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CHANGES OCCURRING IN THE VISUAL EVOKED POTENTIALS DURING MONOPTIC AND DICHOPTIC METACONTRAST

by

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B. S. Colorado State University 1982
M. S. Eastern Washington University 1984

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Changes Occurring in the Visual Evoked Potentials During Monoptic

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ABSTRACT

Recent investigations of the visual evoked potential (VEP) and monoptic backward masking have found inconsistent results. Only one investigation which included dichoptic masking found no change in the VEP during masking.

Four subjects participated in the present study to determine the extent to which parafoveal metacontrast shows an interaction of target and mask responses in the VEP, as indicated in some of the previous investigations. Monoptic and dichoptic viewing conditions were used in this investigation. The stimulus configuration consisted of 3 adjacent squares, the middle one served as the target and the 2 outside ones as the mask.

In a pilot study, several electrode locations were examined. Placements along the midline showed similar results, however, vertex and frontal locations showed the smallest visual responses. Temporal locations showed no significant visual response.

The VEPs for the present study were recorded from 2 midline electrode locations 2.5 cm and 6 cm above the inion. VEPs were recorded for 5 stimulus onset asynchrony (SOA) conditions ranging from simultaneous target and mask presentation to approximately 220 ms. The VEPs from both electrode sites, showed an initial negative peak 100 to 120 ms and positive peak 168 to 213 ms following stimulus onset. Separate VEP records were taken with the target presented alone, the mask presented alone and both presented together for all 5 SOA conditions.

The target alone VEP responses were added by computer to the mask alone VEP responses for all SOA conditions. This composite was subtracted from the VEP that was recorded from the scalp with both stimuli presented. The residual waveform showed a negative component that corresponded to

the positive component occurring in the mask alone response for all SOA values. Correlations between the latency of the negative component in the residual and the latency of the positive mask alone component were all greater than .966 for both monoptic and dichoptic viewing conditions.

This result raises a question concerning whether or not perception is mediated by the occipital cortex, since the masking of the target, apparent in perception, is not apparent in the occiptal/parietal VEP.

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I. Introduction

Recent theories of visual perception have attempted to gain support from neurological studies concerning the processing of visual information. This notion indicates that, in the development of such theories, there is an assumption of a predictable relationship between perception and psychophysiological measurement. However, this relationship is far from straight-forward. Visual masking is an example of a perceptual event that has yet to show any consistent relationship between the perception, the psychophysiological evidence, and the theory. In fact, consistency of the findings is lacking in the current body of visual masking and psychophysiological literature alone. This is primarily due to the inappropriate grouping of different types of visual masking phenomena into one category that typically occurs in studies that use psychophysiological measures. Visual masking occurs in different forms and shows different psychophysical characteristic functions depending on the parameters involved. Many backward masking studies which use comparable stimuli and procedures tend to yield similar results. This thesis will attempt to address the problems experienced in studies concerned with the psychophysiological measures, using the visual evoked potential (VEP), and a special case of backward masking, known as metacontrast.

A. Visual Masking

1. Background, Definitions and Types

Masking occurs when the presentation of a stimulus interferes with the perception of another stimulus. When the perception of the first stimulus presented (target) is influenced or affected by the presentation of a subsequent stimulus (mask) , backward masking results. Metacontrast is a special case of backward masking.

According to Breitmeyer, (1984) masking occurs using a variety of stimuli as the target and the mask. Masking of light by light uses targets and masks which are superimposed flashes that consist of spatially uniform fields. Masking of light by pattern employs stimuli that consist of spatially patterned forms or contours. The typical target and mask configuration used in metacontrast consists of a small disk as the target and a larger, nonoverlapping concentric annulus as the mask. However other stimuli that preserve the spatial contiguity of the two stimuli without overlapping have also been used successfully. An example of this kind would be a square or rectangle of light as the target and flanking squares or rectangles as the mask, respectively. Backward masking functions exist in the following two forms: a) Type A--the characteristic function is monotonic, in which optimal masking occurs when the target and mask are presented simultaneously; and b) Type B--which is a non-montonic or U-shaped function in which maximal masking occurs when the stimulus onset asynchrony (SOA) is positive, usually somewhere between 50-200 ms.

2. Major Parameters

Even though Stigler is credited as the first to investigate the phenomena of metacontrast as early as 1910, Alpern (1953) is usually cited as the first documentation of the U-shape function (Breitmeyer, 1984). The stimuli employed by Alpern consisted of a rectangle as the target and two flanking rectangles as the mask. Situated above the target was a comparison rectangle. A fixation point separated the target and the comparison stimulus. The subject's task was to change the intensity of the target so that the perceived intensity was equal to that of the comparison stimulus which maintained a constant luminance, for a variety of SOA values. Alpern found that as SOA increased from a negative SOA in which the target follows the mask, there was a "slight inhibitory effect" of the mask on the target, known as paracontrast, however the magnitude of the resulting metacontrast was much greater in amplitude. Maximal masking occurred when the mask followed the target by 100 ms. After examining the effects of several parameters, Alpern made the following conclusions.

1) The effects varied with the luminance of the two contrast inducing patches (mask). The magnitude of metacontrast increased as the luminance of the contrast inducing patches increased.

2) As the duration of the target increased the magnitude of the masking effect decreased. Conversely increasing the mask duration resulted in increasing the magnitude of the masking until an optimal value was reached. When the mask was 5 ms in duration, maximal masking occurred with a 5 ms. target and comparison.

3) Certain spatial characteristics were found to be important in metacontrast, such as the separation between the target and mask stimuli and shifting the fixation point. As the angular separation between the target and mask increased, the maxima of the curves and the corresponding area underneath them became progressively smaller. Shifting the fixation point had differing effects. First, when the subject fixated on the center of the target, no metacontrast occurred. As the fixation point was shifted to the periphery of the retina, metacontrast began to occur and the farther the

distance between the center of the fovea and the target, the greater the metacontrast effect.

Alpern concluded that certain parameters are important in metacontrast. These results led him to postulate a theory involving retinal inhibition involving rods and cones to explain metacontrast. However Alpern's conclusions are questionable because more recent investigations have indicated that Alpern's methods were inadequate. Alpern had his subjects manipulate the luminance of the target to maintain a subjective match with the comparison stimulus. Unfortunately, Alpern did not realize that the ratio of the target-to-mask luminance was an important parameter and that by changing the target luminance, he was inadvertently changing the function as well. Since Alpern, other researchers have continued to look at the major parameters involved in metacontrast and as a result, several effects that Alpern was unable to obtain have been demonstrated by subsequent investigators on the basis of more recent information.

Certain variables are important in determining the shape of the function in masking. According to Weisstein (1972), the primary determining variable of the function is the target-to-mask (T/M) luminance ratio, mentioned previously. When the T/M ratio is greater than or equal to unity meaning the target is of equal or greater luminance than that of the mask, type B or the U-shaped function is obtained. If, however ~~the~~ T/M ratio is less then unity, the function shifts from type B to the type A monotonic function.

A second variable important in determining the function is the content criterion of the task, or the stimulus dimension upon which the subject makes his/her perceptual judgement (Breitmeyer, 1984). Type B metacontrast occurs when the content criterion involves the suppression of the brightness or contrast of the target or of the contour or contour detail.

Related to the content criterion is the experimental task required of the subject. This is not unusual since differing tasks require the subject use differing information on which to make the judgement or perform the task. Type B functions have been obtained using choice reaction time such as when the subject is required to respond as fast as possible to a number of possible targets using the target's figural properties (Eriksen & Eriksen, 1972).

When simple detection is the criterion, neither type A or B functions are obtained, simple detection does not vary as a function of masking (Ferher and Raab, 1962; Fehrer and Beiderman, 1962). Schiller and Smith (1966) also examined simple detection criteria in separate experiments. The first experiment used a target and mask of equal luminance and two separate measures of masking. The first measure was similar to Alpern's comparison method. However, instead of manipulating the target's luminance to match a constant comparison stimulus, Schiller and Smith required the subject to change the luminance of the comparison stimulus to match the target which was held constant. This modification assured the integrity of the T/M luminance ratio as constant parameter. At the SOA in which maximum masking was obtained Schiller and Smith indicated that the subjects lost the target sufficiently so that no match could be made. The target was virtually invisible. However, the other measure of masking was that of reaction time (RT) which was completely unaffected by masking. Even when the subjects expressed that the target was no longer perceived, the RT suggested a response to the target.

Schiller and Smith's method was an attempt to resolve Alpern's problem using a variable comparison and constant target. However, a subsequent investigation by Flaherty and Matteson (1971) directly compared the two methods for obtaining the characteristic function of metacontrast. The results showed that even though changing the luminance of the target changed the psychophysical function it was, nevertheless, a more stable and less variable measure then changing the comparison to match the target. This occurred even when the luminance of the target was bright enough so that the target was never lost even during maximal masking.

In a second experiment conducted by Schiller and Smith (1966), subjects were required to respond to the target that appeared randomly in different locations. Again, RT was generally unaffected by masking. However, when the luminance of the disk was set low compared to that of the mask, slight type A masking did occur with maximum masking occurring at the shorter SOAs and decreasing with increasing SOAs.

Several spatial characteristics are important in masking such as the spatial separation between the target and mask found by Alpern and the size of the stimuli especially when retinal location is taken into consideration. Bridgeman and Leff (1979) showed that strong foveal brightness metacontrast could only be acheived with relatively small targets and masks. Increasing the dimensions of the stimuli showed an inverse relationship with the magnitude of foveal masking. Such manipulations during parafoveal metacontrast showed no such relationship.

A related point is that foveal masking is actually stronger than parafoveal masking when the discrimination to be made concerns finer contour detail, however parafoveal is stronger when the response is to be based on brightness suppression. Parafoveal masking also tends to decrease the apparent motion typically experienced in metacontrast suppression (Stroper and Banfy, 1977).

The final parameter to be included in this list is that of the viewing condition. Metacontrast is obtained both monoptically and dichoptically. Dichoptic masking occurs when the target is presented to one eye and the mask to the other eye. Alpern has been cited as not being able to obtain dichoptic masking, in several sources, (Kolers and Rosner, 1960; Schiller and Wiener, 1963; Schiller and Smith, 1966; Lefton, 1973; Breitmeyer, 1984). However, in Alpern's original 1953 paper, the only reference that may be interpreted as a lack of dichoptic metacontrast is found in one sentence with a corresponding one sentence footnote:

> "Experimental attempts have been made to demonstrate binocular metacontrast* and, although the data are limited, qualitative, and inconclusive, under certain conditions such effects have presumably been demonstrated....*The present investigation failed to reveal any trace of binocular metacontrast under a limited range of stimulus conditions." (Alpern, 1953, p. 655).

Without any details concerning the attempt to show "binocular metacontrast" it's difficult to conclude that Alpern failed to show dichoptic metacontrast. In spite of this problem with Alpern, other investigators have successfully demonstrated dichoptic metacontrast, using a variety of stimulus configurations, (Toch, 1956; Kolers and Rosner, 1960; Schiller and Wiener, 1963; Battersby, Oesterreich, and Sturr, 1964; Schiller, 1965; Schiller and Smith, 1968; Weisstein and Growney, 1969; Turvey, 1973).

This is not an exhaustive list of the variables that have been examined in the research on backward masking and metacontrast. However, it is sufficient for the purpose of this thesis, which is to examine the relationship between metacontrast and the corresponding visual evoked potential that arises.

3. Current Theories

The current theories concerning masking fall into two general categories; inhibition models versus summation models. In past literature, theories concerning metacontrast centered, almost exclusively, around some type of inhibition mechanism because, perceptually, that is what appears to happen. In some way the presentation of a subsequent stimulus (mask) affects the perception of the first stimulus (target). The second stimulus is basically unaffected. However, as time progressed and research continued to examine the parameters involved in masking, the basic and more simplistic theories gave rise to more complex ones.

One of the earlies theories was based on research conducted by Stigler (1910, 1913, 1926--see Breitmeyer, 1984), and later modified by Crawford (1947). The overtake-inhibition theory proposed that with a given stimulus with a greater intensity than a previously presented stimulus, excitation of the second may overtake and suppress that of the first. This however does not explain type B metacontrast since recent research has demonstrated that masking also occurs with targets that are equal and greater in intensity than the mask. Earlier theories incorporated other information which subsequent research eventually failed to confirm. In spite of these obstacles, inhibition theories are the most prevalent and incorporate some of the mechanisms proposed as early as 1926.

Current inhibition models are found in many different forms; a complete and thorough review of the theories can by found in Breitmeyer (1984, Chapter 5, pp 136-161). The inhibition theory that provides explanation of a majority of the masking research is that of Breitmeyer and Ganz (1976).

Breitmeyer and Ganz's theory is neurologically oriented and is heavily dependent on the notion of transient and sustained channels. Transient and sustained channels are made up of X- and Y-cells, respectively, first described by Enroth-Cugall and Robson (1966). These cells differ along several dimensions such as retinal distribution, spatiotemporal responses, excitatory and inhibitory interaction and cortical and subcortical projections.

X- and Y-cells have been referred to sustained and transient cells respectively, because of their differential responses to prolonged exposure to a signwave grating. The X-cells response is sustained throughout the duration of the exposure whereas the Y-cells response shows a burst of activity upon stimulus onset and withdrawal. In general, transient cells are considered to be responsible for signalling location and presence of stimuli, or their rapid changes of location, while sustained cells primarily signal aspects such as brightness, contrast and contour.

Given the differences between transient and sustained channels, Breitmeyer and Ganz make certain assumptions. The first assumption is that both target and the mask stimulation activate sustained and transient channels, the former channel exhibits a long latency while the latter exhibits a short latency. A second assumption is that masking may occur one of three ways. The first way is via intrachannel inhibition. Within a class of channels (intrachannel), inhibition occurs as a result of the center-surround antagonism of the receptive fields particularly in sustained channels. The second way masking may occur is through interchannel inhibition, particularly transient-on-sustained channel inhibition. The third way in which masking may occur is through the sharing of common sustained or transient pathways by neural activity generated by the target and mask when they are spatially overlapping.

In the case of spatially adjacent stimuli, as in metacontrast, Breitmeyer and Ganz propose that the transient activity of the mask and the earliest sustained activity of the target can interact via mutual interchannel inhibition. These are the mechanisms involved in metacontrast. However, these mechanisms may be used to explain visual masking in all forms and as a result Breitmeyer and Ganz have developed a comprehensive and formidable theory of visual masking.

The theory of visual masking that relies on a summation of the the two stimuli does not share the rich and pervasive history of that of inhibition. However, inhibition may not be as complete an explanation as one might think. A weakness in inhibition theories pointed out by Burr (1984) resides in the area of the delay of the neural response to the first stimulus. All inhibition theories incorporate the notion of a delay in the response to the first stimulus that must be sufficient for the second stimulus to be able to interfere with the first. Summation theories do not propose any such differential in neurological response. Summation theories suggest that perhaps the target and the mask become perceptually fused so that the two stimuli are no longer seen as two stimuli (Schiller and Smith, 1966; Stoper and Banffy, 1977; Burr, 1984). Burr (1984) used a threshold detection paradigm and found that the presence of the target did increase and enhance the detectability of the two stimuli presented together. This enhancement occurred at temporal intervals which yield the maximum magnitude of metacontrast masking.

In spite of this critical investigation by Burr, more support is necessary for the summation theory. It is unreasonable to generalize a theory in which support has been demonstrated strictly at threshold levels of visual perception. In general, inhibition still provides the most comprehensive explanation of masking. However, given the amount of time and research that has been spent on inhibition, summation may prove to be useful. At this point summation certainly provides a reasonable alternative to inhibition.

B. Visual Evoked Potentials

The term "event-related potential" was proposed by Vaughan (1969). This term referred to a variety of brain responses that demonstrated a fairly stable relationship with the presentation of a stimulus. One classification according to Vaughan was sensory evoked potentials which could be produced by different types of sensory stimulation; i. e., visual, auditory, olfactory or somatosensory. The evoked potential of interest to the present thesis is the visual evoked potential (VEP).

