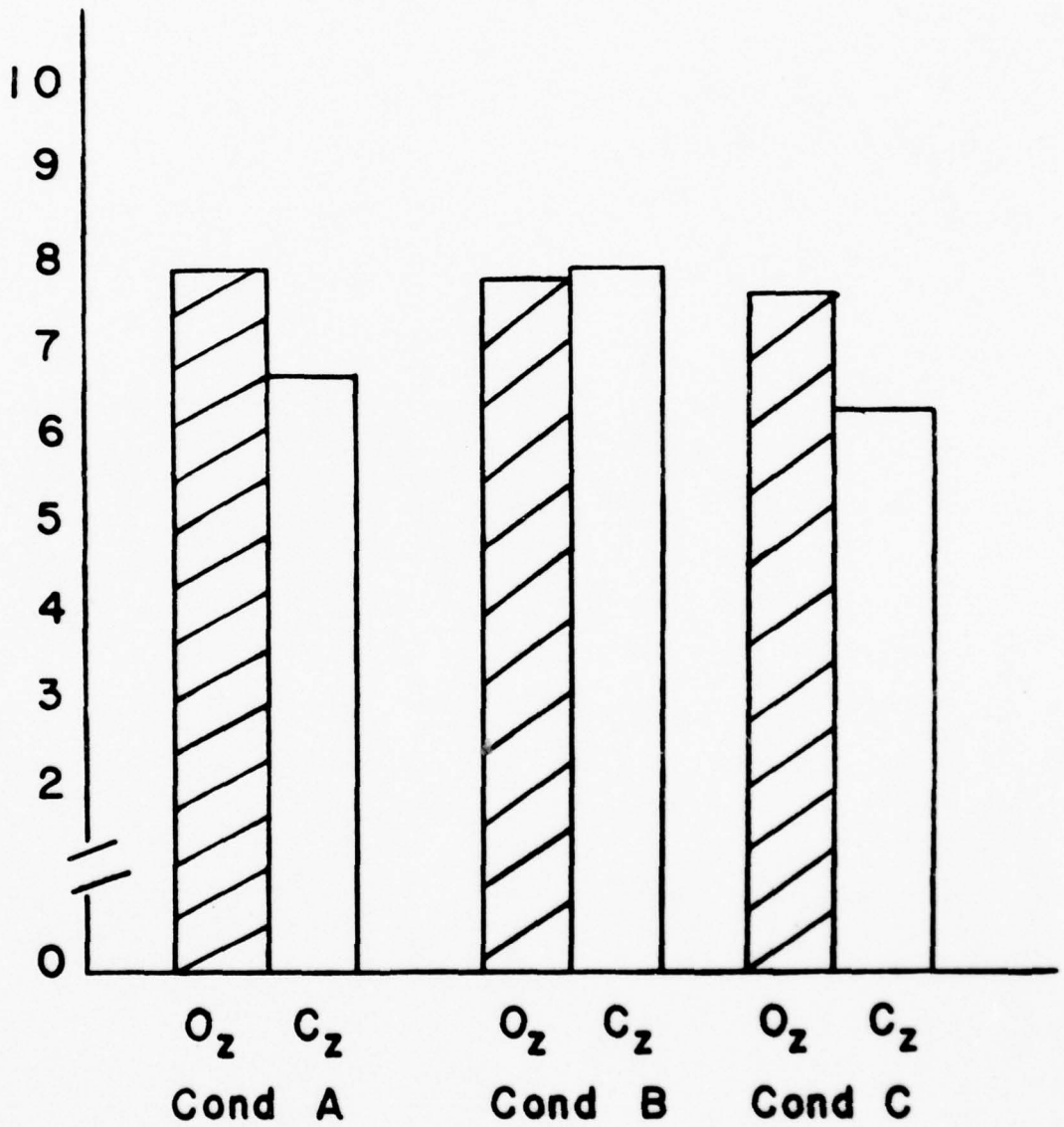


Figure 2 - Mean N2-P2 amplitude of the VEP for Conditions A, B, and C at locations  $O_2$  and  $C_2$ .

two scalp locations as a function of condition. Figure 3 depicts the data in Table 2.

Table 2  
Mean Latency for the VEP Component P2  
at O<sub>Z</sub> and C<sub>Z</sub> for Conditions A, B, and C  
(N=6)

<u>Placement</u>	<u>Conditions</u>		
	<u>A</u>	<u>B</u>	<u>C</u>
O <sub>Z</sub>	211	207	221
C <sub>Z</sub>	228	224	219

The data for the VEP component (N2-P2) were subjected to analysis by t-tests for correlated data. All t-tests were reported through use of a one-tailed criterion since the direction of the results was predicted based on previous work. The results of the t-tests for the amplitude data comparing conditions are presented in Table 3. It should be noted that none of the results obtained were significant at the .05 level.

Table 3  
t-values for Condition Comparisons  
(Amplitudes)

<u>Amplitude (N2-P2)</u>	<u>A vs. B</u>	<u>A vs. C</u>	<u>B vs. C</u>
O <sub>Z</sub>	.33	.46	.80
C <sub>Z</sub>	.31	.05	.27

The results for the latency data are presented in Table 4. The t-value of 2.13 for Conditions A vs. C located at O<sub>Z</sub>, 2.32 for the comparison between Conditions B and C, as recorded from O<sub>Z</sub> were both found to be significant at the .05 level.

MEAN LATENCY IN MILLISECONDS (P2)

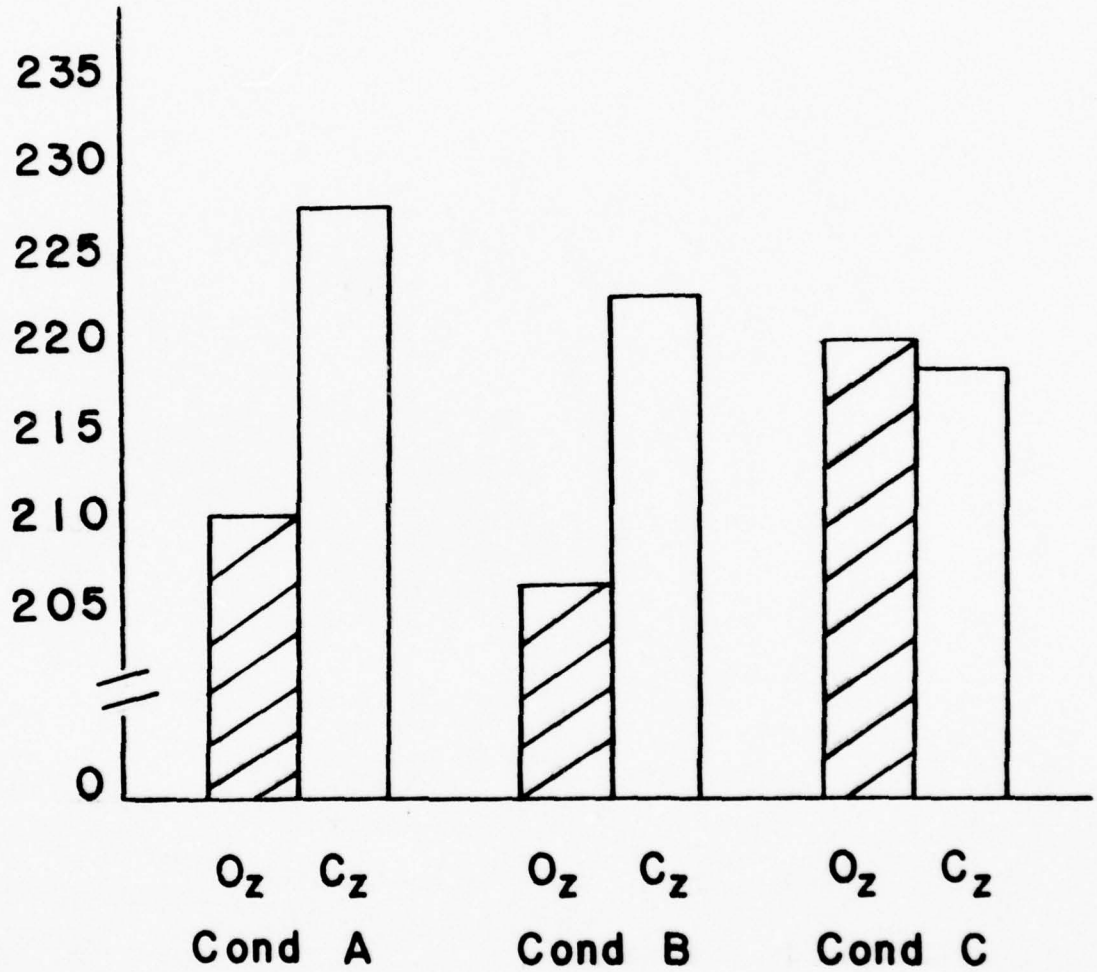


Figure 3 - Mean P2 latencies under Conditions A, B, and C at locations O<sub>z</sub> and C<sub>z</sub>.

Table 4  
t-values for Condition Comparisons  
(Latencies)

<u>Latency (P2)</u>	<u>A vs. B</u>	<u>A vs. C</u>	<u>B vs. C</u>
O <sub>Z</sub>	1.26	2.13 (C > A)	2.32 (C > B)
C <sub>Z</sub>	.56	1.34	.86

Further analysis of the data compares responses for each condition between scalp locations. This information is presented in Table 5. None of the t-values obtained reached significance at the .05 level.