Several parameters are important in the study of VEPs, such as the frequency of stimulation. When the interval between successive stimuli is short (less than 300 ms) the resulting VEP is labelled a steady-state potential (Regan, 1972). Due to the greater rate of stimulation, Regan (1982) states that in the steady-state potential, the response to any given stimulus has not "died away" sufficiently before the response of the subsequent stimulus occurs. This means that in the evoked potential individual stimulus cycles are not reflected in individual response cycles, therefore, the responses to consecutive stimuli may not be isolated. As a result, the analysis of steady-state evoked potentials has been, historically, restricted to the frequency-domain. However, there is some evidence that time domain analysis is not as inappropriate as once believed (Diamond, 1977).

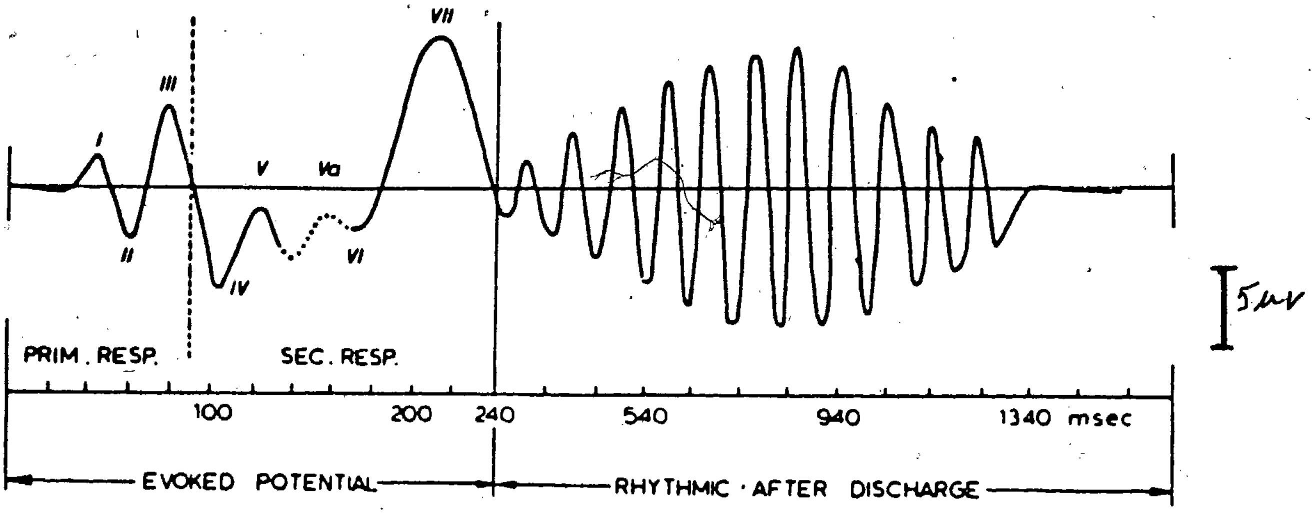
Stimuli that are well separated in time give rise to the transient evoked potential, which is comprised of several components. The size, polarity and latency of these components is a function of the stimulus type and onset or offset. These components have been labelled for different types of stimulation; i. e., flash versus patterned responses.

Diffuse Flash Response

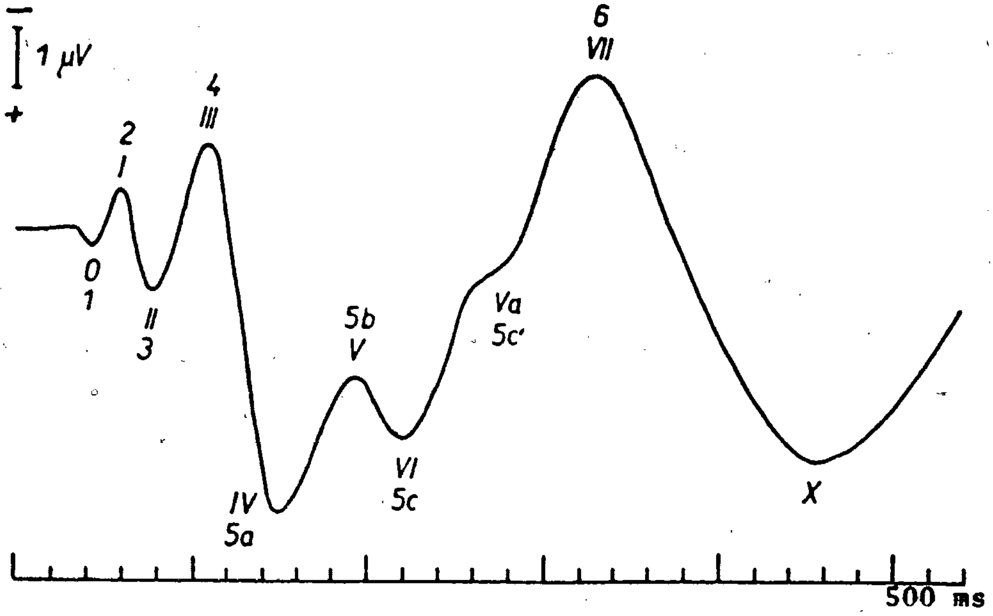
The components found in response to a diffuse, unstructured stroboscopic flash have been given different label sets by different investigators. Figure 1 shows two methods of labelling components; (a), Ciganek (1961) and (b) Gastaut and Regis (1965). Regardless of the label, the components are similar in polarity, latency and distribution, and are recorded with a maximum at electrode locations on the midline, generally 6 cm above the inion (Halliday, 1982).

Figure 1. Components of Flash VEPs. Schematic representation of the VEP recorded during a diffuse, unstructured flash. The top part (a) shows the system of labelling used by Ciganek (1961). The periods represented in this figure are the primary, secondary response and the rhythmic after-discharge. The bottom part (b) is the system described by Gastaut and Regis (1965) which shows the VEP to a flash with upward deflection indicating a negativity recorded from a mid-occipital electrode. The individual components are labelled in Arabic with the corresponding label of Ciganek in Roman numerals (From Ciganek, (1971)).

A


I
II
III
IV
V
Va
VI
VII
PRIM. RESP.
SEC. RESP.
100
200
240
540
940
1340 msec
5µv
EVOKED POTENTIAL
RHYTHMIC · AFTER DISCHARGE

B


−
1 µV
+
0
1
2
I
II
3
4
III
IV
5a
5b
V
VI
5c
Va
5c'
6
VII
X
500 ms

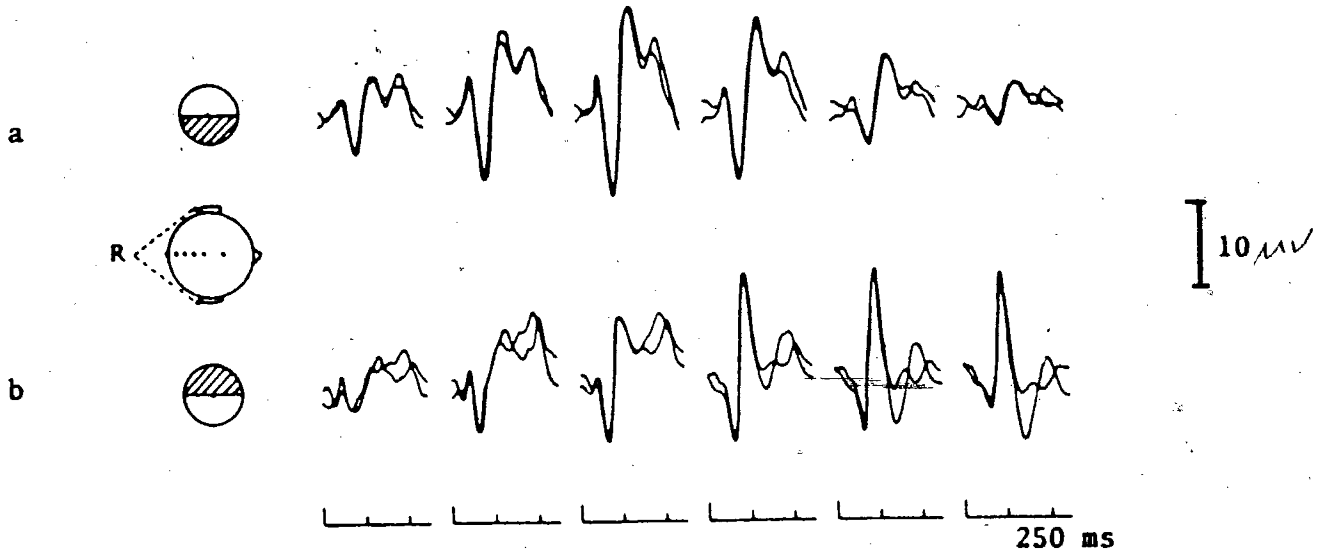
Patterned Flash Response

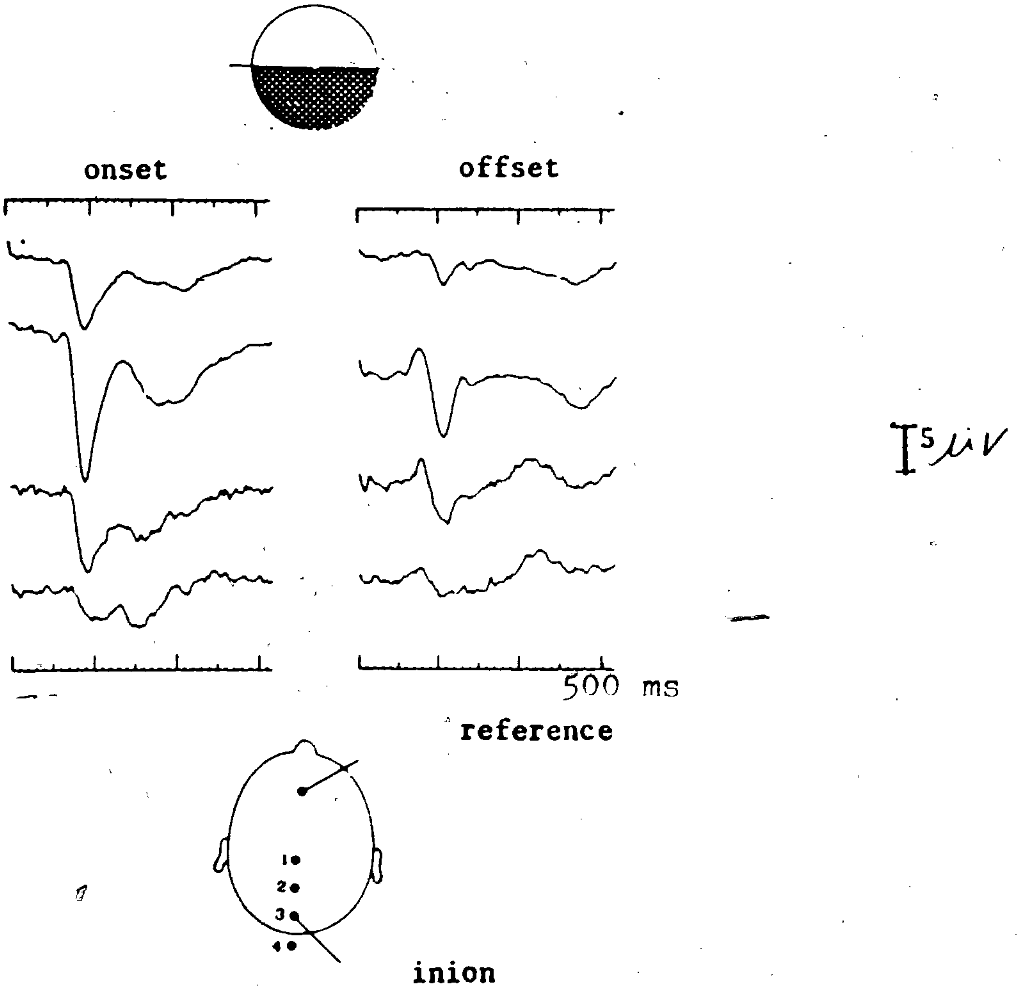
Components occurring in responses to patterned flashes show relatively stable peak latencies which do not appear to vary much as a function of electrode position or within retinal locations. In research conducted by Jeffreys (1977), three distinct components were identified with different surface distribution characteristics. The peak latencies of these components, CI, CII and CIII, occur about 75 ms, 100 ms, and 150 ms, respectively. The form and polarity of the amplitude distributions of these components is, however, dependent on retinal location. Based on the results of Jeffreys (1977) as well as Jeffreys and Axford (1972), certain, basic features are common to the VEP's recorded from the majority of the subjects. Figure 2 shows the responses from different electrode placements for upper and lower half-field stimulation and the following trends are observed:

1) There is a reversal of the polarity of each component in the VEP's obtained to upper and lower half-field stimulation with the lower half-field showing polarities. for CI, CII and CIII that are positive, negative and positive resectively.

2) Consistent shape and polarity differences between upper- and lower-field vertical distributions of CII and CIII, where the lower half-field distributions demonstrate a more symmetrical form of distribution and are more posteriorly located than those of the upper half-field, with a common earlobe reference (Jeffreys, 1971).

Figure 2. Components of Pattern VEPs. This demonstrates the influence of retinal location on the pattern VEP. In the upper portion of the figure the VEPs were recorded from several midline electrodes to both lower (a) and upper (b) half-field stimulation. (From Jeffreys, 1977). The lower portion is the pattern VEP recorded during stimulus onset (left) and offset (right). (From Kriss and Halliday, 1980).


a
R
b
10 μV
250 ms


onset
offset
5 μV
500 ms
reference
1
2
3
4
inion

These components are fairly stable over the majority of the subjects, however some subjects do show some aberrations. Jeffreys associates the deviance with single quadrants of the stimulus fields.

Other investigators have also encountered a certain amount of variability. VEPs between subjects show this variability as well as VEPs from the same subject. Jo Ann Kinney (1977) states that one of the main problems with transient evoked potentials is the variability. In her review of transient VEPs, Kinney demonstrated that the same subject, tested several times over the period of 2 months, may show records that are discrepant in both amplitude and latency while maintaining the same general overall pattern.

C. Visual Evoked Potentials and Masking

Several investigators have examined the question of whether the VEP shows any changes as a function of masking. The results are, at best, equivocal. It is possible that much of the apparent discrepancy may be due to differences in the stimulus configurations used as well as the analysis or criterion the investigator chooses to examine. It is important to bear in mind the parameters that are important in backward masking and how these parameters affect the characteristic function involved.

Many investigators use the global term 'backward masking' generically, whether the stimuli were superimposed, overlapping or spatially adjacent, regardless of the luminances involved. Investigators use the results obtained in a metacontrast experiment as confirming research for a masking experiment with overlapping stimuli. The process involved in type A backward masking may or may not include the same mechanisms involved in type B metacontrast. At this point in the research there is no reason to assume either similarity or disparity of process. Other discrepencies may arise from investigators using different criteria in examining the VEP. Some investigators look at the initial major components, others look at the area under the curve, etc. A review of the findings as well as a comparison of competing methodologies should help resolve some of the confusion.

1. Backward Masking

Studies completed using overlapping or superimposed stimuli for the targets and the masks are generally consistent in the results found. The general conclusion is that somehow the neural response to the target or the first flash is displaced by the response to the second flash during maximum masking (Donchin, Wicke and Lindsley, 1963; Donchin and Lindsley, 1965; Schwartz and Pritchard, 1981). However, this conclusion depends heavily on how the data were analyzed and the assumptions made about the data.

Donchin et al., in both 1963 and 1965 studies, found consistent changes in the recorded VEP as a function of masking. The same stimuli were used in both studies. The target consisted of a semi-circle of light which could be rotated to any of eight positions. The mask was a complete circle of light superimposed with the target. Both stimuli were presented to the fovea. The subject's task was to determine the position of the target. Perceptually, three events were detected and defined. The first was a "no interaction" event in which the two stimuli were perceived as two separate flashes during longer SOA's . The second event was labeled as "perceptual enhancement" in which the target was perceived as being more intense or brighter than it actually was using a direct estimation technique for assessing brightness during intermediate SOA's. The last event was labeled "perceptual blanking", which corresponds with masking, in which the target was not seen. In this study perceptual blanking occurred at the shorter SOAs.

The procedure used by Donchin et al. to examine if and how the VEP changes in masking is important since subsequent investigations in masking, and more specifically metacontrast, have also used this analysis and cited Donchin et al. as justification. To analyze the VEP data Donchin had to make certain assumptions about the data.