Table 5  
t-values for Condition Comparisons  
(Occipital versus Central Placements)

<u>O<sub>Z</sub> vs. C<sub>Z</sub></u>	<u>A</u>	<u>B</u>	<u>C</u>
Amplitude (N2-P2)	1.01	.50	.72
Latency (P2)	.93	1.29	.14

Analysis of the main VEP components showed that at O<sub>Z</sub>, condition C gave significantly longer latencies than either conditions A or B.

Figures 4 and 5 show the superimposed VEP traces for one subject under the three conditions (scalp locations O<sub>Z</sub> and C<sub>Z</sub>) during one recording session.

#### Discussion

The questions asked at the beginning of this research concerned: 1) whether there would be a difference in the latencies and amplitudes of VEPs under conditions of apparent motion, continuous motion and no motion, and 2) will recordings from the occipital and central

O<sub>Z</sub>

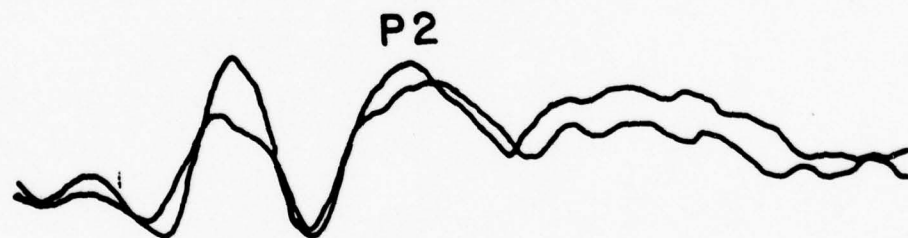
A



B



C



10  $\mu$ V

0 100 200 300 400 500  
TIME IN MILLISECONDS

Figure 4 - Superimposed traces for one subject at location O<sub>Z</sub>. Each trace is based on 100 presentations (negativity is downward).

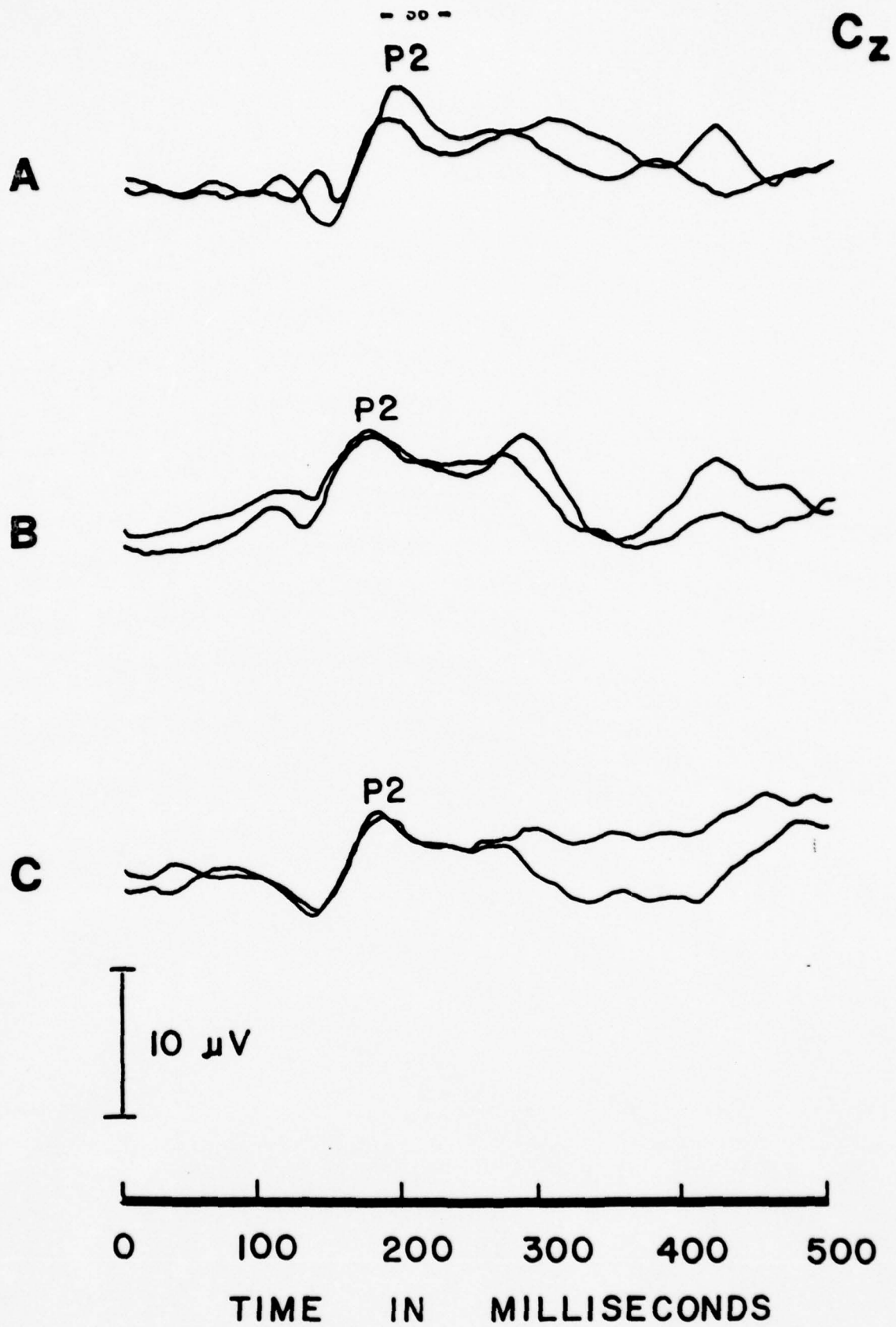


Figure 5 - superimposed traces for one subject at location C<sub>z</sub>.  
 Each trace is based on 100 presentations (negativity  
 is downward).



cortex differ as a function of the different stimulus conditions? Regarding question 1, we see from our results that the major difference between conditions A, B and C was in latency at the occipital site. Condition C showed longer latencies than A and B, but no significant differences were found between conditions A and B. However, if we look at the results obtained in Table 2, we see that the condition involving the perception of stationary stimuli produced the shortest latency, that condition which produced apparent motion showed longer latencies while condition C, or continuous motion, resulted in the longest latency VEPs. Though the difference in latency between conditions A and B is not significant, these results tend to follow a pattern similar to those found by Andreassi et al (1978b). From the results of this previous study, it was found that a condition involving the perception of stationary stimuli produced shorter latencies than those involving movement. One hypothesis which could be drawn from this is that perhaps the visual cortex has less complex processing functions when no motion is perceived than with either type of motion. This interpretation receives support from prior findings, one of which is Andreassi et al (1978a). In this study concerning two velocities of apparent motion and one condition of no motion, it was found not only that the two conditions of apparent motion gave longer latency responses than that of no motion, but also the faster velocity condition produced the longest ERP latencies of all. The results from the present study show that longer latencies were produced by conditions involving movement as compared to the condition perceived as stationary stimuli. Also, in the present study, a longer latency was found for the continuous motion condition as compared to the

apparent motion condition, even though the velocities of the moving stimuli in both conditions were equal. It was hypothesized previously (Andreassi et al, 1978b) that different latency responses between conditions A and C may be due to different velocity detection mechanisms (Kaufman, 1974). However, since the velocities between these two conditions in the present study were kept constant, yet yielded different latency responses, an explanation unrelated to velocity detectors is in order. A simpler interpretation might be that continuous motion requires greater cortical processing time than apparent motion.

Orban's (1977) study dealing with the specialization of neuron cells to motion offers a few suggestions which might reasonably be used to interpret the different responses to stimuli presented at the same velocity. The results from Orban's study showed that the receptive field in area 18 of the cat consists of five types of receptor cells: simple, complex, hypercomplex, direction-independent and amplitude specific cells. Orban also found that all the neurons within area 18 were influenced by the movement velocity of the stimulus presented. Since the velocities of conditions A and C were the same, we would expect neurons in this area concerned with velocity detection to respond similarly. However, although the velocities for conditions A and C were equal and probably did elicit a similar response from the same velocity detection neurons, since subjects' perception of movement differed for these two conditions, perhaps other neurons specific to type of motion (continuous-discontinuous or real-apparent) responded. If such

speculation is the case, then a difference in latency could be expected for conditions A and C since different neurons respond to two types of movement. Also, since the time lag response for condition C was longest, perhaps the pathways leading to this continuous motion detector are longer than those pathways leading to a discontinuous motion detector or a no motion detector. If this is true, this delay in reaching the motion detector may also explain the delayed response of the continuous motion detectors and therefore, the later latency response. These ideas, however, are only speculative and much more research is needed before more definitive proposals may be made.

The last major finding reported in the results of this experiment deals with the lack of significant amplitude and latency differences between  $O_z$  and  $C_z$ . It is interesting to note that in the similar study performed by Andreassi et al (1978b) significant latency differences were reported at conditions B and C, with  $C_z$  producing later responses than those occurring at  $O_z$ . From these results, the experimenters hypothesized that perhaps the occipital area is faster to respond to stationary and faster moving stimuli as compared to the central area. If such were the case, then similar differences between the two scalp locations would be expected in the present study. However, such was not the case, and a look at individual subject responses for amplitude and latency at locations  $O_z$  and  $C_z$  may give some indications as to why significance was not obtained. In reviewing individual subjects' average responses, we found that a great deal of variability exists

among the six subjects on each comparison between the three conditions at  $O_z$  and  $C_z$ . For example, in comparing the scalp locations for amplitude (condition C) three subjects showed greater amplitude responses at  $C_z$ , whereas three subjects had higher amplitude responses at  $O_z$ . Similar results occurred for the A and B amplitude comparisons and for the A, B and C latency comparisons. Due to this high level of variability among subjects, it is, therefore, impossible to suggest an hypothesis which would support or contradict the nonsignificant results obtained.

In summary, it was found that the conditions which simulated continuous (real) motion produced longer latency VEPs (P2) than either the apparent motion or the no motion conditions. This was true for only the  $O_z$  recording site, not  $C_z$ . This result suggests three things: 1) the perception of continuous motion is subserved by different cortical mechanisms than apparent motion, 2) the latency difference may mean that greater cortical processing time is required for apparent motion and no motion perhaps because continuous motion is a more complex perception; 3) the occipital area ( $O_z$ ) is more involved in the differential processing of motion stimuli than the central ( $C_z$ ) area. Taken together these last two points suggest that the visual cortex (occipital) may require greater analysis time with continuously moving (more complex) stimuli versus apparently moving ones or stationary stimuli. These results are interesting and suggestive but require further replication in the form of additional studies of motion, velocities and recordings from various scalp locations. The next study in this annual report is focused upon velocity variation in continuous versus apparent motion conditions.

Experiment IV - Visual Evoked Potentials Under Varied Velocities  
of Continuous and Apparent Motion, and with  
Stationary Stimuli<sup>1</sup>

Movement is perceived as the displacement of an object across the retina or when an object is stationary on the retina and the eye tracks it. For many years it was thought that the perception of motion depended on the sequential stimulation of closely adjacent points on the retina, and that this temporal succession of stimulation was similarly represented in the cortex; hence motion was considered to be a primary visual perception (Boring, 1942). The classic experiment of Wertheimer (1912), provided new information about motion perception. When two lines were presented at two relatively distant points in space, and when the time interval was between 30 and 200 milliseconds the subject reported seeing movement. This experience of motion is called the Phi phenomenon (or beta movement) and often cannot be distinguished from real movement. This result showed that stimulation of closely adjacent retinal areas was not necessary for the perception of motion but it did not rule out the theory that motion was a primary visual sensation.

The variables of intensity, spatial separation between the stimuli, and the time interval between presentations was found to be crucial to the perception of apparent motion. Korte (see Schiffman 1976, p. 261) studied the relationships among these variables and established some general laws on the interaction of these

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<sup>1</sup>This study was conducted in the Psychophysiology laboratory at Baruch College by J.A. Gallichio and was submitted as a thesis for the M.S. in psychology at Hunter College of the City University of New York.

factors. Briefly, the laws concerning the interrelationship of these variables are: 1) when luminance is held constant and the spatial separation between the two stimuli is increased, the time interval between presentations must also be increased in order to obtain apparent motion; 2) when the spatial separation between stimuli is held constant, the luminance of the stimuli should decrease as the time interval separating the two stimuli increases; 3) if the time interval separating the two stimuli is held constant, apparent movement varies with luminance, i.e., luminance should increase as distance between stimuli increases. The different types of apparent motion are alpha, beta, delta, and gamma but the form of movement most often associated with Korte's Laws is beta.

As in apparent motion, real motion also depends upon the factors of luminance, time and distance. The minimal velocity (distance divided by time) that can be detected is the velocity threshold and the minimal distance over which movement can be detected is called the displacement threshold. Graham (1965) reviewed much of the literature on these thresholds and certain points deserve to be mentioned. Graham noted that velocity threshold varies inversely with luminance and stimulus duration and that as velocity increases acuity decreases. Certain relationships hold for both velocity and displacement thresholds. Peripheral thresholds are lower with stationary reference points, and for displacement thresholds, higher luminance resulted in lower thresholds.

Gregory (1973) has outlined two systems for the perception of movement (i.e., image-retina and eye-head). The image-retina system operates when the eye is stationary and the image moves

across the retina. The eye-head system operates when a moving target is tracked by the movement of the eyes and motion is perceived. With these two systems in mind, the conclusion may be drawn that when two different retinal points are stimulated, as in high velocity real movement and apparent movement, the image-retina system may play an important role. The eye-head system, on the other hand, may play an important role in low velocity real motion and apparent motion when the same retinal site is stimulated by successive stimuli.

The result of a study by Rock and Ebenholtz (1962) showed that apparent motion could be experienced when the same retinal area was stimulated by two light flashes. Subjects moved their eyes back and forth so they could view each stimulus foveally. The flashing of the lights, seen through apertures, was synchronized with eye movements. Six of the ten subjects reported seeing a single object in motion. However, when different retinal regions were stimulated by the same stationary flash no motion was perceived. The authors state that their results show that eye movement is not a necessary condition for the perception of apparent motion. Therefore, theories that depend on eye movement effects for apparent motion are in error. Furthermore, the stimulus conditions in apparent motion may be similar to real motion since the intervening positions of real motion are often blurred.

Kolers (1963) conducted several experiments concerning the difference between real and apparent motion with regard to what would happen to a stimulus presented in the space between the initial and terminal positions of the stimuli. The results showed that

when a target was presented in the space traversed by an objectively moving line of light the threshold for detection increased with decreasing distance between the two stimuli. When the same targets and target positions were used in an apparent motion experiment, the same increase in threshold of detection was not observed. Further experiments found that when a supra-threshold object was present in the path of an object in apparent movement, the object in apparent motion appeared to move in depth. Kolers concluded from these results that even though the experience of motion was the same in both situations, they could have been produced by different physiological mechanisms interacting at different places in the nervous system. He went on to say that spatial factors might influence real motion and that temporal factors may influence apparent motion more directly.

The discovery of cortical and retinal cells which respond to movement (Hubel and Wiesel, 1962 and Barlow and Hill, 1963) lent strong support to the idea that there were particular physiological mechanisms involved in processing motion information. For example, in studying the visual system of cats, Hubel and Wiesel found cortical cells that responded only when their receptive field was stimulated by a moving bar, but did not respond when the bar was stationary. Barlow and Hill found ganglion cells in the retina of the rabbit that responded to motion in certain (specific) directions only.

Sekuler and Ganz (1963) conducted an experiment relating to directional sensitivity. Their hypothesis was that if motion perception was mediated by cortical motion detectors, then viewing motion in one direction should decrease that detectors sensitivity



and elevate the threshold for motion in that direction. The experimenter had subjects view stripes that moved in one direction for five seconds under stabilized retinal image conditions. Then subjects were tested for luminance thresholds for stripes that moved in the same direction or in the reverse direction. In every subject the threshold for motion in the same direction as the previously viewed pattern was elevated. This finding supported an idea that there were specific motion detecting systems in humans.

A similar method was used by Clatworthy and Frisby (1973), in a study on the differences between real and apparent motion. They hypothesized that if real and apparent motion were mediated by the same mechanisms, then adaptation caused by long exposure to real motion should affect the subsequent perception of apparent motion. Grids of three lines were used and real motion was presented as a single grid mounted on a motor driven shaft. Apparent motion was generated by two fixed grids alternately illuminated. Control conditions consisted of two stationary grids and flickering stationary grids. The findings showed that movement perception times following real motion adaptation was only about 50% of those following both stationary and flickering grids. The experimenters took these results to mean that real and apparent motion were mediated by the same mechanism. They went on to say that it was unlikely that the adaptation observed took place because of factors other than adaptation to motion since the same type of adaptation effect was not observed with the stationary or flickering grids.

Schouten (1967) attempted to explain motion perception by postulating a model for velocity detecting mechanisms. According

to this model, two receptors must be stimulated within a certain time period, this time period is determined by the temporal setting of a coincidence detector. The coincidence detector would fire only when the proper time and space relationships were met. Kaufman (1974) draws from his own research concerning the relationships between real and apparent motion and posits that these two experiences may be complementary (i.e., different underlying mechanisms) rather than parallel processes. In one of Kaufman's studies an observer viewed the luminous part of a rotating curve through a slit, under three conditions. In the first condition the subject saw both stationary and moving segments of the line. In the second condition the subject saw only the alternating stationary end points of the line. The third condition allowed for the subject to see only the moving segments of the line. The results showed that in the first condition movement was perceived, and the line blurred when the velocity was about 10.6 degrees of arc/second. When only end points were visible, apparent motion occurred and no blurring of the line occurred (velocity of 8.9 degrees/second). Kaufman concluded that apparent motion occurred when an object in real motion began to streak or blur. Kaufman interprets these results as supporting the idea that real and apparent motion are complementary and not parallel processes. One set of velocity detectors would respond when the movement of an object in real motion is slow. These receptors would not respond when only two points in their field were stimulated as in apparent motion. Another set of detectors would respond when two points in their receptive field were stimulated in rapid succession. These receptors would be the same for high-velocity real and apparent movement.