The first assumption was that of the additivity of the averaged VEP. It was assumed that the neural response to a pair of stimuli is a linear sum of the responses to each of the two individual stimuli. Furthermore, it is assumed that since the second flash is not influenced by the first flash perceptually, the corresponding neural response to the second is also unaffected by the neural response to the first flash. These assumptions made it reasonable to assume that if the reponse to the second flash was subtracted from the VEP to the paired flashes that the residual of this subtraction would, in essence, be the response to the first flash. Then the residuals could be compared over all SOA values to determine how the response to the first flash changed as a function of the perceptual event.

In testing this assumption the (Donchin et al.) used computer synthesized EP's to compare with the obtained VEP. The results indicated that during the "no interaction" and "perceptual enhancement" events, the synthetic waveforms quite accurately reflected the obtained VEP waveform in both amplitude and latency. However, for the "perceptual blanking" event, the synthetic and recorded waveforms were "discrepant in both amplitude and latency of the major components" (Donchin and Lindsley, 1965; p. 330). The investigators conclude that the brain operates on the two stimuli in an additive manner, within limits. That is, the single response to the two flashes is a sum of the responses to the idividual flashes as long as they are perceived as two flashes. According to this conclusion, subtracting the VEP to mask alone from the response to the paired flashes is appropriate for the "no interaction" and "enhancement" perceptual events but not for the event of "perceptual blanking". However, the investigators use this subtraction procedure for all three perceptual events.

Based on the result of the subtraction process the investigators conclude that the target response was displaced during the masking stage. This conclusion was based on the changes that occured in the residual remaining after the subtraction of the mask alone response from the response to the paired flashes. The results showed that the correlations between residual and the response to the first flash alone were quite high at later SOA conditions indicating that the response to the target was not influenced by the presentation of the second flash. These correlations also show a decline as the SOA decreased. At the lower SOA's, negative correlations were obtained. The residuals obtained during optimal masking found the residual to be quite small and the response to the paired stimuli at maximal masking resembled the VEP elicited by the mask alone.

The discrepancies between the assumptions made about the data and the procedures used to examine the data render the conclusions for the masking VEP unclear. Regardless of the the confusion involved in the research conducted by Donchin and his associates, the conclusions, at this point, are still particular to backward masking with superimposed stimuli presented to the fovea and may or may not have any bearing on the evoked potential changes, if any, that occur during metacontrast, foveal or parafoveal in which the stimuli are adjacent. In fact, a later study used spatially adjacent stimuli presented to the parafovea to test this additivity assumption. Using the synthetic waveforms, Schiller and Chorover's (1966) data did not support the additivity of the VEP's and, therefore, no support for the displacement of the target's response by that of the mask's response was obtained during parafoveal metacontrast suppression.

2. Metacontrast

The research concerned with the VEP and metacontrast does not share the consistency of results that the previous studies conducted by Donchin and others have found. The results using non-overlapping stimuli are somewhat conflicting. Some studies show support for changes occurring in the VEP as a function of masking (Vaughan and Silverstein, 1968; Schwartz, Whittier and Schweitzer, 1979--experiment 1) while others show no consistent changes during masking (Schiller and Chorover, 1966; Schwartz et al. 1979--experiment 2; Jeffreys and Musselwhite, 1986).

Early studies found no consistent changes occurring in the VEP during visual masking. Schiller and Chorover used the typical disk and surrounding annulus as the target and mask. The stimuli were presented to the parafoveal retinal region of one eye. In comparing the VEP's recorded during several SOA conditions, including those at which masking was reported, the investigators found no changes in the latencies of the initial negative and positive components for any of the waveforms, including the ones recorded during masking.

One criticism of this study pointed out by Vaughan and Silverstein (1968) was that by presenting the stimuli to parafovea using such high luminances for the target and mask (135 ft-L) Schiller and Chorover were getting foveal VEP's due to scattered light impinging on the retina. Scattered light producing a VEP is not improbable considering that stimuli focussed on the blind spot may produce evoked responses.

In an attempt to address the problem of scattered light, Vaughan and Silverstein compared foveal and parafoveal metacontrast with the same stimuli but at less intense luminances (5.8 mL). They demonstrated that with an adapting field, the parafoveal VEP virtually dissappeared. Without the adapting field, the VEP's recorded during parafoveal metacontrast did not change during masking but the VEP's recorded during foveal metacontrast did show distinct changes. These changes took the form of a reduction in size of the VER component with a maximum at an asynchrony of 200 ms after the onset of the target.

The conclusion to be drawn from Vaughan and Silverstein is that although parafoveal metacontrast suppression may easily be perceived and is quite strong, it is not appropriate to use a VEP to examine the mechanisms involved in metacontrast. The conclusion stated by the authors, however, is that alterations that occur in VEP as a result of metacontrast brightness suppression can only be appropriately measured during foveal metacontrast. If this is true, then there is no way to test whether or not changes may be found in the VEP during metacontrast when the stimuli are presented dichoptically. This is the first issue that Schwartz et al. (1979) needed to address since they were interested in dichoptic masking.

Schwartz et al. (1979) first had to demonstrate that the VEP recorded during metacontrast suppression was not a result of scattered light on the retina. The stimuli used in this demonstration consisted of arrowhead-shaped spots of light as the target with a luminance of 6.5 ft-L. The mask was a non-overlapping concentric annulus with a luminance of 10 ft-lam. At this point it is important to notice the non-overlapping nature of the stimuli. Theoretically, this sets up a metacontrast rather than a masking function, but the T/M luminance ratio is less than unity and thus, has the effect of shifing the function from type B or U-shaped to type A.

The stimuli were presented to the right visual field of the right eye. The VEP's were recorded from bilateral, bipolar occipital-parietal electrode placements. These locations were O_1-P_3 and O_2-P_4 using the international 10-20 system of EEG electrode placement. The experimental task was a discrimination task. The subjects were required to discriminate the orientation of the arrows.

The results of this experiment showed shorter latencies for onset and component peaks on the left side of the head occurring in the VEP as compared to the right side. These latency differences suggest that the stimuli were isolated on the nasal retina with direct projection to the left hemisphere and transcallosal conduction to the right. The investigators concluded that these latency differences indicate that stray light was probably not a factor or at least cannot be explained using stray light.

The psychophysical results showed that optimal masking occurred , for most subjects, during interval separations between 7 and 15 ms during which the accuracy of discrimination fell to 55% or less. The VEP's were then analyzed using Donchin's subtraction procedure. The residuals obtained from subtracting the mask alone VEP from the response to the paired stimuli showed the same changes as found in Donchin's earlier studies. The investigators concluded that the response to the target was somehow replaced in the VEP recorded during masking similarly to the results of Donchin et al. (1963, 1965).

The conclusion to be drawn from the results found by Schwartz et al. is unclear. The purpose of this experiment expressed by the authors was to examine the VEP during dichoptic masking and to contrast the VEP to that found during monoptic masking. Unfortunately due to methodological considerations neither of these issues may be addressed directly by Schwartz and his associates, for several reasons.

First of all, the stimuli used for the second experiment were not the same as those used in the first experiment because "dichoptically presented, the stimuli of Experiment 1 did not produce masking" (p. 109). They consisted of targets that were black 'M' or 'W' and upright or inverted 'V' shapes. The mask was randomly placed black bars that appeared on an illuminated background overlapping the target. This is no longer a type B metacontrast situation but a type A backward masking situation. In addition to this modification, the intensities of the stimuli were also changed. The target's luminance was 8 ft-L and the mask's was 4 ft-L. This is the inverse relationship of the target and mask's ratio of the first experiment (6.5 ft-L/10 ft-L, respectively). According to existing literature this change should result in shifting the function from type A to type B. Given these two modifications it is difficult then, to predict which function should be obtained. This results in a confound. Any differences found between the VEP's recorded during monoptic and dichoptic may be the result of one of the changes the authors made in the stimuli and/or the intensity ratio. Or any differential result may indicate a true existing difference between monoptic and dichoptic viewing.

In the dichoptic viewing experiment (experiment #2), only one SOA value was used. The target and mask were separated by 10 ms for all subjects. Discrimination of the target was only moderately similar for the three subjects. Two subjects showed only chance discrimination while the third subject varied between 61% to 78% accuracy for different sessions. Regardless of the discrepant psychophysical results among the subjects the VEP results were amazingly similar. The VEP residual was nearly as large as the VEP to the unmasked targets alone. This result also occurred for subjects who were only discriminating the target at a chance level. The conclusion made by the authors is that the loss of amplitude in the residuals during the monoptic condition is due to retinal interactions between stimuli. However, the authors do caution the reader concerning this inference "since the stimuli in these two experiments differed physically as well as in the monoptic-dichoptic dimension" (p. 109). In spite of the differences that do occur between the two experiments, the second experiment is the first and only experiment to examine the VEP occurring during dichoptic masking. The results do indicate that during dichoptic masking, no changes may be found in the VEP using the subtraction procedure first used by Donchin et al.

It must be pointed out that even though Schwartz et al. used the same procedure to analyze the VEP the two investigations were not necessarily comparable. First of all Schwartz et al. did not attempt to test the additivity of the VEP with their data and several variables used in their study differed from the stimuli used in Donchin's investigations. Schwartz et al. used spatially adjacent stimuli presented to the parafovea while Donchin used superimposed stimuli presented to the fovea. Schwartz used intensities for the target and the mask (6.5 ft-L and 10 ft-L respectively) that were fairly equal for unequal stimulus durations. Donchin used intensities that were quite disparate; the mask was 9000 mL while the target was only 90, 9 or 0.9 mL, depending on the condition, but were equal in duration. These incongruencies indicate that a test of the additivity of the VEP should have been performed by Schwartz et al. before the subtraction procedure was used indescriminately.

In a follow-up investigation Schwartz and Pritchard (1981) examined the VEP's that occur during a masking task that shows the U-shaped characteristic. The investigation used a variety of stimuli to obtain such a function. The first experiment used a target that consisted of 12 randomly arranged squares of light, one of which was presented for any one trial and the mask was comprised of the letters "O" and "N" which contained overlapping contours to that of the target. The second experiment used a contoured discrete target, the letter "A", rather than the formless spot target, while the masks used in experiment 1 were maintained for the second experiment.

The results for both experiments were similar in terms of the VEP changes found and yet the psychophysical results were somewhat disparate. To evaluate the results of both experiments, a U-shaped function was defined using two possible criteria. The first was a decrease in performance using a signal detection procedure followed by an increase as the temporal interval between the two stimuli increased from a zero point. The second indication of the U-shaped function was a decrease in the VEP residual as the SOA increases from zero to some intermediate interval at which the residuals begin to increase. Residuals in this case consist of the waveform that remains when the response to mask alone is subtacted from the response to the paired stimuli as previously described.

The results of the first experiment showed a U-shaped function occurring in the psychophysical measure (d') while the VEP residuals show a monotonic function with small waveforms occurring at lower SOA intervals and increasing in size with the increase of the interval. In fact, up to the intermediate SOA interval the d' scores were negatively correlated with both absolute amplitude of the residual and their size relative to that of the longer SOA. The second experiment showed similar results for the VEP residuals. The residuals show a monotonic increase in size as a function of the SOA. The psychophysical results are less clear. Out of a total of nine subjects, three obtained a monotonic function, five obtained the expected U-shaped function and one subject failed to show any masking at all with a 100% hit rate.

The conclusion reached by Schwartz and Pritchard, is that using stimuli that should show a U-shaped relationship between detection and SOA, the perception is not paralleled by the VEP residual and therefore, has no relationship with the psychophysiological measurement of the VEP. This is not the only conclusion that may be drawn from the experiments conducted by Schwartz and Pritchard.

It appears that although the psychophysiological measure was consistent for all stimulus conditions, the psychophysical or perceptual measure was excessively variable. Such variability is not found in the majority of the masking literature. It is true that the interval at which optimal masking occurs, using spatially adjacent stimuli, is slightly variable and ranges from 60-100 ms. However, there is nothing in the current literature examined by the present author that shows different subjects showing completely different psychophysical functions. Previous research indicates that all subjects show the same general function either U-shaped or monotonic when using one stimulus configuration. However, the maximum of the U-shaped curve or the magnitude of masking may show some variability between subjects. This raises the question of whether the stimuli used were appropriate to evaluate the VEP occurring during masking.

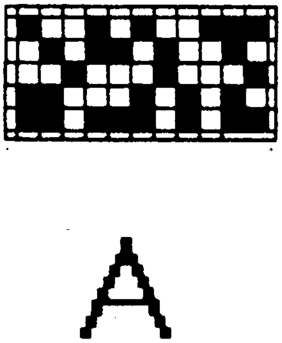
Breitmeyer and Ganz (1976) describe stimuli used in masking as well as the criteria involved in the stimuli. The authors present typical stimulus configurations shown in Figure 3, which fall in one of the three following categories:

> A) Stimuli used in and metacontrast; which are characterized by the typical disk and surrounding annulus configuration.
>
> B) Masking by noise; described as using a mask whose contours overlap those of the target. The mask is described typically as consisting of a random array of black and white areas that bear little or no structural relationship to the target pattern.
>
> C) Masking by structure; which indicates a configuration in which the mask is spatially overlapping and is structurally related to the target, in that the mask shares the contour orientation, curvature, and other figural features of the target. (p. 2).

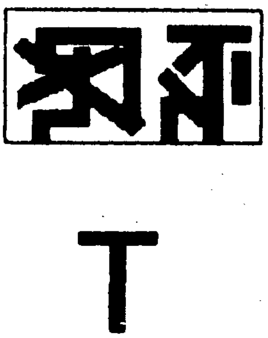
Given these descriptions of stimulus configurations, it is apparent that Schwartz and Pritchard's configuration doesn't fall neatly into any one of

Figure 3. Examples of typical target and mask stimuli used in (a) paracontrast and metacontrast; (b) pattern masking by noise; and (c) pattern masking by structure. (From Breitmeyer and Ganz, (1976)).

(a)



(b)



(c)

the categories. The description that most closely fits the stimuli is the masking by noise category. The masks ('O' and 'N') are slightly structurally related to the target ('A') but not so much in contour orientation. It is true that one feature of the target ("\") which appears on the right and serves to connect one line at the apex of "A" and closes the triangle that appears between the three connecting lines does have a corresponding feature that occurs in the "N", which connects the two vertical, parallel lines. Another similar feature is the sharp angles between the "A" and the "N", but that's where the similarity ends. There is no figural relationship between the "A" and the other mask "O". However, the mask is not a true noise mask, in that it holds meaning for the subject and it is readily identifiable.

It is unclear exactly how the stimulus configuration figures in a discussion of the results, except as a variable that has yet to be shown appropriate for investigations centered on the VEP. This configuration doesn't show any consistency in the characteristic function obtained psychophysically. It is possible that the configuration alone may be responsible for the inconsistency between the VEP and masking. However this unknown and unpredictable variable is not the only weakness in Schwartz and Pritchard's experimental design.

The final analysis of Schwartz and Pritchard's investigation falls short due to the subtraction procedure used to determine changes occurring in the VEP. The authors made no attempt to test the additivity of the VEPs for the individual stimuli, and therefore, it is possible that the residuals do not accurately reflect the target's contribution to the VEP elicited by the pair of responses. Fortunately, the authors do entertain the possibility of error in the procedure. In fact, they offer the three following ways in which an error may have been committed:

1) The subtraction of the waveform of the mask alone response from the paired response may consistently overestimate the contribution of the mask. If this error was operating, the effects of this error should decrease with the increasing SOA. The greatest magnitude of this error should occur at the shorter SOA's. In response to this possibility, the authors state that given the amplitudes of the VEP's recorded from the mask alone and from the target-mask combination, it is unlikely that the error would result in changing the monotonic function of the residuals obtained into a U-shaped function.

2) The mask 's contribution is consistently underestimated and, therefore, not enough is subtracted out. Again the authors "[can not see] how this assumption could change the data to show a U-shaped function".

3) The final possibility is that across SOAs the mask's contribution to the target-mask response varies inconsistently. The authors admit that there is "no logical way to counter this assumption with the present data...[however]...the results of the experiments suggest that it is not sufficient to account for our result" (p. 681).

Perhaps it is true with the data obtained by Schwartz and Pritchard, that these questions may not be answered; however, simply testing the additivity of the VEP's similarly demonstrated by Donchin and his associates (1965) as well as Schiller and Chorover (1966), would lend some validity to the use of the subtraction procedure. This would have been quite simple given that the experimental task involved signal detection theory. In the procedure used, half of the trials contained both the signal (target) and noise (mask). The other half of the trials consisted strictly of noise (mask alone). The VEPs were measured accordingly. No attempt was made to examine the

VEP recorded from the target alone. Looking at the combination of the 'target alone' and the 'mask alone' responses might have indicated some relationship existing in the data. This would, in effect be testing the additivity of the individual stimuli and determine the extent to which the subtraction procedure was appropriate.