Recently, Bonnet (1975) presented a model for the perception of motion that has some very compelling points to it. In this model two subsystems exist, one is the Displacement Analyzing System (D.A.S.), which gives rise to the experience of something changing place in time in a given direction. According to Bonnet, motion would be detected in this system by the processing of the stationary or terminal points of a stimulus that was moving. This process would also incorporate the comparing of the final position of an object with the memory trace of its original position. A second system, the Movingness Analyzing System (M.A.S.) would discriminate between moving and stationary stimuli. When this system was active, motion detecting cells would signal the presence of motion in the visual field. Through a series of experiments Bonnet demonstrates how these two systems would work under three types of motion. In one condition (continuous motion) the moving objects appear while in motion and disappear while in motion (CM). A second condition was one where discrete presentation of displacement was used, called apparent motion (AM). A third condition (stop-go-stop motion) combines both of the other types, i.e. one continuous motion is presented between two stationary positions. The M.A.S. system would primarily process a continuous motion presentation, while the D.A.S. would come into play with stop-go-stop motion and discrete motion conditions.

Tolhurst (1973) using adaptation examined the effect of temporal modulation i.e., movement, on channels sensitive to spatial frequency information. In the experiment subjects viewed sinusoidal gratings that either were moving or were stationary. Stimuli were presented on an oscilloscope and subtended 4.1 degrees of arc.

Subjects set contrast thresholds at the point where the screen was not spatially or temporally uniform. When the gratings were stationary, the subject was allowed to move his eyes so that the image did not fade. The gratings had spatial frequencies from about .4 cycles/second to 10 cycles/second and drifted at 5 cycles/second from right to left. The results showed that adaptation to drifting gratings caused threshold elevation that was spatially and directionally sensitive, but little difference was found between drifting and stationary gratings with respect to contrast threshold elevation. When the adapting grating drifted in the opposite direction of the test grating the contrast threshold was lower than when the test and adapting grating moved in the same direction. Both curves peaked at the same spatial frequency.

Tolhurst interpreted his results as indicating that spatial frequency channels are of two classes: Movement dependent, which were temporally sensitive, and movement independent channels, which respond to both stationary and moving gratings. Thus, this second channel would be involved in the analysis of the spatial structure of the stimulus whether or not the stimulus was moving. This was seen in the result that adaptation to both stationary and moving gratings elevated the threshold for stationary gratings at all spatial frequencies.

From the models presented by Bonnet (1975), and Tolhurst (1973) the basic parameter of space and time interact in a unique way giving rise to the perception of motion. Bonnet (1977) shows that these two models are consistent to some degree with each other. The displacement analyzing system of Bonnet would be similar to the movement independent channels described by Tolhurst.

Both these systems would respond to stationary or stationary like features of the stimulus, i.e. apparent motion and stop-go-stop motion. Whereas the motion analyzing system would be similar to the movement dependent channels. These two models process continuous motion by some type of temporally sensitive velocity detectors.

As previously noted, Hubel and Wiesel (1962) have shown that cells in the cortex of the cat are sensitive to motion in their receptive fields. Further evidence for specialized, motion sensitive, cells in the cortex of the cat has been presented by Orban (1977). Orban measured the firing rate of cells in area 18 of the cat in response to gratings and random square patterns that varied in three movement parameters: velocity, direction, and length. His results showed that of the cells which responded to motion about half were direction specific, i.e., responded to only one direction of movement. All neurons were influenced to some degree by velocity and most of these cells were classified as complex and hypercomplex. From these findings, Orban states that area 18 is specifically involved in the processing of motion in the frontal plane. He goes on to speculate that in area 18 simple and complex cells operate in parallel since velocity and amplitude functions for complex cells are similar, with both types of stimuli, but simple cells only responded to gratings. He deduces from this that detection and analysis of motion are processed by two different systems operating in parallel. He concludes by positing that a simple cell chain may be responsible for the analysis of the moving pattern, but that complex cell chains would be responsible for motion detection. Both systems could and should have subcortical projections.

Therefore, there seems to be evidence here for two systems operating to process motion information, one for form and the other for movement itself.

Thus, Hubel and Wiesel (1962) and Orban (1977) do provide some evidence for motion sensitive cells in the cortex of animals such as the cat. Tolhurst (1973) shows suggestive evidence for channels in the human visual system that are sensitive to or respond specifically to motion. The question that may be asked now is whether or not the electrical activity of the human brain can manifest the activity of the proposed channels or systems.

Coffin (1977) studied the effect of the quality of apparent motion on the electroencephalogram (EEG). Two small squares were presented on an oscilloscope, separated by about  $3.5^{\circ}$  of arc. Interstimulus intervals (ISI) ranged from 10 to 90 msec and electrodes were placed at occipital and parietal areas. The results showed that when the quality of apparent motion was high it produced faster EEG activity at the short ISI's, i.e. peak frequency shifted downward as ISI increased at mid-occipital area. The right occipital area showed the same tendency though not significantly, and the left occipital did not differ with the quality of motion. Coffin points out that the spatiotemporal nature of the task might explain why the right hemisphere was effected more than the left. Yet, the only significant effect was at the midline placement.

Another, EEG derived, form of recording the electrical activity in the brain has been called "event-related potential" (ERP) by Vaughan (1969). These event-related potentials can be recorded in response to a specific stimulus for a particular modality,

e.g., visual stimuli produce visual evoked potentials (VEP) and auditory stimuli produce auditory evoked potentials (AEP). Barlow (1964) recorded VEP's to sudden changes in the vertical position of a spot on an oscilloscope and photic stimulation. The recordings showed a definable component at approximately 80 msec for spot shift trials and a component as early as 25 msec for photo stimulation. The amplitude of the movement elicited component was increased when tracking was performed. Barlow points out that the evoked responses were not produced by eye movement artifact since there were no consistent relationships between the electrooculogram (EOG) and the VEP. The clearest result of this study was the fact that evoked potentials could be elicited by a moving stimulus.

Mackay and Rietveld (1968) examined the questions, A) whether any evoked potentials could be detected when a stationary stimulus was set in motion, and B) whether a reference point effected the form of any detected response. The stimulus was a single horizontal seven cm. line displaced vertically. The main results of this experiment showed that evoked potentials were obtained when the line moved from rest at a velocity of 2 cm second. The magnitude of the VEP component at approximately 60 msec was affected by the presence of a reference line and the number of lines in motion, but not by direction. The question arose as to whether these evoked potentials were due to the momentary presentation of the stimulus at zero velocity. Clarke, (1972) used a noise slide pattern that had a contrast ration of 1 log unit and an intensity of 0.8 log foot Lamberts. The pattern moved at a constant speed horizontally and took 0.5 seconds to reverse and was presented under conditions of periodic (continuous line) and aperiodic

(discontinuous line) stimulation. No significant differences in the VEP occurred within the first 180 msec.

Further experimentation showed that when reversal was virtually instantaneous, as compared to an optically switched condition, no differences in the VEP to the two conditions were found. Clarke suggested that if the VEPs observed were not due to momentary stationary appearance of a motion reversal stimulus, they may be due to contrast sensitive mechanisms rather than motion sensitive mechanisms. A final part of Clarke's study showed that the amplitude of the VEP decreased with increased velocity from  $3^{\circ}$  to  $90^{\circ}$ /second.

Clarke (1973, a and b) measured VEPs to a visual noise pattern under conditions of motion onset, motion offset, and motion reversal and compared them to VEPs to the appearance and disappearance of stationary and moving noise patterns. When comparing motion offset, motion reversal and the appearance of a stationary pattern, Clarke found no difference in the VEPs to these three conditions, but motion onset VEPs were different from motion offset and pattern reversal VEPs in that the latency of the 140 VEP component increased to about 170 msec at low velocities. Lower amplitudes, as velocity increased, were observed for pattern appearance and disappearance for moving stimuli. Pattern appearance and disappearance VEPs were different for moving and stationary conditions, i.e. stationary patterns had larger amplitudes. Clarke took these findings as evidence for a conclusion that motion sensitive mechanisms in the visual system accounted for the VEPs to motion onset and offset.

Andreassi et al. (1973) studied VEPs under two conditions of



apparent motion and one condition which did not produce apparent motion. In all conditions 20 Xs, of identical intensity and presentation time were presented sequentially on a CRT screen. Different display orders produced different perceptual experiences. In one condition the Xs appeared to converge towards the center from left and right, and in a second condition the Xs appeared to diverge from the center in both directions. In the third condition subjects reported seeing about 10 Xs with spaces between them. The VEPs were recorded from  $O_1$  and  $O_2$  and did not differ under the three conditions. Perhaps the difference between the Andreassi study and the other studies noted was due to the use of real motion by the others as opposed to apparent motion.

Andreassi et al. (1979) compared apparent motion at two velocities,  $7^\circ/\text{sec}$  and  $14^\circ/\text{sec}$ , to a no motion condition. Under all these conditions the subjects viewed one X on the CRT screen for 20 msec followed by a second X 2.8 cm. to the right of the first. In the no motion condition an ISI of one msec produced the impression of simultaneous presentation of the two Xs. The main finding of this experiment was that the P2 component of the VEP took significantly longer to occur under the apparently faster condition ( $14^\circ/\text{sec}$ ) when compared to the other two conditions. There were no significant amplitude differences as a function of condition but the occipital-midline recording site had shorter latencies and larger amplitudes than central and frontal areas. Using the velocity detecting model of Kaufman (1974), Andreassi et al. discussed the longer latency responses for the faster apparent motion condition in terms of a "pre-set time constant" needed to transmit a signal to a motion detector. They proposed

that  $7^{\circ}/\text{sec}$  velocity was not quite fast enough for the motion detectors to be stimulated. Instead this slower velocity may have stimulated other areas which were quicker to respond to the two Xs in terms of features other than the so-called true motion detector. The fact that there were no significant differences between the slower apparent movement and the stationary presentation suggest that similar mechanisms in the visual system process both stationary and slow moving stimuli. The higher amplitudes at the occipital region as compared to other recording areas reflects the role of the visual cortex as primary processor of visual information. It is also possible to state from these results that the occipital cortex may play a role in detecting the differences in motion velocities.

In another study, Andreassi et al. (1979) recorded VEPs under conditions of apparent motion, no motion, and continuous motion. Vertical lines were used and the two motion conditions had the same velocity i.e.,  $9.26^{\circ}/\text{sec}$ . The continuous motion condition consisted of 19 lines presented in succession from left to right. The same temporal and spatial relationships were used for the two motion conditions and the total luminous energy for all conditions and was constant at 7.0 mL. The stationary condition used an ISI of one msec between two lines and this resulted in the perception of simultaneity. The continuous motion condition resulted in significantly longer latencies than the no motion and apparent motion conditions (see Experiment III, this report). There was some evidence to show that the stationary condition produced shorter latencies than the motion conditions. These findings provide some support for

a hypothesis that apparent motion and continuous motion may be processed differently at the cortical level. It was suggested further that it takes less time to process stationary as opposed to moving features of a stimulus. The amplitude data showed no significant differences between occipital and central areas.

At the present time there seems to be strong evidence that VEPs occur in response to moving stimuli of various types, i.e. lines, patterns, gratings, and motion reversal. There is also some evidence for differences in the VEP wave-form as a function of type of motion, velocity, and cortical area sampled. The present study was designed as an extension of the Andreassi et al. (1979) study on differences between real and apparent motion. Three velocities and two electrode placements were used in order to obtain more information about the role of these factors with regard to motion perception.

The research questions asked are: 1) Will VEPs differ with continuous motion as opposed to apparent motion when velocity is held constant? 2) What VEP characteristics occur to no motion as compared to both continuous and apparent motion? 3) Within each type of motion, what effect will velocity have on the VEP? 4) Will conditions of apparent motion, continuous motion and no motion differ as a function of recording at occipital and central sites?

#### Method

Subjects: The subjects were four males and three females associated with the City University of New York. None had visual system defects other than myopia (corrected to at least 20/25).

Apparatus and Procedure: The apparatus used to obtain the VEP included a Beckman Dynograph, a computer of average transients (CAT/1000), and X-Y plotter and a PDP-8/E computer with its associated Teletype. Stimuli were displayed on a VR-14 CRT (Digital Equipment Corp.) which was mounted at the subject's eye level. The subject viewed the displays from inside an electrically shielded and sound-attenuated IAC Chamber. The CRT was under program control of the PDP-8/E computer. A small fixation point, 3mm in diameter, was used to maintain the subject's line of vision towards the center of the CRT. The fixation point was a dim (0.001 mV) red neon light source located 6mm above the center of the stimulus display. A Bausch and Lomb chin rest was used to keep the subject's head in a fixed position. The computer was programmed so that the total luminous energy appearing on the CRT was equal under all stimulus conditions at 6.68 mV.

The averaged even-related potential (ERP) was obtained from  $O_2$  and  $C_2$  (Ten-Twenty System, Jasper, 1958) with Grass silver cup electrodes referenced to a silver clip electrode on the subject's left ear lobe. The Beckman Type RM Dynograph recorder was used to record the EEG and the Mnemotron Computer of Averaged transients (CAT/1000) was used to average the responses to stimuli. The 9806A coupler of the Dynograph was used to condition the EEG signal (bandpass set at 0.5 to 32.0 HZ). The filtered and amplified signal was then fed into the CAT. A "start" signal from a PDP-8/E digital computer triggered the CAT to take EEG samples of 500 msec duration following the presentation of each stimulus to the subject. After 100 stimulus presentations, the summated ERPs were plotted from CAT memory on a Hewlett-Packard X-Y plotter.

The electro-oculogram (EOG) was measured by a separate channel of the Beckman Dynograph and was conditioned by a type 9859 coupler. On-line monitoring of the EOG was accomplished with a Tektronix 502A oscilloscope and any trials suspected of contamination by eye movement or eye blink were discarded. At the end of each trial, the subjects were asked to draw what they had seen.

There were seven conditions consisting of three apparent motion conditions, three continuous motion conditions and one stationary or no motion condition. In the apparent motion conditions a .5 cm vertical line was presented for five msec followed by a second line 2.80 cm to the right of the first line at inter-stimulus intervals (ISI) of 175, 107, and 73 msec. This method resulted in the perception of Beta type apparent motion. In the continuous motion conditions the single line appeared on the screen for five msec followed by 18 successive lines at on and off times that summated to equal the ISI used in the apparent motion conditions. Thus both types of motion were equated for velocity. i.e.  $8^{\circ}$ ,  $13.08^{\circ}$  and  $19.18^{\circ}$  per second. In the continuous motion condition, as defined in this experiment, the perceptual experience was that of a single line moving across the CRT screen at different speeds. The characteristics of the display system used, made this the best approximation of the experience of "real motion." Pilot screening of the experimental conditions with four observers showed that in all motion conditions motion was perceived. In the stationary condition a single line was on the screen for five msec followed one msec later by a second line 2.80 cm to the right of the first line. Thus, in all conditions the same spatial, temporal and luminance levels

were used. See Figure 1 for a schematic representation of the two types of motion conditions.

In summary:

- Condition A - Apparent motion at  $8^{\circ}$ /sec velocity.
- Condition B - Apparent motion at  $13.08^{\circ}$ /sec velocity.
- Condition C - Apparent motion at  $19.18^{\circ}$ /sec velocity.
- Condition D - Continuous motion at  $8^{\circ}$ /sec velocity.
- Condition E - Continuous motion at  $13.08^{\circ}$ /sec velocity.
- Condition F - Continuous motion at  $19.18^{\circ}$ /sec velocity.
- Condition G - Stationary condition.

In every instance there was 1500 msec between each condition. For example, two lines were presented in rapid succession followed by a pause of 1500 msec, and then the next set of lines appeared. The 2.80 cm separation between the first and last line in the series produced a visual angle of  $1^{\circ}24'$  of arc at a viewing distance of 114.3 cm (45 in.). The seven experimental conditions were counter-balanced across subjects, in three experimental sessions for a total of 21 ERP traces from both  $O_z$  and  $C_z$ .

The data analysis was accomplished by computing the mean amplitudes ( $\mu V$ ) and latencies (msec), for each subject, for the obtained VEPs. The N1 component was considered to be the first negative dip in the trace, from the baseline, which occurred 50 msec after the stimulus. The baseline was determined by the initial horizontal portion of the X-Y plot. The N1-P1 component was measured as the vertical distance from the trough of the N1 component to the first positive peak. The N2-P2 component was measured as the vertical distance between the second depression (trough) and the second peak. Latencies (or time after stimulus presentation) were measured to the midpoints of each positive and