In any case, it is difficult to determine how the results and conclusions reached by Shwartz and Pritchard fit in the current body of literature on masking. The problematic experimental design and analysis renders the investigation, at best, inconclusive and at worst, misleading.

So far, the results concerning the VEP and metacontrast include both negative and positive results. However, the positive results use either foveal metacontrast (Vaughan & Silverstein) or a procedure that has yet to test the assumptions that it requires (Schwartz, Whittier & Schweitzer, 1979). The negative result found by Schiller may be incomplete as suggested by a more recent metacontrast investigation (Jeffreys & Musselwhite, 1986).

The conclusion arrived at by Schiller et al. is that the VEPs elicited during metacontrast suppression do not parallel the perception. However, no examination was made of the rest of the VEP waveform. No attempt was made to determine if anything other than the initial components were affected during masking. Therefore, implicit in this lack of examination is the assumption that the major components that may arise with the onset of the target are the only components that are expected to change with masking. Now, given that perceptually it appears that only the target is affected by the temporal asynchrony, it doesn't seem reasonable that any response that may be associated with the onset of the mask is affected during masking. This doesn't mean that the components found in the response to the mask are unaffected.

The study conducted by Jeffreys and Musselwhite, (1986) does show that components that are associated with the mask in the VEP are indeed affected by the presentation of the first stimulus. Jeffreys and Musselwhite conducted a metacontrast experiment using complex pattern stimuli presented to specific locations on the retina. They used a multi-elemental version of the flanking squares because these stimuli, when presented to certain areas in the visual field, produced the distinct onset related components described earlier. In addition to predictable peak latencies, polarity and form the components show scalp distributions which are consistent with specific source generator sites in the striate and extrastriate regions of the visual cortex (Jeffreys, 1971; Jeffreys and Axford, 1972). They found that the initial onset related components were unaffected during masking. As the temporal interval between the target and the mask stimuli increased a second peak began to emerge that related to the onset of the mask. At shorter SOAs the amplitude of the second peak was attenuated; however, further increases in the SOA resulted in an increase in amplitude of the second peak, until eventually it reflected the same amplitude as the first peak.

The question that arises in metacontrast is no longer, how the response to the target is affected by masking but can the VEP recorded during masking demonstrate changes as a function of masking. These changes may occur in initial onset related components as well as attenuated amplitudes of components time-locked with both target and mask stimuli.

A second question that has been given little consideration in the previous literature is whether VEP changes can be detected during metacontrast, and how the VEP elicited during monoptic masking differs from that elicited during dichoptic masking.

D. Purpose of the Present Research

The purpose of the present investigation is to address both of these questions concerning VEP changes that occur in the VEP during monoptic and dichoptic metacontrast. One way in which to approach these questions is to determine the extent to which the VEP changes as a function of monoptic metacontrast and directly compare these changes with those occurring during dichoptic metacontrast. This approach is similar to that of Schwartz, Whittier and Schweitzer (1979), the only investigation in the literature to examine the VEPs recorded during dichoptic metacontrast.

To examine the question of changes occurring in the VEP, as previously stated, several analysis techniques have been used. The technique used for the present investigation is similar to a subtraction procedure used successfully by Kinney, McKay, Mensch and Luria (1972), and the technique used by Donchin and his associates and subsequent investigators; however no assumptions about the data, such as additivity, will be necessary. The purpose of the present investigation is to determine the extent to which the VEP recorded at the parieto-occipital scalp during masking, both monoptic and dichoptic, reflects an interaction between the responses to the separate stimuli.

II. Methods

Subjects

Four observers (Ss); BLC, DVD, ND and CMT served as subjects for this investigation. Two of the subjects were female and two were male with an age range of 23-52. All subjects had normal or normally corrected vision.

Materials and Apparatus

The stimulus configuration was similar to that used by Fry and Alpern (1946), made up of three flanking squares as shown in Figure 4 (a). Each square was 1.9^{0} (in visual angle) on a side. The two outer squares (masking stimuli) were separated from the center square (target stimulus) by a border 18' of arc, with a total of 6.3^{0} in visual angle. The fixation point presented binocularly was 2.3^{0} directly above the target. A set of points could be seen 5.9^{0} to the right of the center fixation point and served to enable the subjects to maintain binocular convergence during the dichoptic metacontrast measurement. In the monoptic situation, all the stimuli were presented to the subject's right eye. In the dichoptic situation the two mask squares were presented to the right eye and the target to the left.

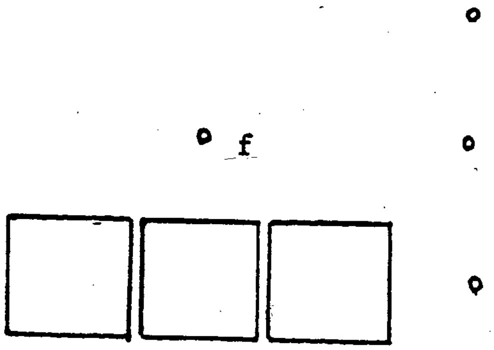
Figure 4 (b) shows the apparatus in which the stimulus was viewed. The subjects looked into two adjacent boxes which contained the stimulus. The boxes were 30 cm in length and 5 cm in width. The two sides and the bottom of the boxes were made of black plexiglass, the lid was made of

Figure 4. Stimulus Configuration and Apparatus. This figure shows (a) metacontrast stimulus configuration modified from Fry and Alpern (1946) including fixation points (f), and (b) the apparatus into which the stimulus was viewed including (d) diopter lenses, (s) the three layer slide containing a diffusing surface, glass slide and black cardboard limiting stop, and (L) the stimulus board of LEDs.

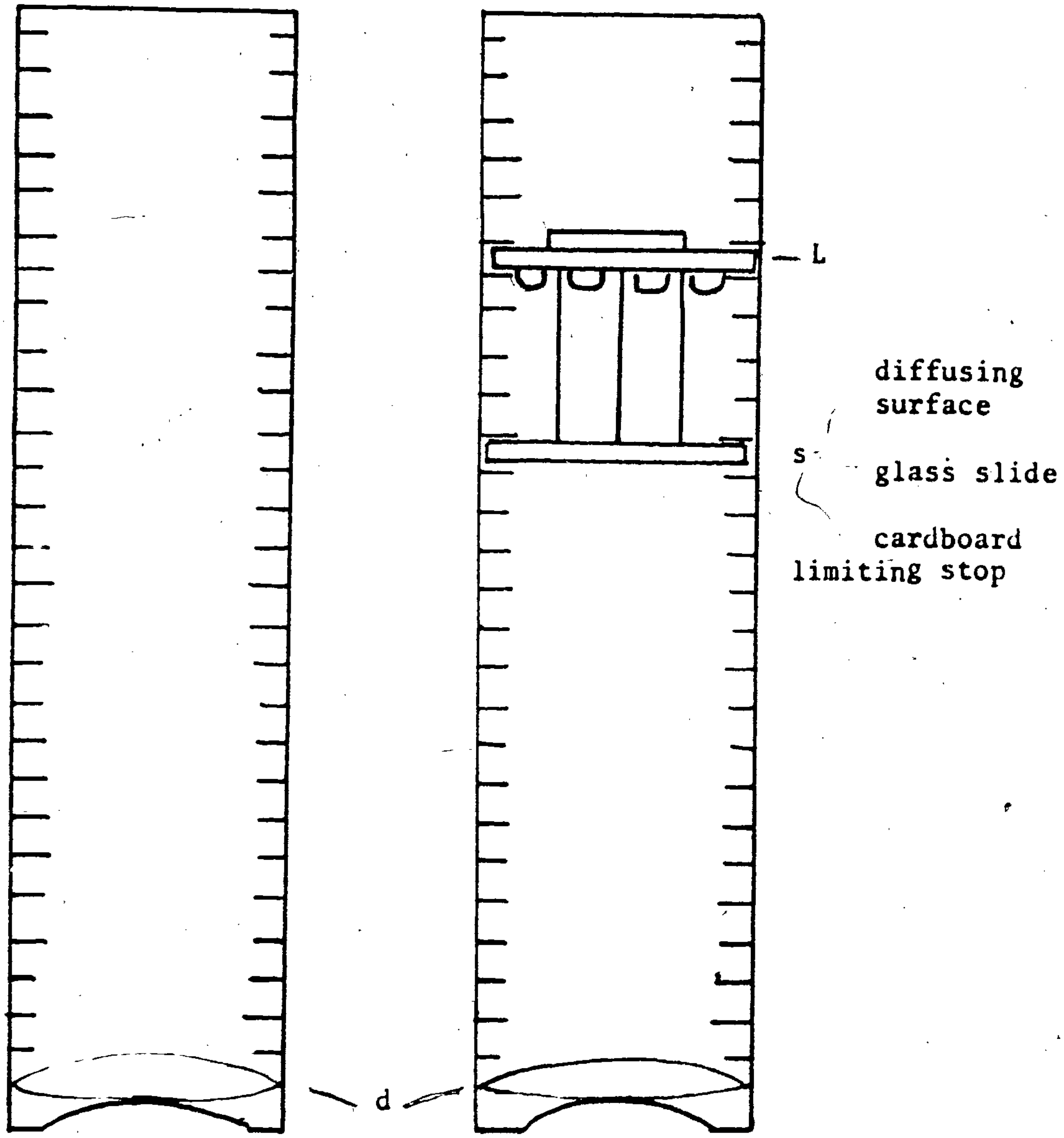
The following diopters were used for Ss:

1) BLC +2, both eyes
2) DVD +6 right eye; +9 left eye
3) ND -1.25, both eyes
4) CMT +2, both eyes

a)


f

b)


L
diffusing surface
s
glass slide
cardboard limiting stop
d

aluminum. The inside of the box contained grooves the thickness of photographic slides (3 mm).

The light source for the metacontrast stimulus was comprised of orange LEDs from Stanley Electric Co., Type * ESAA 5507 with a peak wave length of 605 nm. The fixation points were made up of red LEDs from General Instrument Ultra bright HLMP-3850 with a peak wavelength of 585 nm. The LED's were situated on a fiberglass board that was placed towards the end (away from the the Ss) of the black box.

Approximately 14 cm from the the Ss eye, a three layer slide was placed between the LED board and the Ss. The three layers were made up of diffusing surface closest to the LEDs, a glass slide for stability, and the layer closest to the Ss was a black cardboard limiting stop which defined the stimuli and fixation points. One LED defined any given stimulus. The light from individual LEDs used for the separate stimuli was isolated using 2 layers of thin partitioning cardboard which was attached to the fiberglass board between two LEDs and was pushed up against the diffusing surface.

The LEDs were connected to interval timers which were accurate to 200 nanoseconds. The timers controlled the temporal interval between the stimulus onsets of the target and the mask independently and the duration of the stimuli. The duration for both target and mask was 5 ms. The intercycle interval (ICI) was the interval at which successive pairs of target/mask pulses occurred. The ICI was 1000 ms. The fixation points were driven by a DC source and maintained a constant intensity which was clearly discernible above threshold, during the entire session.

The luminance of the target square was 8 ft-L. The squares making up the mask both had luminances of 14 ft-L. These luminances were used for both the monoptic and dichoptic conditions. Luminance was measured by a Pritchard Spectra photometer which was calibrated using 9 ft-L regulated light souce. There was, however some drift measured in the LED luminance which eventually settled to a specific output after about a 5 minute warm-up period.

The Ss placed their eyes against the plastic goggle-shaped devices that protruded from each box which served to limit the amount of outside light getting into the box. Fixed directly behind the goggle attachment with respect to the Ss, lenses of varying diopters were individually chosen for each S. During the dichoptic condition, three of the four subjects required the use of prisms to be able to converge the target which was presented to the left eye and the mask presented to the right. The fixation points appeared with both stimuli and served to maintain binocular convergence. The monoptic stimulus configuration was presented to the right eye. An artificial pupil was not used in either monoptic or dichoptic condition. Dichoptic viewing made the use of artifical pupils extremely difficult and since luminance was not a variable, but a constant, the artificial pupil was not used for the monoptic condition either.

The VEPs were recorded using Beckman silver-silver chloride electrodes positioned in two places: 2.5 and 6 cm above the inion. Both active electrodes were referenced to a silver electrode clipped to the left ear. Another Beckman silver earclip electrode attached to the right ear served as ground, electrode impedance was never greater than 5000 ohms for all Ss.

The VEPs were recorded and electronically averaged by a Tracor #3000

Analyzer recording two channels simultaneously with a bandpass width of .1 to 250 Hz. A 500 ms sweep was used and the 64 sweeps comprised one waveform measurement. The Tracor sweep was triggered off the target pulse for all measurements including during measurements in which the target was not visually presented to the S. The VEPs for both electrode placements were recorded simultaneously. The individual waveform, which consisted of a 256 digit array, was transferred from the Tracor to an Apple II Plus for storage and data analysis.

Procedure

Metacontrast Masking Measurement

The monoptic and dichoptic conditions were run in two separate but similar sessions. The first session was the monoptic condition, since three of the four Ss had to be trained and the monoptic condition was easier for training purposes. The dichoptic metacontrast required not only training in masking but instruction and experience regarding the binocular convergence as well. Other than the convergence training, the two sessions were the same.

Once the Ss arrived at the lab they were asked to read and sign a consent form. The Ss were then given instruction about visual masking and metacontrast and were shown the stimuli and how different SOAs affected the perception of the middle square. Five separate SOA conditions (labelled 0 - 4) were to be used for the VEPs, these were as follows:

1) The first condition (0) was a simultaneous presentation of the target and the mask, i. e. SOA = 0.

2) The second condition (1) was an SOA value that was half-way between simultaneous presentation and maximal masking.

3) The third SOA (2) was the interval that indicated maximum masking for individual Ss.

4) The fourth SOA condition (3) was the interval at which the target appeared to resume its brightness and border properties.

5) The last SOA (4) was 100 ms greater than the fourth SOA value to insure a point at which the subject reported two separate flashes. Only the third (masking SOA) and the fourth conditions required multiple trials to establish the values. The methodolgy used to establish both the third and fourth SOA values was a stepwise forced-choice, discrimination comparison (Coren, Porac and Ward, 1984). The first point to be established was the SOA in which optimal masking occurred for the Ss. The S was given two choices in which s/he was to indicate in which of the two cases, the target appeared as a) the most complete, b) the brightest; or c) the most easily seen. Although the definition appears vague, pilot data indicated that Ss do not experience masking in the same way. Some may see a perceived brightness suppression while others see only a degradation of the target's border and, therefore, the operational definition of metacontrast for the purpose of this experiment had to encompass all the possibilities.

The stepwise procedure went as follows: a maximum of 20 pairs of stimuli comprised one trial and 2 trials were used to establish the SOA at which optimal masking occurred. Each pair of values as well as both members of a pair were separated by 10 ms. The direction of the difference for any pair was randomly presented; i. e., the longer SOA between the two may be presented as '1' for one trial and the following trial may have the longer SOA as '2'. The first trial started at the SOA value of 50 ms. The other choice in this pair would be 60 ms. As long as the shorter SOA was designated as showing a "better" or "stronger" target, the SOA would be increased. This procedure continued until the S reported that the longer SOA value demonstrated a more easily seen target.

The SOA that was chosen as the point of optimal masking was the point at which a decrease or an increase in the SOA resulted in a brighter or more easily seen target. The second trial started at the SOA value of 150 ms. and decreased as long as the longer SOA was reported as the "better" of the two targets. If the SOA chosen as the masking SOA was different for the two different trials an average of the two served as the masking SOA for the VEP. To determine the fourth SOA condition, the same general procedure was used, however the Ss' task was to determine the point at which one of the targets of the two alternatives returned to its original brightness and/or figural identity i. e. a square. When the two psychophysically determined SOA values were established, the other two SOA values (condition 2 and 4) were easily determined. The total amount of time for this part of the session was approximately 20 minutes.