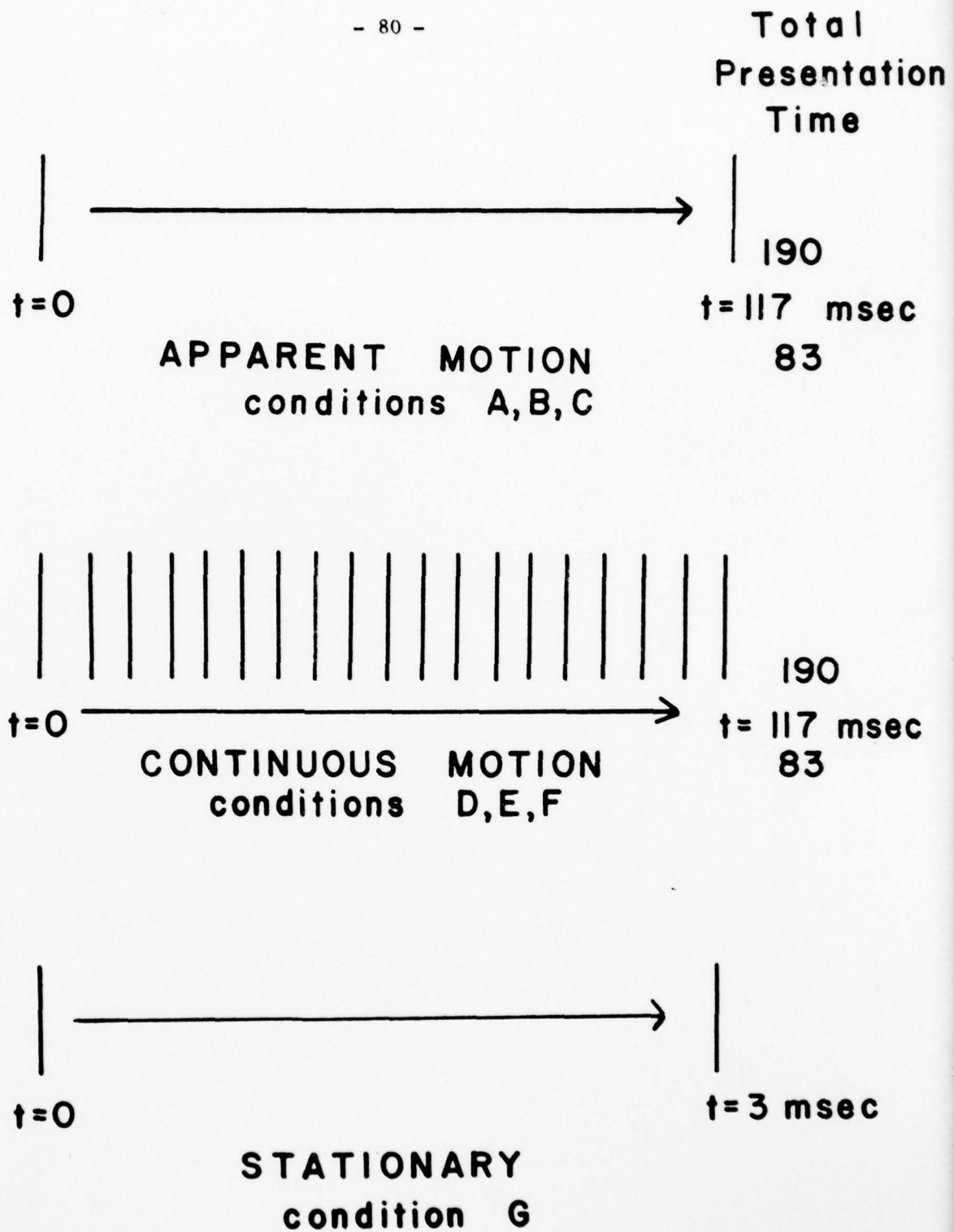


Figure 1 - Schematic of the two motion and one stationary conditions used in this experiment. The apparent and continuous motion conditions were presented at three different velocities, as described in the text.

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.

### Results

The perceptual reports and diagrams produced after each condition indicated that in conditions A through F all subjects reported seeing motion from left to right. In conditions A, B, and C (apparent motion) all subjects reported seeing one line either jumping or flashing across the CRT screen. Three subjects reported seeing more than two lines in conditions A and B. In conditions D, E, and F (continuous motion) all subjects reported seeing one line or bar moving across the screen. In condition G (stationary condition) all subjects reported two stationary lines flashing on and off.

The mean amplitude data for major VEP component N2-P2 is presented in Table 1 for all conditions and recording locations. The N2-P2 component proved to be the most consistent and reliable of the VEP components in the present study.

Table 1  
Mean Amplitude (uV) for the VEP  
Components N2-P2, for all Conditions  
(N=7)

<u>Conditions</u>	<u>Scalp Locations</u>	
	<u>O<sub>z</sub></u>	<u>C<sub>z</sub></u>
A	6.29	6.31
B	5.64	6.55
C	5.55	6.38
D	5.95	6.52
E	6.81	6.12
F	8.14	7.52
G	7.36	6.40



Table 2 shows the mean latency data for N2 and P2 components of the VEP for all conditions and recording locations. The information in Table 1 is graphically represented in Figure 2.

Table 2  
Mean Latency (msec) for VEP  
N2 and P2 for all Conditions  
(N=7)

CONDITIONS	Scalp Locations			
	VEP Components			
	O <sub>z</sub>		C <sub>z</sub>	
	N2	P2	N2	P2
A	159	215	150	210
B	161	213	150	204
C	161	218	147	215
D	160	219	153	219
E	156	220	151	215
F	158	229	148	212
G	157	212	140	203

The data for the main VEP components of amplitude and latency were subjected to analysis of variance (ANOVA). A three way fixed model was used (Winer, 1971). To assure that the data would conform to the assumptions of the ANOVA a log transformation of all raw data was performed. The results of the ANOVA for the VEP components, N2 and P2, and N2-P2 are presented in Table 3.

From the information in Table 3 it can be seen that the main effects of subjects, and conditions were significant for all components. A Newman-Keuls multiple comparison test (Winer, 1971) was used to further examine the observed differences. The N2 latency component at O<sub>z</sub> showed that there were no significant differences between conditions, ( $p > .05$ ). At the central area,

TABLE 3  
 SUMMARY OF THE RESULTS  
 OF THE

ANOVA FOR N2, P2, and N2-P2 COMPONENTS

SOURCE	N2 LATENCY F VALUE	P2 LATENCY F VALUE	N2-P2 AMPLITUDE F VALUE
SUBJECTS (SUB)	7.75 (6/196)**	3.33 (6/196)**	13.53 (6/196)**
CONDITIONS (COND)	3.75 (6/196)**	4.00 (6/196)**	3.44 (6/196)**
PLACEMENTS (PL)	84.00 (1/196)***	9.67 (1/196)**	.06 (1/196)
SUB X COND	1.25 (36/196)	1.17 (36/196)	1.17 (36/196)
SUB X PL	17.50 (6/196)**	9.17 (6/196)**	4.41 (6/196)**
COND X PL	2.25 (6/196)*	1.33 (6/196)	3.29 (6/196)**
SUB X COND X PL	1.25 (36/196)	.83 (36/196)	.63 (36/196)
ERROR	.004	.006	.129

\*p < .05  
 \*\*p < .01  
 \*\*\*p < .001

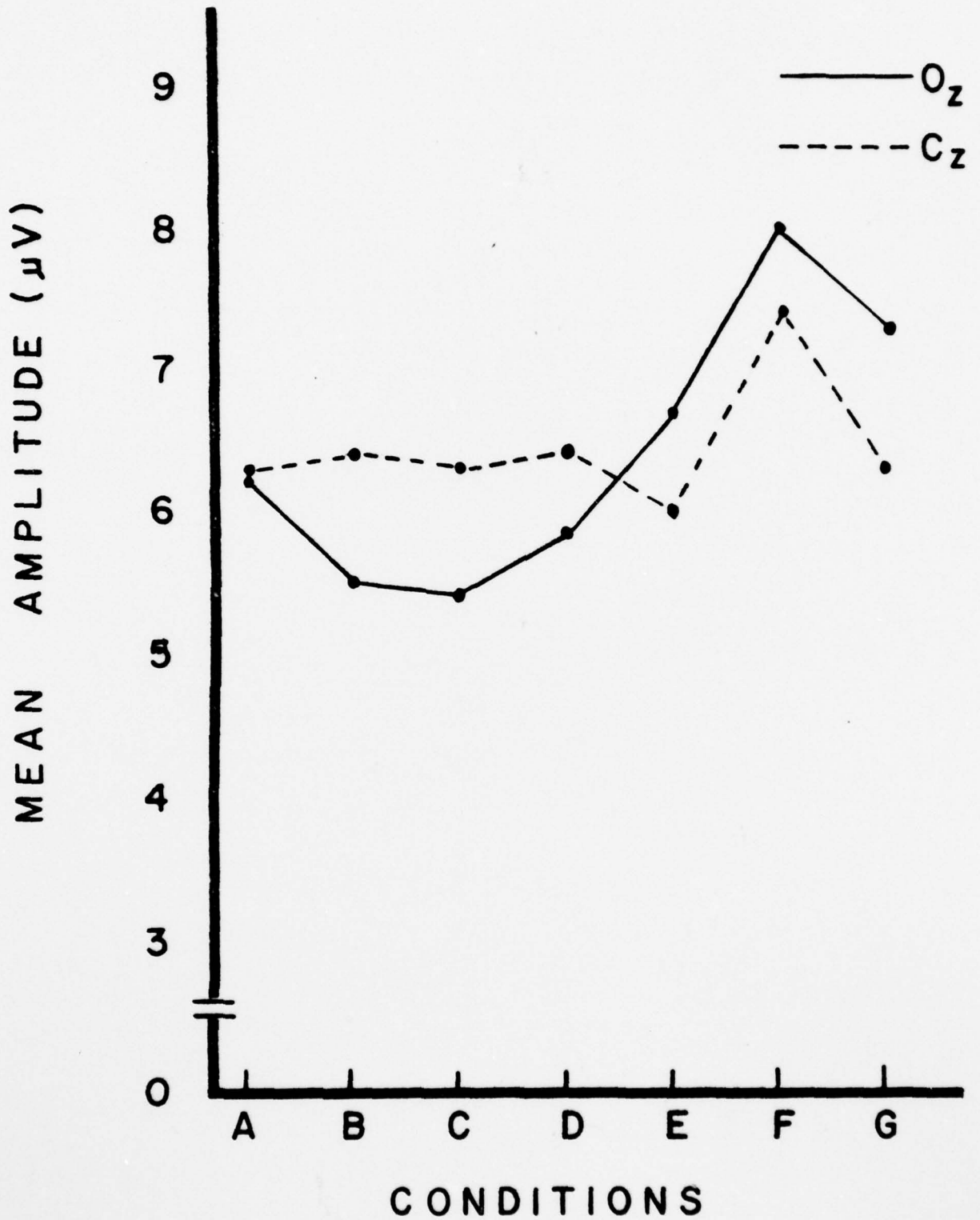


Figure 2 - Plot of significant condition by placement interaction under various conditions of this experiment.

the stationary condition produced significantly shorter latencies than all other conditions ( $p < .01$ ). The P3 latency component comparison at the occipital recording site showed that the highest velocity continuous motion condition had significantly longer latencies than all other conditions,  $p < .05$  for continuous motion at  $8^{\circ}$  and  $13.08^{\circ}/\text{sec.}$  and  $p < .01$  for all other conditions. The P2 component for the stationary condition was significantly shorter than the three continuous motion conditions, and the highest velocity apparent motion condition, ( $p < .01$ ).