Evoked Potential Measurement

Once the psychophysical data had been obtained, the electrodes were attached and VEPs were recorded. The Ss were dark adapted for approximately 10 minutes where they sat in a dimly lit room with their eyes closed. The beginning of a recording trial was marked with a 10 second stimulus adaptation period during which the subject was to observe the stimuli. The VEP was recorded during the next 64 seconds (64 repetitions of the stimulus which occurred one per second). After the VEP was recorded

Table 1. Evoked Potential Recording Sequence. This sequence was used for all subjects, SOA condtions and viewing condtions.

SOA Condition	Stimulus Presented
0	Target/Mask
	Mask Alone
	Target Alone
1	Target/Mask
	Mask Alone
2	Target/Mask
	Mask Alone
	Target Alone
3	Target/Mask
	Mask Alone
4	Target/Mask
	Mask Alone

for any one condition the subjects were given a 60 second rest period during which they were asked to sit quietly and relax with their eyes closed. After the 60 second rest period the adaptation period for the next recording began. Table 1 shows the VEP recording conditions and sequence of presentation. For two of the five SOA conditions (SOA condition 0 and 2) VEPs were recorded from the following:

a) The mask presented alone.

b) The target presented alone.

c) The target and mask presented together.

For the remaining SOA conditions only the VEP for a) and c) were recorded. VEP's were also taken with both stimuli presented at an SOA of 100 ms for a between subject comparison, as well repeated VEPs for the SOA of 0 and the SOA for the Ss' third SOA conditions. These last VEPs served as a test of variablity for the Ss. The total time required to complete the VEP recording was approximately 45 minutes.

The second experimental session for dichoptic metacontrast was similar to the first with the inclusion of the following:

1) Training of binocular convergence for the target and mask squares.

2) At the end of the VEP recording period, a VEP was recorded using the monoptic simultaneous presentation condition which served as a reliability check for the subjects.

Results

Metacontrast Masking

Table 2 shows the SOA's used for both the monoptic and dichoptic viewing conditions for all subjects. During the monoptic measurement of metacontrast optimal masking occurred when the mask followed the target with SOA values that ranged from 75-95 ms. The SOA at which the target resumed its appearance fell within the range of 120-150 ms. Dichoptic metacontrast masking appeared optimal between the SOA values of 65-100 ms. The range of SOA values for the return of the mask was 120-150 ms. The SOA values for all subjects showed the characteristic type B function although all subjects reported that the target was visible at all times. The target was never completely lost, even during optimal metacontrast masking.

Evoked Potential

Description

Both electrode locations showed similar VEP results, however the electrode at or near the parietal location (6 cm above the inion) showed less noise and larger amplitudes for all subjects. For this reason, only the parietal location will be discussed in the text of this thesis, however, all the occipital data can be found in Appendix A along with the parietal data that are not presented in the text.

Due to excessive noise all the VEPs found in this thesis have been filtered using a running average algorithm. This algorithm uses a certain number of

Table 2. SOAs for all Ss VEP Recording. Included in this table are SOAs in ms for both monoptic (left) and dichoptic (right) conditions.

	Monoptic					Dichoptic				
Ss	0	1	2	3	4	0	1	2	3	4
BLC	0	40	80	120	220	0	35	70	120	220
DVD	0	45	90	150	250	0	50	100	150	250
ND	0	47	95	130	230	0	40	80	120	220
CMT	0	37	75	125	225	0	32	65	120	220

points out of the 256 found in the VEP, (for all subjects this number was 6 points) and computes a running average. The average then becomes the value for those 6 points. The algorithm repeats this process a specified number, usually 6 or 8 times.

Figure 5 shows the data for DVD, both monoptic and dichoptic at the parietal electrode. The occipital VEPs for DVD can be found in Appendix A with the data from the other subjects. Both viewing conditions yielded similar VEP results. However to avoid confusion, both viewing conditions will be discussed separately.

Monoptic Condition

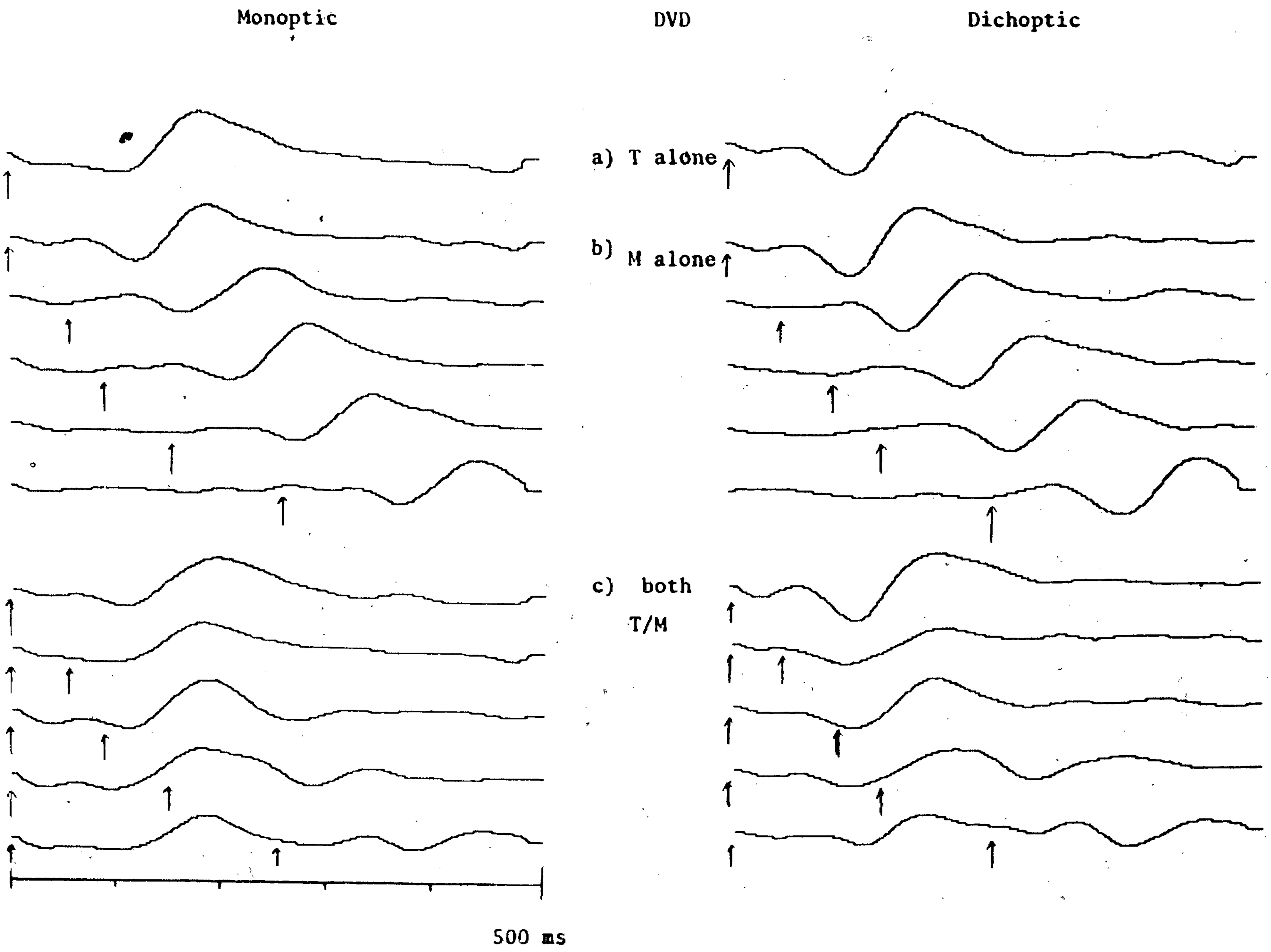
The VEP taken during the monoptic condition for DVD shows the target alone, mask alone and the VEP recorded with both stimuli presented. The target alone response shows a large positive peak with a latency of 180 ms after the onset of the target. The mask alone responses for DVD (Figure 5 b-middle) show a positive peak occuring at a latency that ranged between 181-196 ms after the onset of the mask. This positive peak appears to be moving out as a function of the interval between the target pulse (VEP trigger) and the mask stimulus.

The VEPs recorded from target and mask together show that for the first 3 SOA conditions, the VEP shows virtually one positive peak occuring in the range 175-185 ms after the onset of the target. The two bottom rows in figure 5 (left) are the VEPs in which the two stimuli are separated by 150 ms and 250 ms, respectively, and the subject clearly perceives both stimuli, a second positive peak emerges, however, with a very small amplitude.

Figure 5. VEP Descriptive Data for DVD. This shows the data recorded at the parietal electrode location for both monoptic (left) and dichoptic (right) conditions showing:

a) the Target alone response
b) the Mask alone response
c) the response to the pair (T/M) of stimuli

The arrows indicate where the stimuli occurred. In all subjects' waveforms in this thesis, negativity is shown as a downward deflection.


Monoptic
DVD
Dichoptic
a) T alone
b) M alone
c) both
T/M
500 ms

Dichoptic Condition

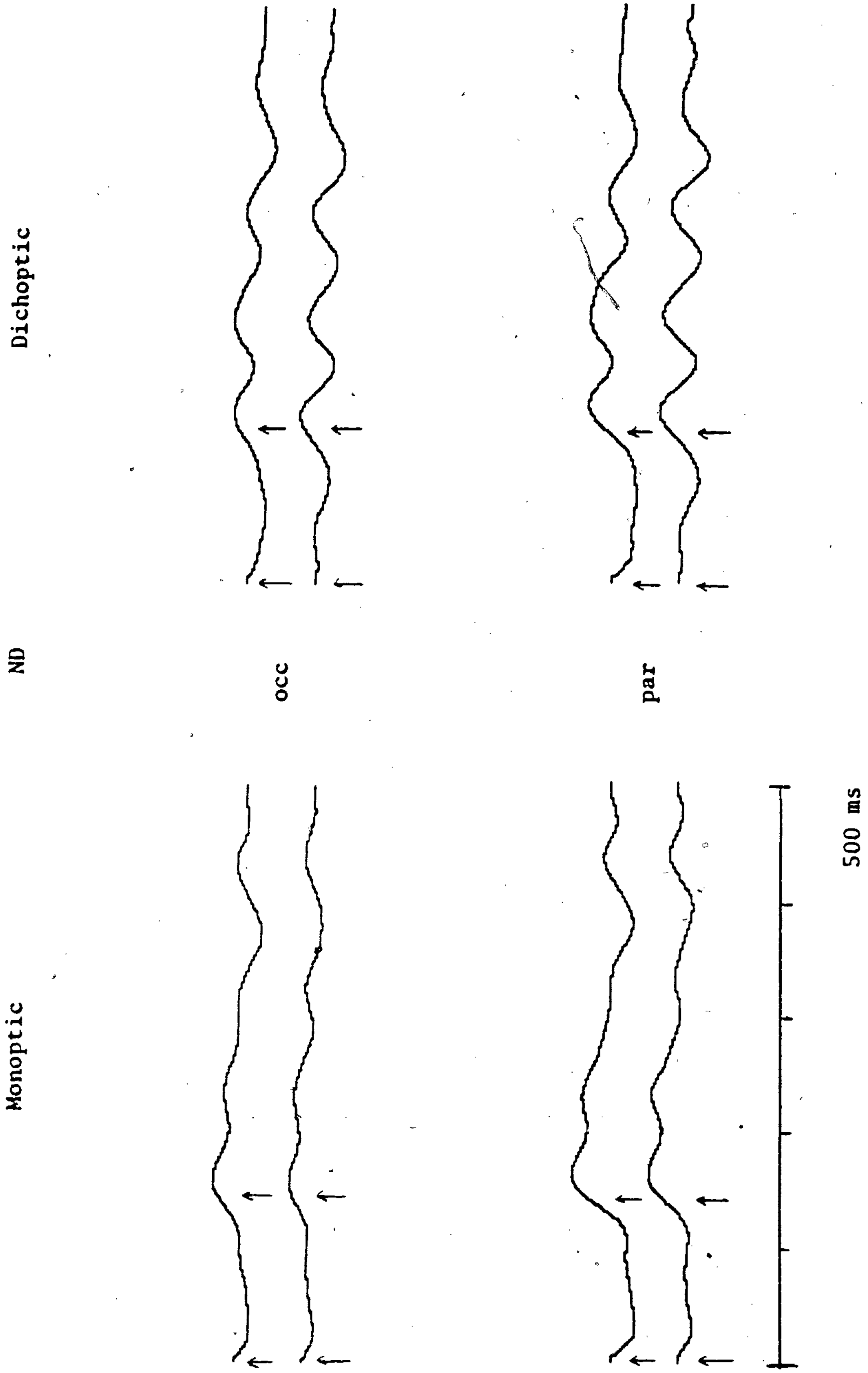
The VEP taken during the dichoptic condition (Figure 5b) shows a positive peak occurring at a latency of about 185 ms after the trigger. The mask alone VEPs also show the large postive peak moving as the interval between the trigger-target pulse and the stimulus-mask onset. The positive peak found in the mask alone responses occurs at latencies between 185-193 ms after the onset of the mask. As in the monoptic condition, the VEPs recorded during the presentation of both stimuli together show one postive peak for the first three SOA conditions and a smaller positive emerging during the VEPs in which the target and mask are separated by 150 and 250 ms.

The other subjects showed similar results. The actual latencies for the target alone and the mask alone responses can be found in Appendix B. The target alone responses for the monoptic condition shows the positive peak occurring with latencies in the range of 162-207 ms. During the dichoptic condition the Ss' positive peak occurred at latencies that ranged from about 148-216 ms. All of the Ss' mask alone responses for both monoptic and dichoptic stimulation show the positive peak moving out as a function of the interval between the trigger-target pulse and the stimulus-mask onset. All the subjects also show one large positive peak occurring in the VEPs recorded with both stimuli presented for the first three SOA condition with a smaller positive peak emerging in the last two SOA conditions.

Reproducibility of the VEP: Within One Session

Figure 6 graphically displays the reproducibility of the VEP of one subject

Figure 6. VEP Reproducibility Data: One Session for ND. This shows 2 independent VEPs recorded during both monoptic (left) with an SOA of 130 and dichoptic (right) conditions with an SOA of 120 ms for a) occipital and b) parietal electrode locations.


Monoptic
ND
Dichoptic
occ
par
500 ms

(ND). This figure shows the 2 separate VEPs recorded from the condition in which the mask followed the target by 130 ms (monoptic) and 120 ms (dichoptic). Both waveforms show similar shape and amplitude. The reproducibility data for the other subjects VEPs recorded during one session can be found in Appendix C.

Between subject differences were also found. Figure 7 demonstrates the variability between subjects for stimuli which were separated in time by 100 ms for both the monoptic and dichoptic conditions.

Reproducibility: Between Two Sessions

The reproducibility of the VEP recorded during two sessions is demonstrated in Figure 8. The figure contains data for two subjects, BLC and CMT. For both subjects there are two waveforms, recorded from the occipital and the parietal electrodes. The first waveform was recorded during the first experimental session and the second recorded during the second experimental condition. These waveforms were recorded using the monoptic viewing condition with both stimuli presented simultaneously. The first subject is typical of three of the four subjects, BLC shows very similar waveforms over both sessions, and electrode locations. The second subject, CMT, shows somewhat less similar waveforms in terms of the latencies of the large initial positive, as well as number of components, amplitude etc. However, the responses from this subject typically showed a double peak response (see Appendix A) and the larger of the two positive peaks tends to fall in the range 200-210 ms after stimulus onset, for both records. The reproducibility data over two sessions for Ss: DVD and ND can be found in Appendix D.

Figure 7. VEP Between Ss Comparison at an SOA = 100 ms. This figure shows VEPs for monoptic (left) and dichoptic (right) conditions for occipital (a) and parietal (b) locations.

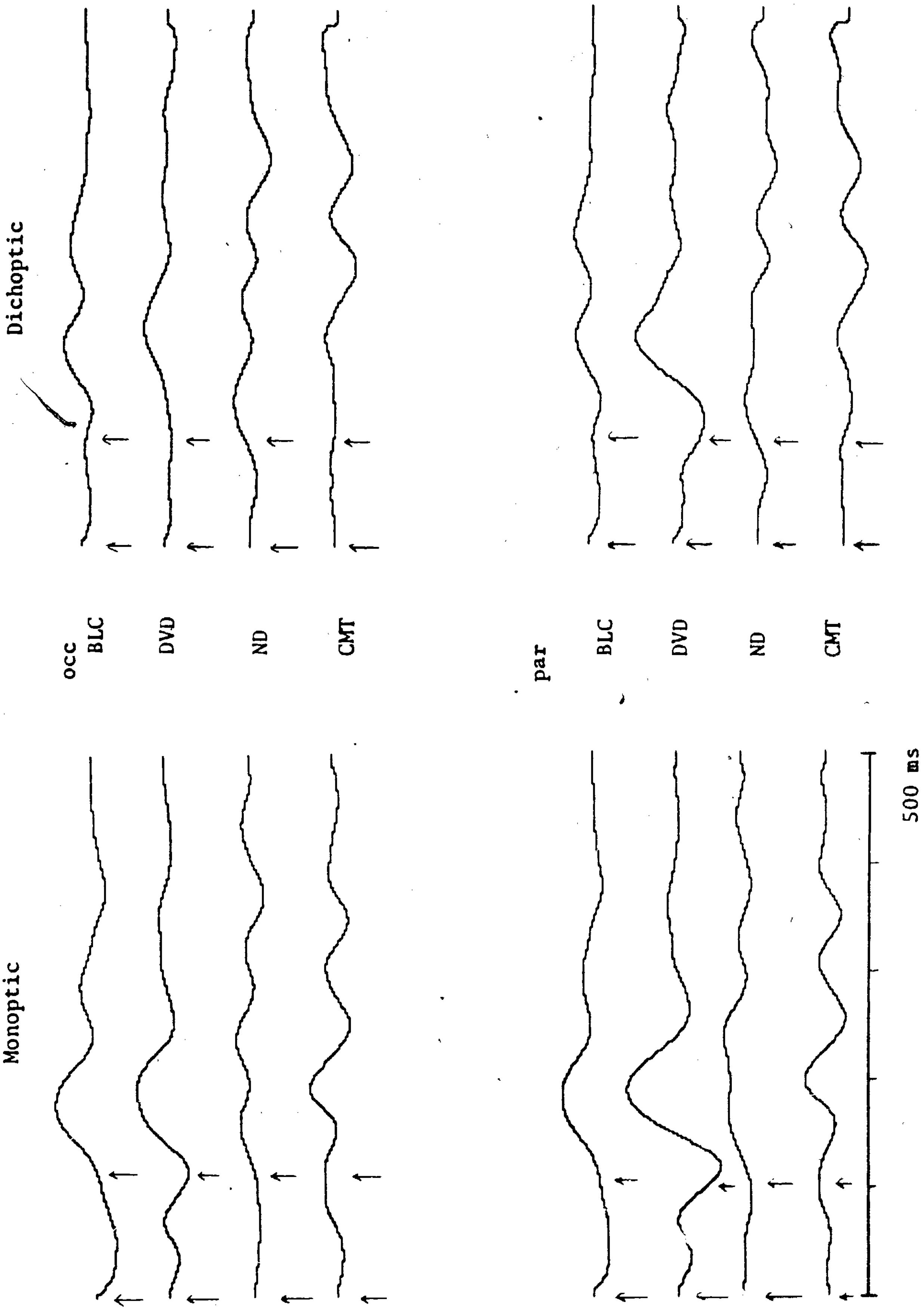
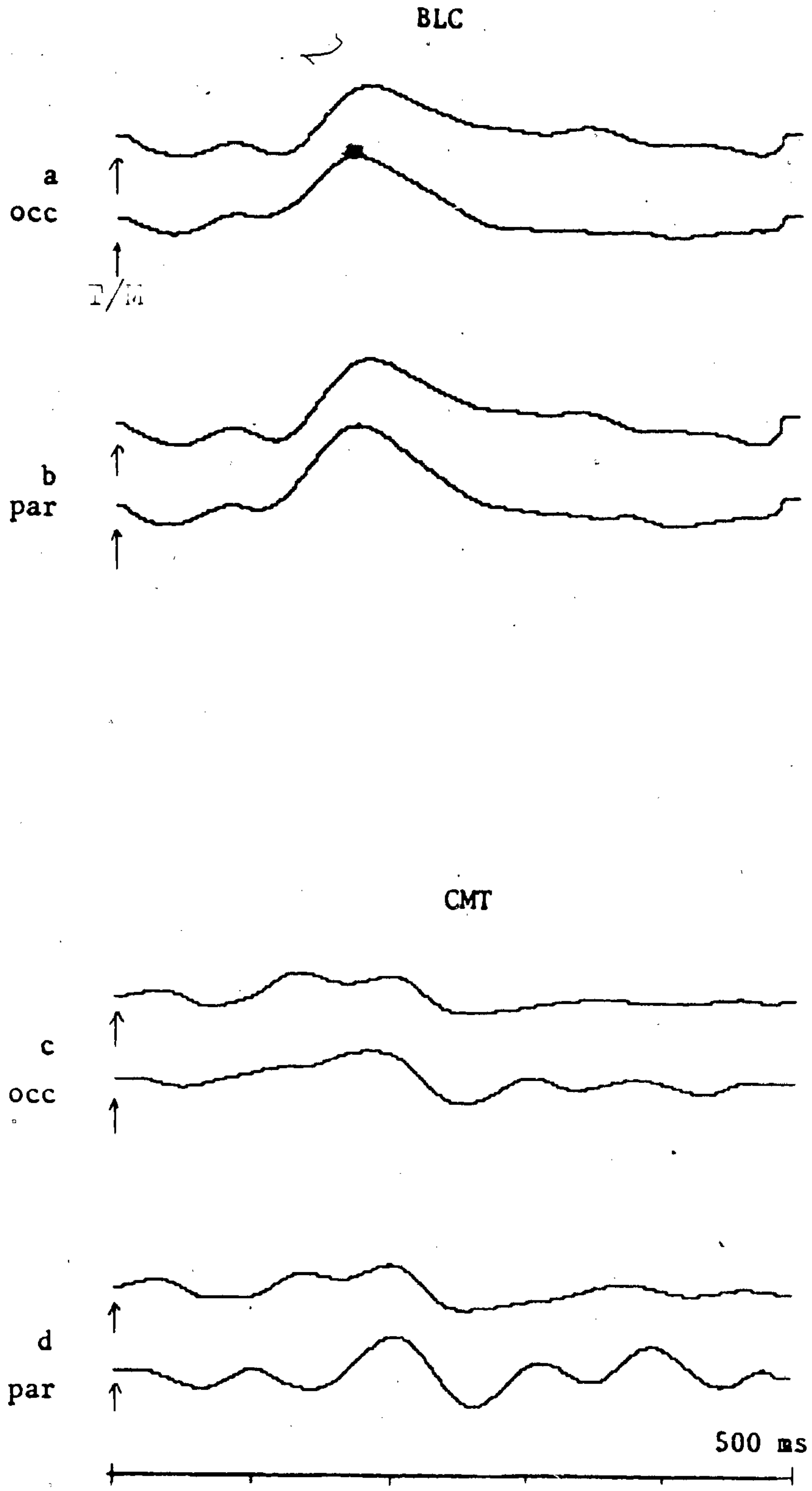

Dichoptic
Monoptic
occ
BLC
DVD
ND
CMT
par
BLC
DVD
ND
CMT
500 ms

Figure 8. VEP Reproducibility Data: Two Sessions for BLC and CMT. VEPs were recorded during the monoptic condition for BLC (upper) and CMT (lower) over 2 sessions for occipital (a and c) and parietal (b and d) locations.


BLC
a
occ
T/M
b
par
CMT
c
occ
d
par
500 ms

Composite Procedure and Results

To determine the extent to which there is an interaction between the target and mask responses which shows up in the VEP recorded with both stimuli, the VEPs to the target alone and the mask alone were added together by computer. The response to the target alone was added with the response to the mask alone recorded at all the SOA conditions to form computer "composites". These computer composites represented the waveform that would result if the responses to the stimuli did not interact spatially or temporally. Figure 9 shows the waveforms which were combined to form the composites for subject DVD, for both the monoptic and dichoptic conditions and the resulting composites. The computer composites show the initial large positive peak found in both target alone and mask alone responses. The first two composites (0 and 1) show one positive peak and the subsequent composites (2-4) show the positive peak that corresponds to the target alone response and a second positive peak that reflects the mask alone response. This procedure was carried out for all subjects' data. Appendix E contains the computer composites for the remaining subjects and for both monoptic and dichoptic conditions.

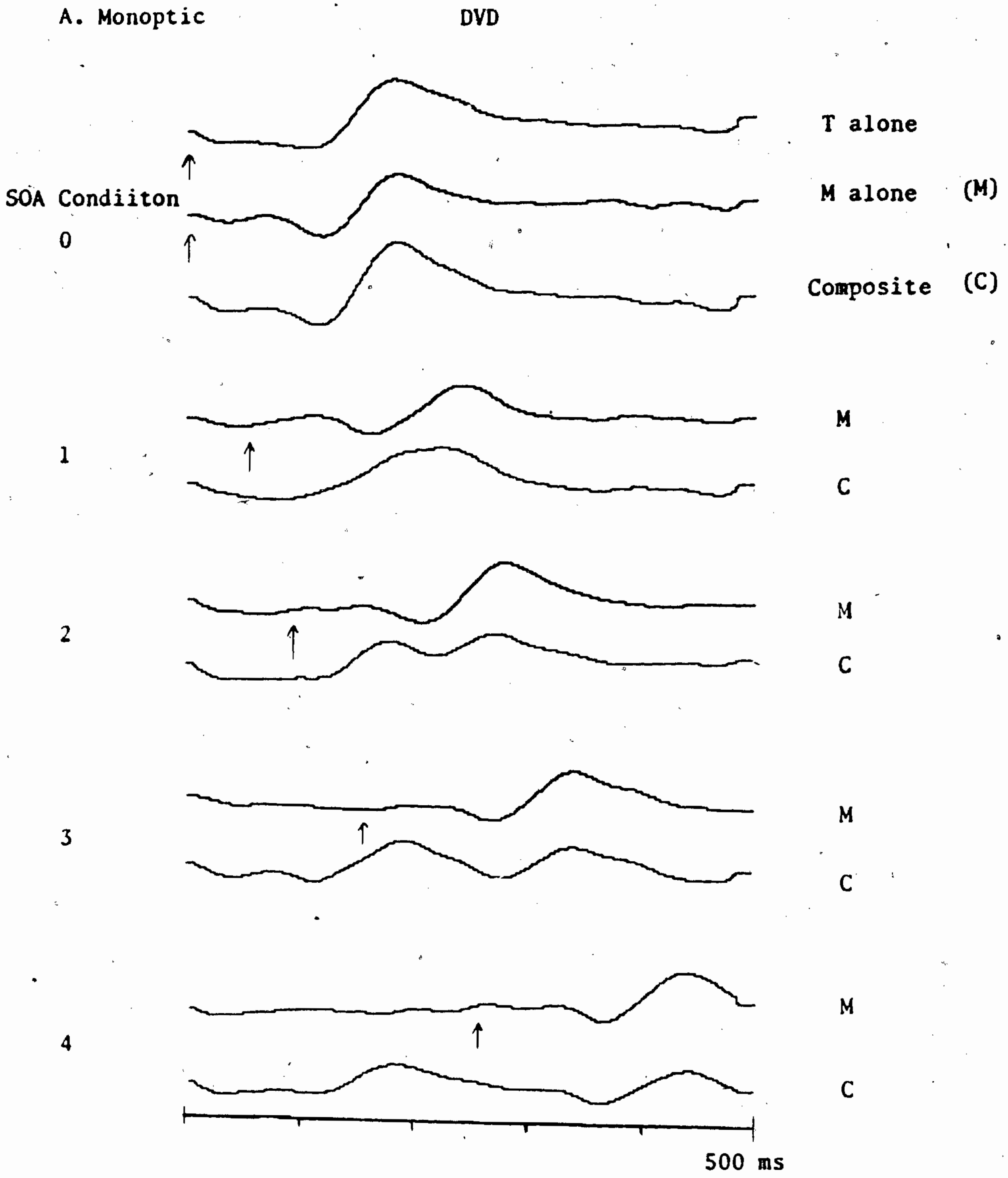
Residuals

Once the computer composites were calculated, each composite was subtracted from its corresponding VEP recorded from the brain with both stimuli presented. Figure 10 shows the data for subject: DVD. The first waveform is that of the mask alone for the given condition and beneath it the residual waveform.

Figure 9. VEP Composite Waveforms for DVD. Composites computed for A) monoptic and B) dichoptic conditions at the parietal location. Waveforms included:

1) Target alone response

2) Mask alone response and corresponding composite waveform for all SOA conditions.