The N2-P2 amplitude comparison at the occipital recording site showed that the highest velocity continuous motion condition produced significantly larger amplitudes than the three apparent motion conditions and the lowest velocity continuous motion condition. The amplitude of the N2-P2 component for the stationary condition was significantly larger than the two highest velocity apparent motion conditions ( $p < .01$ ). There were no significant amplitude differences at the central recording area ( $p < .05$ ).

The placement main effect significant for both N2 and P2 latency and showed that in both cases the latencies recorded from the central area were shorter than those from the occipital area. A significant interaction was obtained for N2-P2 amplitude (Condition X Placement) which can be observed in Figure 2. The super-imposed traces for one subject (M.L.) are presented in Figures 3 and 4 for all conditions and recording locations.

O<sub>z</sub>

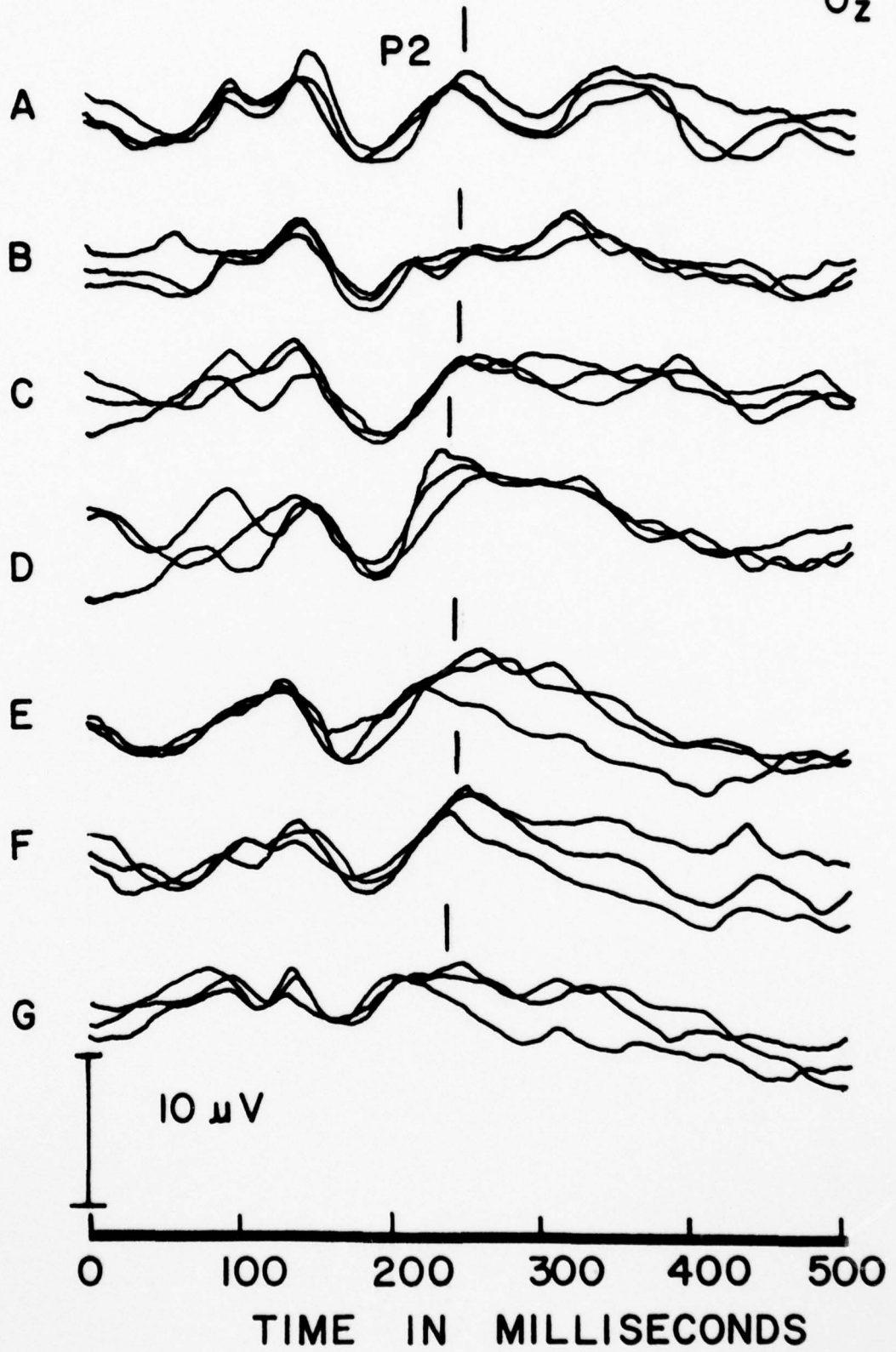


Figure 3 - Superimposed traces for one subject at location O<sub>z</sub>. Each trace is based on 100 presentations (negativity is downward). The vertical line over each trace indicates the P2 component.

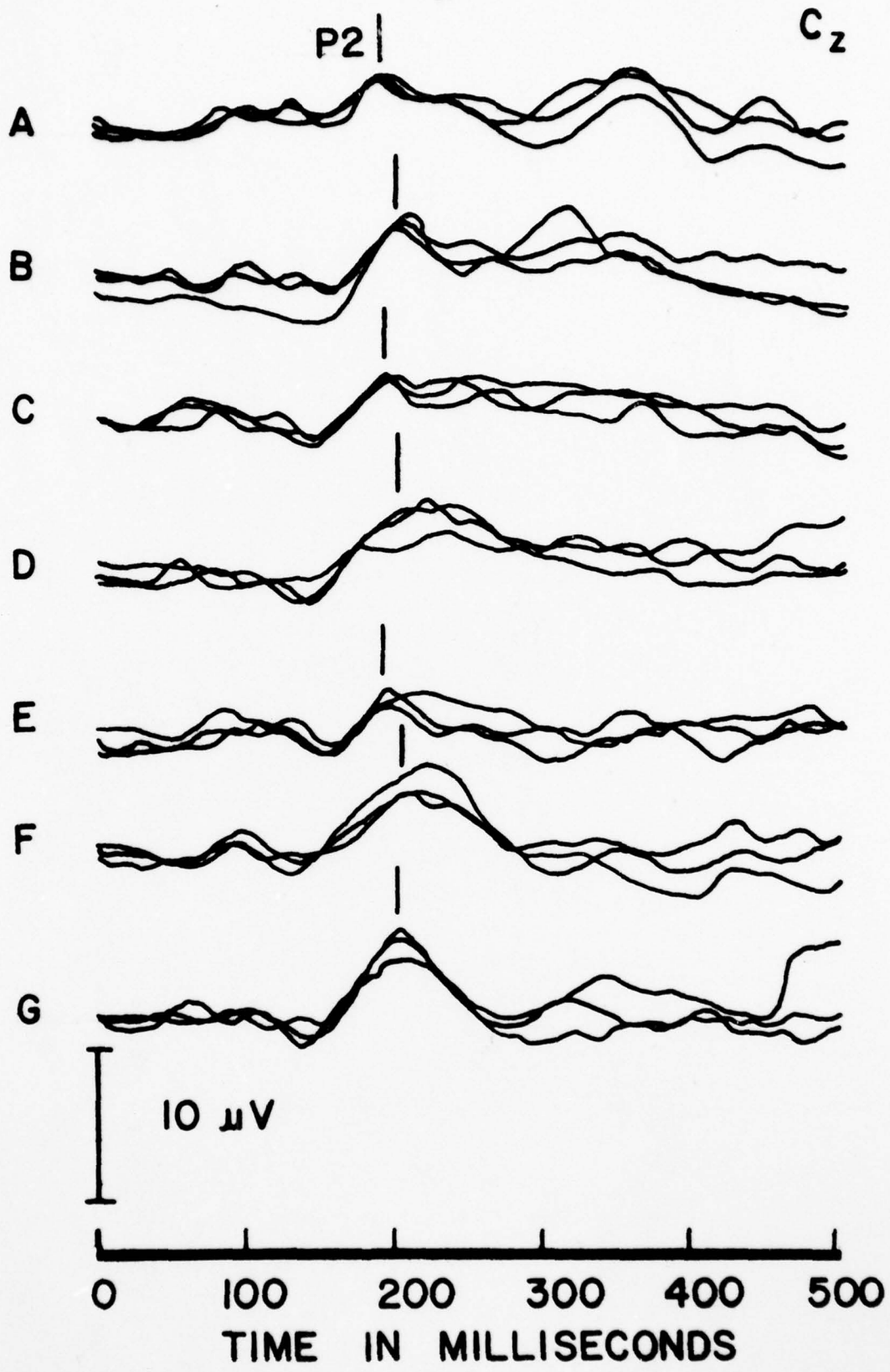


Figure 4 - Superimposed traces for one subject at location  $C_z$ . Each trace is based on 100 presentations (negativity is downward). The vertical line over each trace indicates the P2 component.