A. Monoptic
DVD
T alone
SOA Condiiton
M alone
(M)
0
Composite
(C)
1
M
C
2
M
C
3
M
C
4
M
C
500 ms

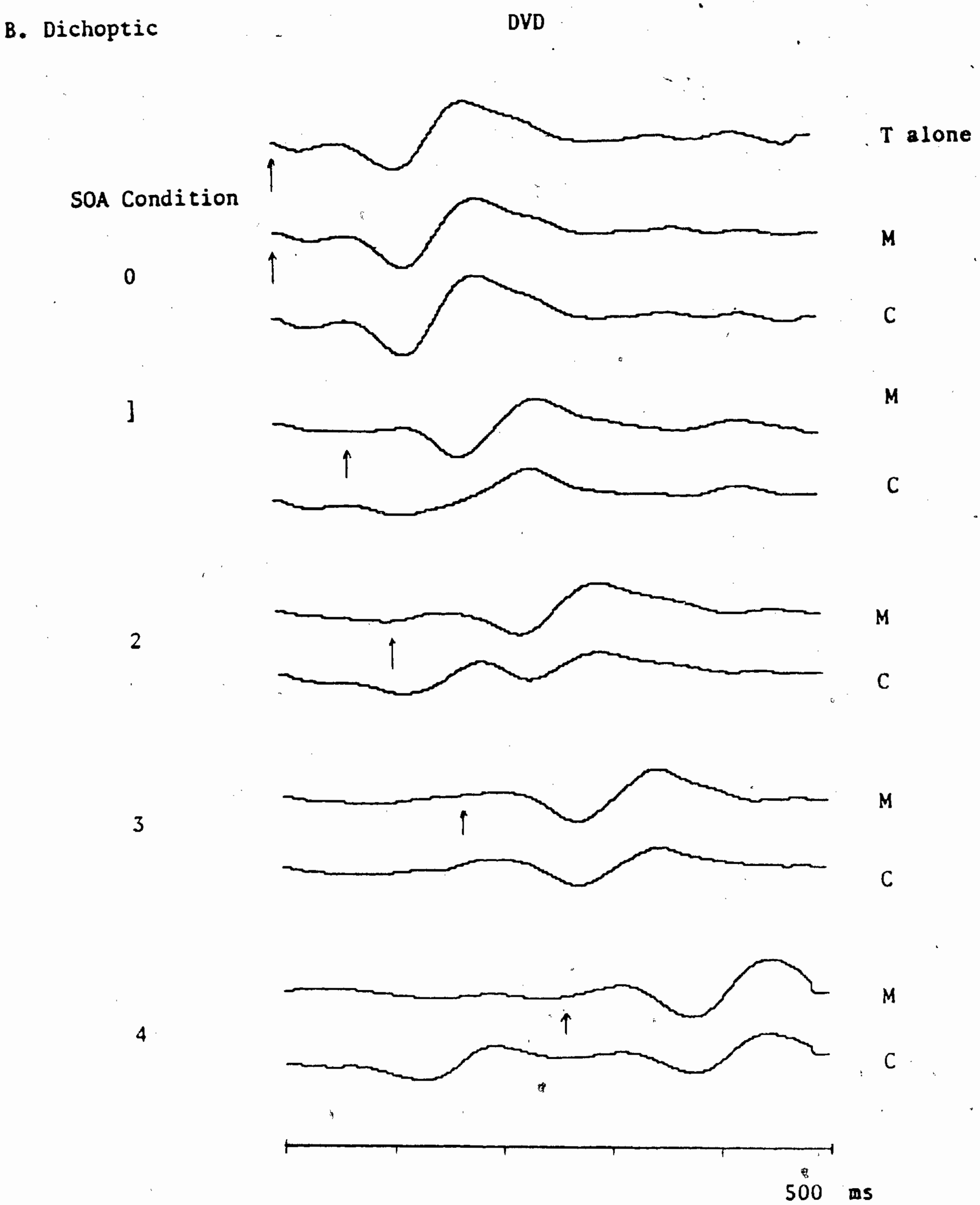
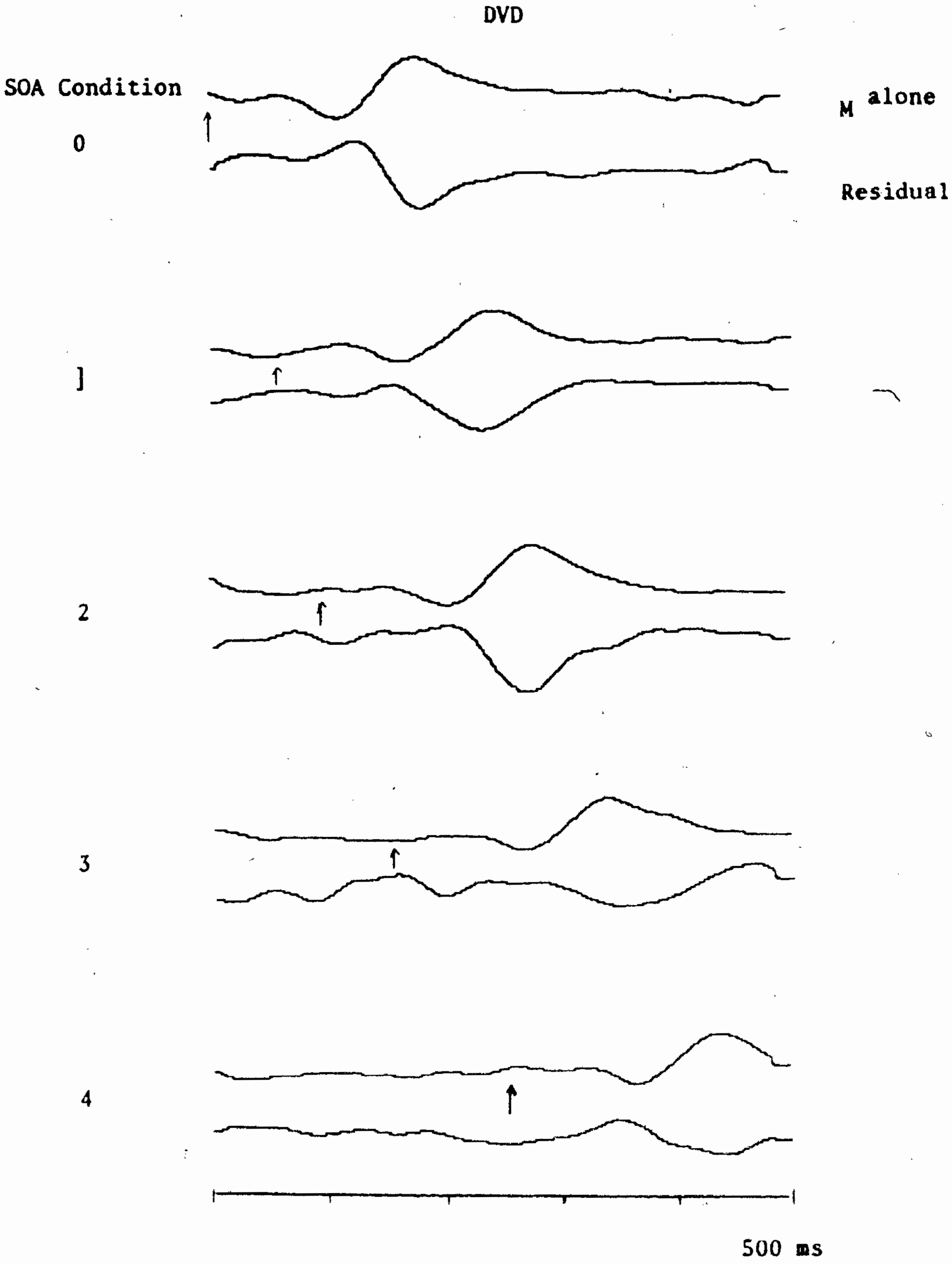
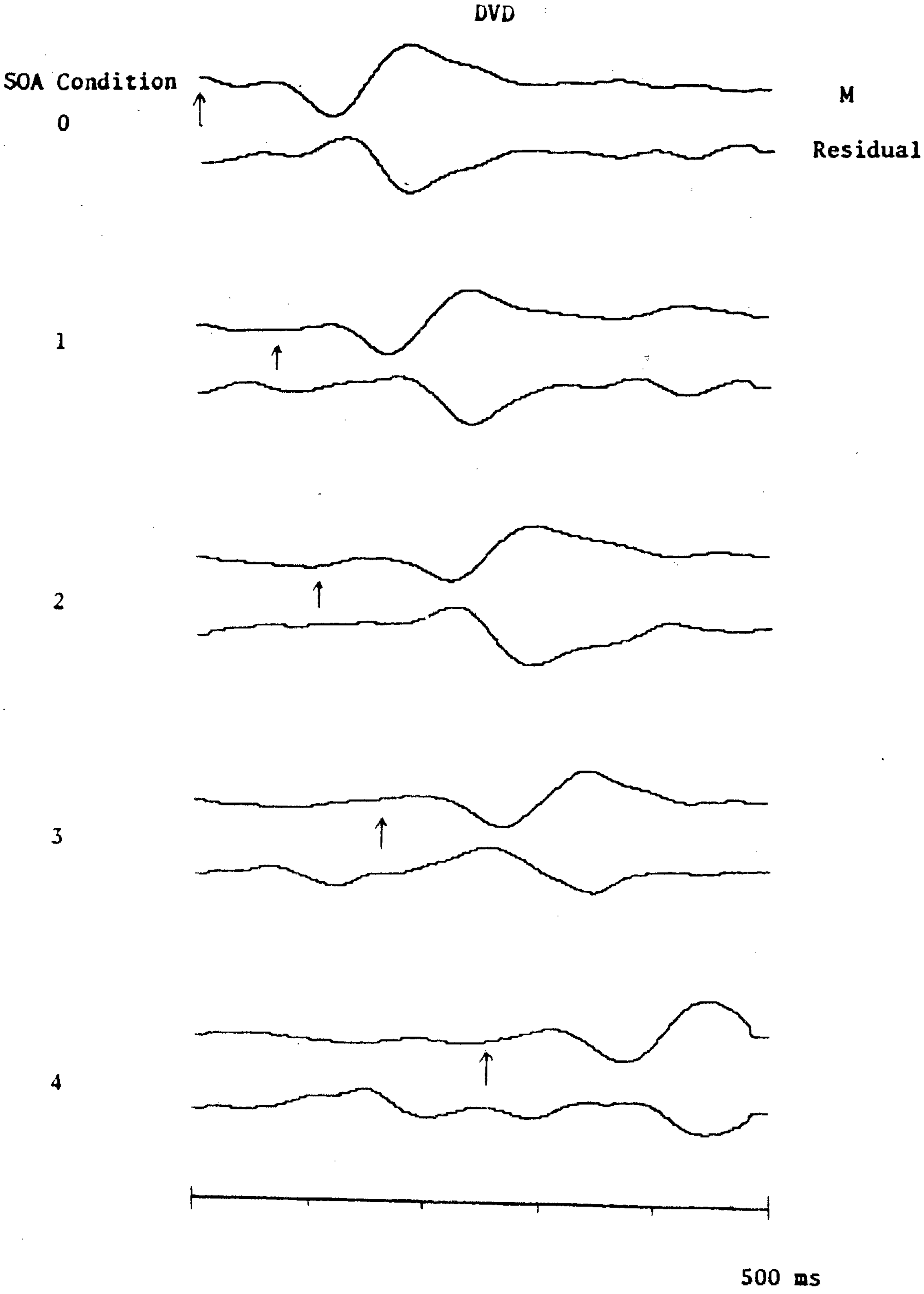

B. Dichoptic
DVD
T alone
SOA Condition
0
M
C
1
M
C
2
M
C
3
M
C
4
M
C
500 ms

Figure 10. VEP Residual Waveforms for DVD. Residuals computed for A) monoptic and B) dichoptic conditions at the parietal location. Waveforms include mask alone response and corresponding residual waveform for all SOA conditions.

A. Monoptic



B.Dichoptic



This residual waveform represents the extent to which an interaction between responses of the separate target and mask stimuli occurred in the brain response to both stimuli. If the subtraction procedure resulted in a straight line, this would indicate no interaction between the responses of two stimuli; the extent to which the residual is not a straight line indicates that an interaction between the responses did occur in the VEP recorded from both stimuli.

Figure 10 shows that the residuals computed for DVD were not straight lines. There was a negative peak occuring in the residual with a latency similar to that of the large positive peak occurring in the mask alone response. Table 3 contains the latencies of the positive peak found in the mask alone responses and the latencies of the negative peak found in the residuals.

The latencies of the positive mask alone peak was then correlated with the latencies of the negative in the residuals using an Apple II Plus statistics package called 'Statsplus'. Table 4 shows the correlations for all subjects, both monoptic and dichoptic for both electrode locations. Table 4 shows that the correlations ranged from .986 to .999 for the monoptic condition and .966 to .999 for the dichoptic condition. Also included in table 4 is the r^2 for all subjects, or the amount of variance in the latencies of the negative peak in the residuals accounted for by the positive peak latencies in the mask alone response.

Table 3. Latencies for Positive Peak in Mask Alone Responses and Negative Peak in Residuals. Latencies in ms included for all subjects both monoptic (left) and dichoptic (right) conditions.

	Monoptic		Dichoptic	
	Mask +	Residual -	Mask +	Residual -
BLC				
Occ	175	183	172	175
	218	222	207	216
	259	264	246	246
	292	289	290	335
	404	410	398	416
Par				
	177	181	180	186
	218	228	208	216
	265	265	253	254
	295	308	300	317
	404	462	406	452
DVD				
Occ				
	183	181	180	177
	241	234	240	238
	279	275	287	289
	339	353	343	347
	435	445	446	437
Par				
	181	181	183	179
	244	230	240	240
	277	275	292	289
	339	382	341	345
	451	455	443	440

	Monoptic		Dichoptic	
	Mask +	Residual -	Mask +	Residual -
ND				
Occ				
	150	166	141	169
	198	193	192	199
	237	255	232	235
	288	252	263	325
	401	449	379	392
Par				
	160	169	156	177
	208	222	218	215
	269	260	250	259
	327	341	291	314
	409	431	398	400
CMT				
Occ				
	200	207	205	216
	240	254	240	253
	277	292	276	299
	322	327	333	333
	441	452	424	413
Par				
	205	210	208	218
	244	255	242	246
	279	292	279	302
	324	332	335	330
	423	416	425	420

Table 4. Correlations Between Latencies of Positive Mask Alone Peaks and Residual Negative Peaks. Also included in this table is the r^2 and S. E. for all subjects, both monoptic and dichoptic conditions and both occipital (left) and parietal (right) locations. All correlations are based on df = 3.

	Monoptic		Dichoptic	
	Occipital	Parietal	Occipital	Parietal
Ss:				
BLC				
r	.996	.994	.986	.997
r^2	.992	.988	.972	.994
SE	8.037	11.988	16.125	7.575
DVD				
r	.984	.998	.999	.999
r^2	.968	.996	.998	.998
SE	20.222	6.090	4.451	2.221
ND				
r	.986	.995	.966	.992
r^2	.972	.990	.933	.984
SE	19.604	10.675	23.985	10.862
CMT				
r	.999	.998	.995	.993
r^2	.998	.996	.990	.986
SE	4.475	5.527	7.854	9.424

Discussion

Metacontrast Masking

The masking data show that different subjects do perceive masking occurring maximally at different SOA intervals. Although the SOA interval at which different subjects indicate maximum masking is different, all the subjects reported the target as remaining visible at all times. The masking data also show the characteristic function of type B metacontrast. When the target and mask were presented simultaneously, no masking occurred. As the interval between the presentation of the target and the mask increased to some optimal interval, the target appeared to change in its appearance, perceived duration and/or brightness. As the interval continued to increase the target began to assume it original appearance until the two stimuli were separated sufficiently so the target appeared to be unaffected.

The lack of a complete disappearance of the target during masking has been reported before. Flaherty and Matteson (1971) in a quasi-replication of Schiller and Smith (1966), used fairly high intensities for the sole purpose of keeping the target visible at all SOA intervals.

The visible target during masking is consistent with the reaction time studies of masking. Several investigators have found that reaction time in simple detection studies do not show the U-shaped function of type B masking (Fehrer and Beiderman, 1962; Fehrer and Raab, 1962; Schiller and Smith , 1966).

The target's visibility may be related to the stimulus configuration. The majority of the metacontrast studies have used the typical disk and annulus stimuli, or a configuration in which the mask borders surround those of the target. Other investigators have used stimuli in which the area of the target or masked stimulus is small. Stoper and Banffy (1977), for example, used long vertical bars 1.8^0 in length and only 2' in width. Alpern (1953), used vertical rectangles 2.5^0 in height and only $.5^0$ in width. Since studies in which the target does completely disappear use stimuli in which the proportion of adjacent border is larger than the area of the target, perhaps metacontrast masking is more of a border suppression phenomenon than global suppression.

There is the question of the validity of the metacontrast measure. The operational definition of optimal masking was less than optimal. It was vague, and difficult to determine for certain subjects. Most of the subjects expressed difficulty as well as apprehension in making the judgement between two pairs of SOA intervals especially for pairs in which masking was occurring.

It is also difficult to determine what criterion the subjects actually used in making the judgement. Although the subjects were questioned as to how the target was affected, it is not necessarily true that subjects actually used the criteria expressed. Demand characteristics may also have affected the judgements of the subjects. All the subjects were instructed in the U-shaped characteristic of the masking function. Perhaps the expectation of the increased masking and the return of the target to its original appearance influenced the subjects' judgements. This, however, seems unlikely since the subjects were not always sure of the direction of the difference between the two pairs of SOA intervals to be judged.

It is also possible that the strong apparent motion (beta) also influenced the subjects' choice. Every subject expressed the difficulty of the choice because of the amount of motion that was perceived, however this motion tended to show a monotonic increase with the increase in SOA. One subject expressed that even though he perceived the complete target at the longest SOA value, it seemed to him that the target was actually becoming the two adjacent masks. The target appeared to be presented to the center of the field but then split and became the mask squares.

Regardless of the influences exerted by the demand characteristics and the amount of apparent motion, it isn't really necessary to question the validity of the masking judgements concerning the VEP measurement. For all of the subjects, the range of SOA values used for the VEP ranged from simultaneous presentation (SOA = 0) to a much longer SOA which was over 200 ms for all of the subjects. There is no previous literature that demonstrates visual metacontrast masking occurring at SOAs over 200 ms. So there is some assurance that using the 5 SOA conditions encompass the metacontrast function for all the subjects. Perhaps some other psychophysical procedure would result in different SOA values as defined by the author of the present investigation, but, it is highly unlikely that any of the subjects would experience maximal masking occurring at SOAs greater than 200 ms.

Evoked Potentials

The VEP data in this investigation present an interesting and yet perplexing result. According to Figure 10, the residuals for DVD, both monoptic and dichoptic show a negative peak whose latency is highly correlated with the latency of the large positive peak found in the mask alone VEPs. Table 4 shows these correlations to range from .966 to .999 for all subjects. The residuals for all subjects, both viewing conditions and both electrode placements, show this relationship between the mask alone responses and the residuals. Two conclusions may be drawn from this result.

First, it is apparent that the VEP, recorded from scalp electrodes positioned over occipital and parietal areas with both target and mask stimuli presented, is not simply a summation of the responses to the separate stimuli. The response recorded from the brain is an interaction of the two responses from the target and mask. This conclusion is in opposition to the conclusion made by Donchin and his associates (Donchin, Wicke and Lindsley, 1963; Donchin and Lindsley, 1965) , and similar to that made by Schiller and Chorover (1966).

Donchin and Lindsley (1965), showed that the additivity assumption could be demonstrated under certain conditions. Donchin and Lindsley used superimposed stimuli and concluded upon testing the additivity assumption that, within limits, the response to both stimuli was a summation of the responses to the two separate stimuli, furthermore the VEP recorded with the paired flashes is a sum of the responses to the two flashes "as long as they are perceived as two flashes" (p. 330).