Discussion

The questions asked at the outset of this study were addressed to VEP differences between continuous and apparent motion, motion versus no motion, the effect of velocity on continuous and apparent motion, and differences between occipital and central recording sites. The results of the present experiment show that there are differences in the VEPs recorded from the occipital site to continuous and apparent motion as seen in the finding that the highest velocity ( $19.18^{\circ}/\text{sec}$ ) continuous motion condition produced longer latencies and larger amplitudes than the other motion conditions. In addition, the moderate velocity ( $13.08^{\circ}/\text{sec}$ ) continuous motion condition produced longer latencies than the apparent motion condition at the same velocity. Thus, a major finding is that two of the continuous motion conditions result in longer latency VEPs than similar velocity apparent motion conditions.

Taken together these results indicate there is a greater amount of cortical activity (amplitude) and processing time (latency) with continuous motion as compared to apparent motion, especially at the higher velocities. Also suggested by these results is that the human visual system processes these two types of motion differently.

Another finding was that the highest velocity apparent motion condition produced longer latency responses than the moderate velocity apparent motion condition. The N2-P2 amplitudes for continuous motion were larger than the amplitudes for apparent motion. This non-significant trend was clearest for two highest velocity continuous motion conditions at the occipital recording

area. Also, the stationary condition produced significantly shorter VEP latencies than all motion conditions at the central recording site.

Clarke (1973 a and b) reported that stationary patterns produced shorter latencies than moving patterns, a finding consistent with those in the present experiment. Other findings similar to those obtained in the present study were reported by Andreassi, et al. (1979). These investigators found that the P2 component of the VEP took significantly longer to occur under the highest velocity apparent motion condition when compared to a no motion and slower velocity condition. In a second experiment a continuous motion condition resulted in significantly longer latencies than an apparent motion and a no motion condition. The present study has also shown that continuous motion requires more processing time when compared to apparent motion and that within apparent motion longer latency VEPs are associated with higher velocity conditions.

The present results are not like those of Clarke (1972) who found no differences between conditions of continuous and discontinuous motion and that the amplitude of the VEP component in the first 180 msec decreased with increasing velocity. The differences between Clarke's findings and those of the present study may be due to the use of noise slide patterns in his investigations as compared to vertical lines used here.

Bonnet (1975, 1977) provides a comprehensive model of a motion information processing system that seems to account for the results obtained in the present study. For the experience of continuous motion Bonnet proposes a Movingness Analyzing



System (MAS) which would process motion information by activating cells that only respond to continuous motion. The activity of these cells may be reflected in the longer latency and higher amplitude VEPs in the present study to continuous motion when compared to apparent motion. Empirical evidence for the existence of such cells in cats has been reported in the work of Hubel and Wiesel (1962). These researchers found specialized cells in the cortex of the cat that only responded to a moving bar of light. The continuous motion conditions in the present experiment did provide this type of perceptual experience as evidenced in the subject's perceptual reports. Bonnet proposes a Displacement Analyzing System (DAS) which is involved with the processing of a stimulus that changes position over time. This is accomplished through a comparison of the initial and terminal positions of the stimulus. In apparent motion the subject experiences a stimulus that makes an abrupt change in position and only has an initial and terminal location. The present results concerning apparent motion suggest that the more abrupt (higher velocity) the change in location, the more time is required by the DAS to process this information.

Orban (1977) presents a dual cell chain system to process motion information. The function of Orban's complex cell chain system would be to process continuous motion. These cells would be the specialized motion sensitive type observed by both Orban and Hubel and Wiesel. Such cells would perform the analysis attributed to the MAS model by Bonnet. The present results, i.e. longer latency and higher amplitude VEPs to continuous motion, suggest that these motion specific cells fire more vigorously and

and for a longer period of time than the cells involved in processing apparent motion. According to Orban, a simple cell chain system would only process the spatial and temporal aspects of the moving object. Such a cell chain would be involved with the type of motion experienced in apparent motion and would provide information to the DAS in Bonnet's model. The spatial and temporal nature of these cells may explain why the results concerning apparent motion were only confined to the latency aspect of the VEP.

In the present experiment both types of motion show different trends in relation to velocity. There is a tendency for amplitude to increase in continuous motion but in apparent motion amplitude seems to decrease as velocity increases (see Figure 2). This difference may be explained by considering velocity as an intensity factor for continuous motion. In continuous motion the MAS would not emphasize the initial and terminal positions since it does not provide relevant information for this system, but it could emphasize the velocity factor via successive stimulation. Furthermore, Orban has shown that all the cells in his complex cell chain were influenced to some degree by velocity. In apparent motion the spatial nature of the DAS would diminish the role of velocity as an intensity factor and emphasize the change in spatial location as a factor. This would be done because the DAS needs to compare stimuli in order to signal motion. This interpretation would be consistent with Bonnet (1977) and Tolhurst (1973). Bonnet points out that velocity could be considered as an intensity factor in continuous motion since Tolhurst has shown that there are channels in the human visual system that are sensitive to

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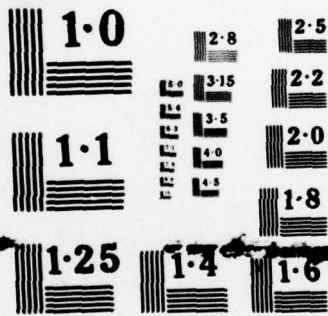
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spatial and successive stimulation factors in motion. Spatially sensitive channels would provide information about change in location to the DAS, while channels sensitive to the frequency of stimulation would provide information to the MAS.

Differences between central and occipital recording areas are seen in the significantly shorter VEP latencies at the central recording area when compared to the occipital area. This is especially true when stationary stimuli are presented. A similar finding was obtained by Allison, et al. (1977) with patterned stimuli. Their results showed that central recordings were on the average, 10 msec shorter than the occipital recordings for a positive component occurring at approximately 190 msec. Further, the main differences between continuous motion and apparent motion in the present study were not observed at the central site but at the occipital recording site. These results are consistent with Coffin (1976) and Andreassi, et al., (1979) who both report their significant findings occurred at the occipital recording site. These findings reflect the fact that the occipital area is the primary processor of visual information.

→ In summary, the present findings show that there are perceptual differences between continuous and apparent motion and that these differences may be reflected in the latency and amplitude of the VEP. Furthermore, theoretical and cell system models were presented to account for the observed differences. These models propose that continuous motion is processed by specialized motion detecting cells which may respond to velocity as an intensity factor in motion. In apparent motion, the models suggest that cells would respond to the spatial and

↘ temporal change in position over time aspects of this type of motion and the role of velocity as an intensity factor would be diminished.

Thus, it is suggested that future studies be undertaken to compare continuous and apparent motion using a wider range of velocity conditions and recording locations. Also, the direction of motion should be systematically examined for both continuous and apparent motion. ↙

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identical to itself. As in previous masking studies, perceptual masking of the target was achieved and this was accompanied by significant attenuation of the visual ERP to the target stimulus. This effect was specific to the occipital (visual) recording site and not the central. This probably reflects the role of occipital cortex in the processing of visual stimuli, a role not shared by the polysensory central cortex.

The second experiment examined the visual ERPs to the mask alone, and to the target-mask combination, at interstimulus intervals designed to eliminate the masking effect. Responses to the mask alone were the greatest in amplitude at the occipital location (not central). In addition, ISIs which precluded perceptual masking (10 msec and 100 msec) were not accompanied by visual ERP attenuation.

Motion perception was examined in experiments III and IV with respect to VEP correlates. In Experiment III, it was found that a condition in which a vertical line was perceived to be in continuous motion across a screen resulted in significantly longer VEP latencies as compared to a condition of beta or apparent motion in which the same line appeared to jump from one location to one adjacent to it. A third condition, no motion, resulted in VEPs like that of apparent motion. This effect was observed at the occipital recording site not at the central one. It was hypothesized that different brain mechanisms underlie the perception of continuous and apparent motion.

In a more complex motion experiment, three velocities of apparent motion and continuous motion were compared with each other and with a no motion condition. The VEPs recorded from the occipital site again differed for the continuous vs. apparent motion conditions. The latencies for the highest and middle velocity continuous motion conditions were significantly longer than for the apparent motion condition. In addition, the highest velocity continuous motion condition produced significantly larger amplitudes than the three apparent motion conditions. These results suggest a greater amount of cortical processing time (latency) and activity (amplitude) with continuous motion, especially at the higher velocities. Also suggested by these results and those of Experiment III is that the human visual system processes these two types of motion differently. The results were related to recent concepts regarding motion perception and the neurophysiological bases of such perception.

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