During masking, which in Donchin's case occurred when both stimuli were presented simultaneously, the perception of the masking or blanking flash completely displaces that of the target or blanked flash. With the addivity assumption, sutracting out the mask alone response would result in a residual that would reflect the amount of the target response in the VEP a residual that would reflect the amount of the target response in the VEP to both stimuli. In the case of the present investigation, the metacontrast masking of the adjacent stimuli occurred at some SOA interval within the range of 65-100 ms, and the target was visible at all times. Perceptually, the target was never completely displaced except to the extent of the apparent outward motion of the target towards the mask.

The subtraction process used in this investigation did not assume the additivity of the responses but actually tested it. The residuals shown in Figure 10 and Appendix E, reflect the extent to which the VEP to both stimuli is not simply the result of the target and mask responses summating. This supports the conclusions based on the results of Schiller and Chorover's (1966) investigation. These investigators used the disk and annulus configuration to obtain metacontrast masking. Using the synthetic EP waveforms obtained by summing the responses to the two stimuli, Schiller and Chorover found little support for the notion that components of the VEP recorded using both stimuli "under metacontrast conditions represent a summation of evoked responses to the individual stimuli" (p. 153).

A second conclusion may be drawn from the results of this investigation. Not only is the VEP recorded using both stimuli not a simple summation of the two individual responses, but what appears to be most affected is the positive peak that most closely corresponds with the mask alone response. This conclusion is somewhat paradoxical. In perception, the stimulus most affected is that of the target, however, in the VEP what is most affected is a component that is related to the mask.

This conclusion is not without support. Jeffreys and Musselwhite (1986), found a similar result. Jeffreys and Musselwhite used a multi-elemental version of the adjacent squares stimulus configuration. However, the configuration was designed, and presented to certain areas on the retina in the attempt to evoke specific pattern-related components; i. e., CI and CII. The results showed that the initial positive onset related component (CI) was unaffected during masking which occurred between the SOA range of 50-100 ms. The VEPs showed that for SOAs of 30 ms and greater a second positive peak was clearly detectable which reflected the CI component to the masking pattern. This emerging component showed an attenuated amplitude which gradually increased along with the latency as the SOA increased. At SOAs of 80 ms. or greater, the two peaks had comparable amplitudes.

Jeffreys and Musselwhite concluded that the attenuation of the second positive peak was a result of the temporal overlap of a negative peak in the target-evoked VEP (see Figure 2) as well as a genuine attenuation of the CI component evoked by the mask pattern at the shorter SOAs which was presumably due to the adaptation of the CI source generators by the previously presented target pattern. This conclusion may well address the attenuation of the mask response in the monoptic condition of the current investigation, however, it is unclear just how this might work in either of the viewing conditions.

Other explanations also appear insufficient. Schwartz, Whittier and Schwitzer (1979) concluded that changes in the VEP found in the monoptic condition were due to retinal inhibition. However, such explanations are inadequate for several reasons. First, the investigators made several changes from the monoptic condition to the dichoptic condition which render any direct comparison between the two conditions invalid. Secondly, Schwartz, et al. assumed the additivity of the separate stimuli (as did Donchin and his associates) without testing the assumption using his data and his adjacent stimuli. Thirdly, Schwartz et al. found conflicting results between the monoptic and dichoptic conditions, therefore, the conclusion reflects this discrepancy. The current investigation, however obtained similar results for both the monoptic and dichoptic conditions which were directly comparable in terms of the parameters used.

Conclusion

The general conclusion of the current investigation is that (1) the VEP elicited during monoptic and dichoptic metacontrast masking is not simply a summation of the responses to the individual stimuli, and (2) the response that appears most affected is the response that is more closely associated with the mask response. There appears to be no obvious explanation for these results. It appears that the perception is not reflected by the psychophysiological measurement. However, other VEP investigations have shown poor correlations between evoked potentials (EP) and sensory perception as well. Regan (1981) cites many different examples of visual perceptual phenomena that do not correlate with the specific sensory EP, such as VEPs recorded below subjective flicker thresholds.

It appears that the perception of metacontrast masking is not a case in which the psychophysiological measure reflects the perceptual phenomena.

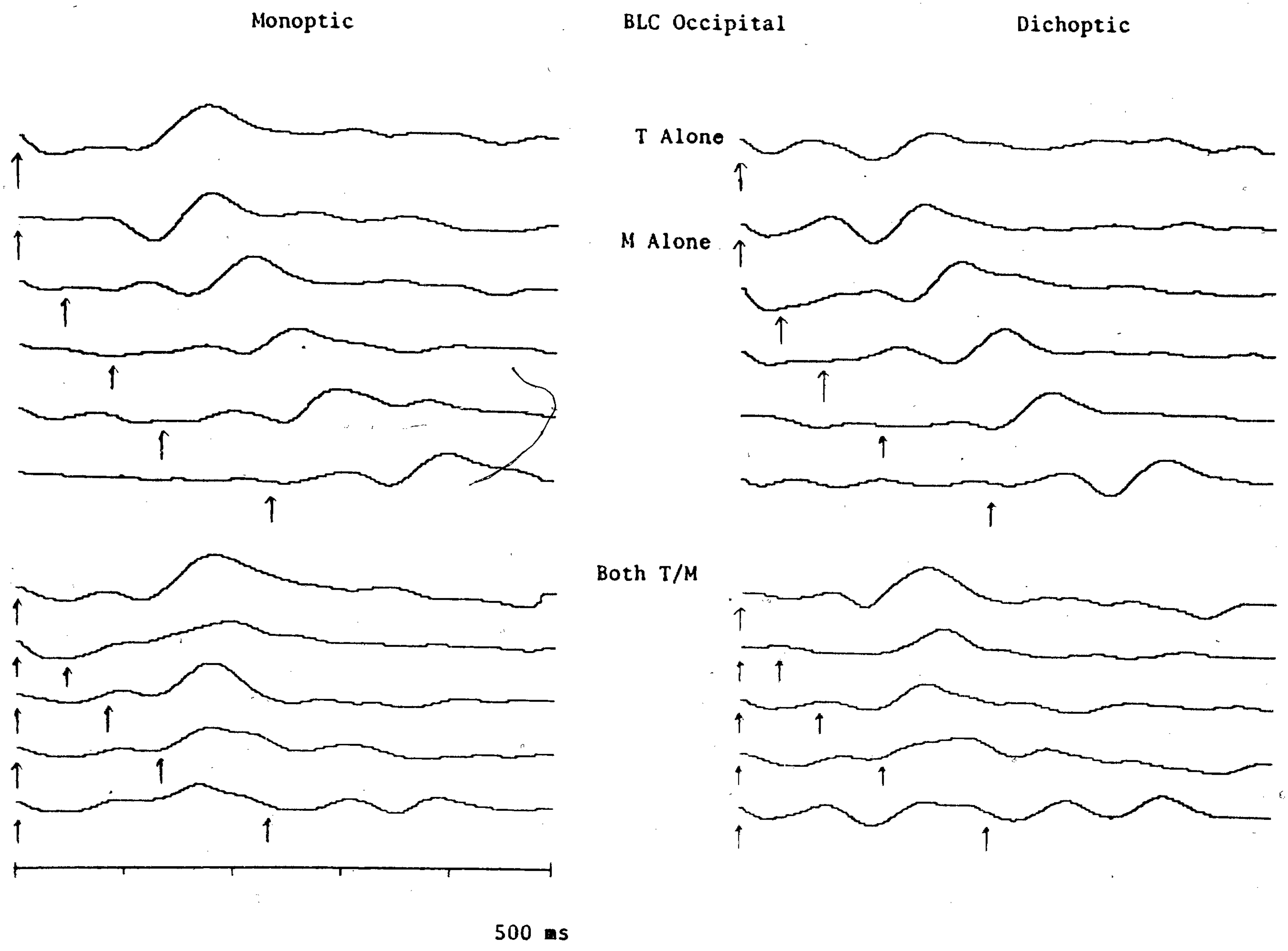
Either the perception is not mediated by the occipital or parietal areas or at the very least cannot be measured using scalp VEPs located over these sites. It may be possible to measure the perception of masking at other locations but the question is, "Where?" Pilot data revealed that measurements taken from other placements along the midline (vertex and frontal) do not vary from the occipital/parietal placements used in this investigation except in amplitude. Other likely placements, such as temporal locations (T_3 and T_4) did not yield a substantial VEP. Appendix G contains data taken from temporal placements and it is apparent that the waveforms elicited by the stimuli do not vary significantly from those waveforms taken as general noise levels.

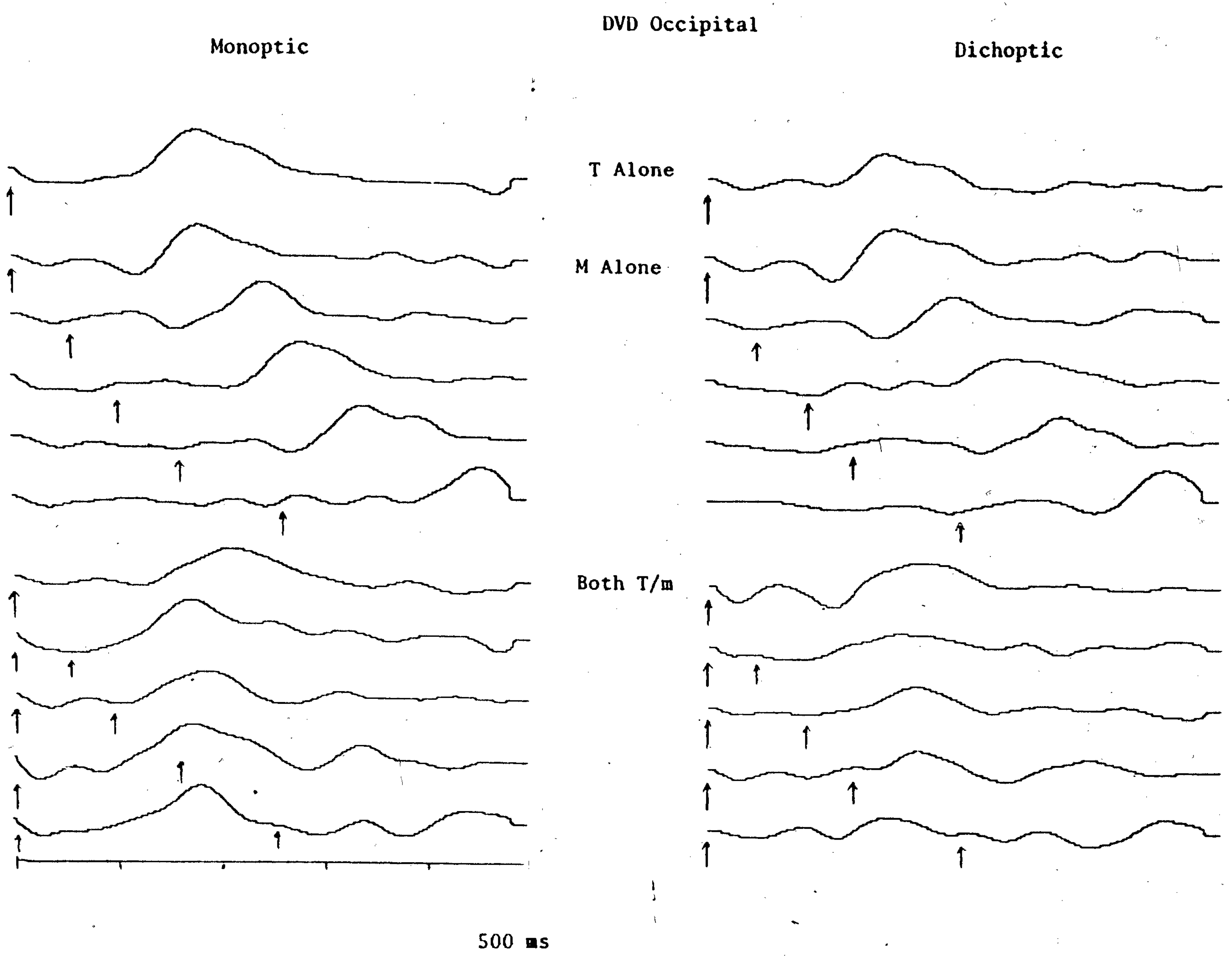
The results of this investigation also present certain problems theoretically in that it provides no overwhelming support for either inhibition or summation theories. If summation had occurred, then the results would show an increase in the amplitude of the positive peak occurring in the mask alone rather than an attenuation.

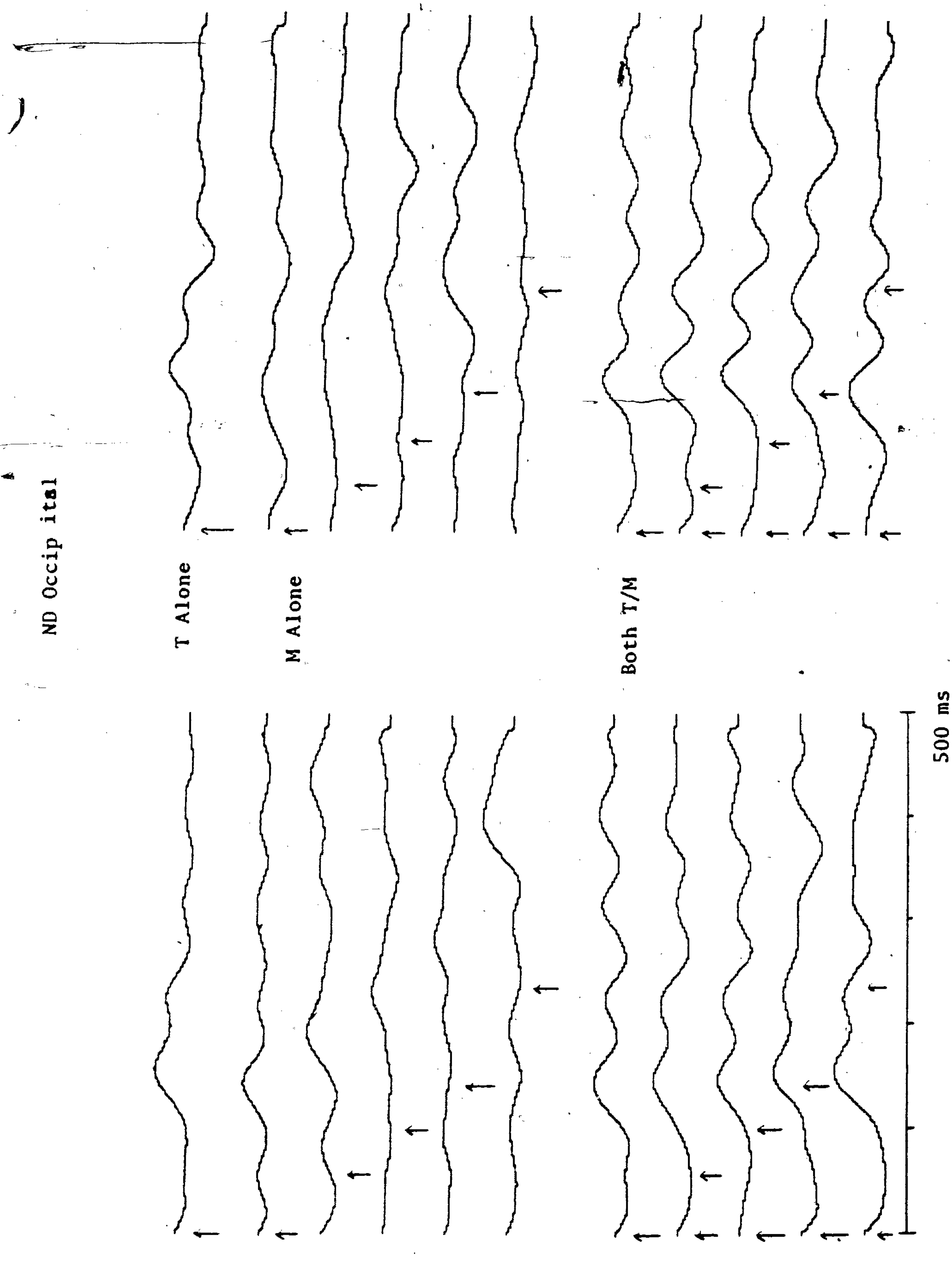
A stronger case may be made for inhibition theory. According to Breitmeyer and Ganz, the target activates both transient and sustained activity, and only the earliest of the target's sustained activity is inhibited by the transient activity of the mask. Theoretically, the transient activity of the target is not affected by the mask activity. Perhaps, the current investigation shows the extent to which the target's transient activity is unaffected.

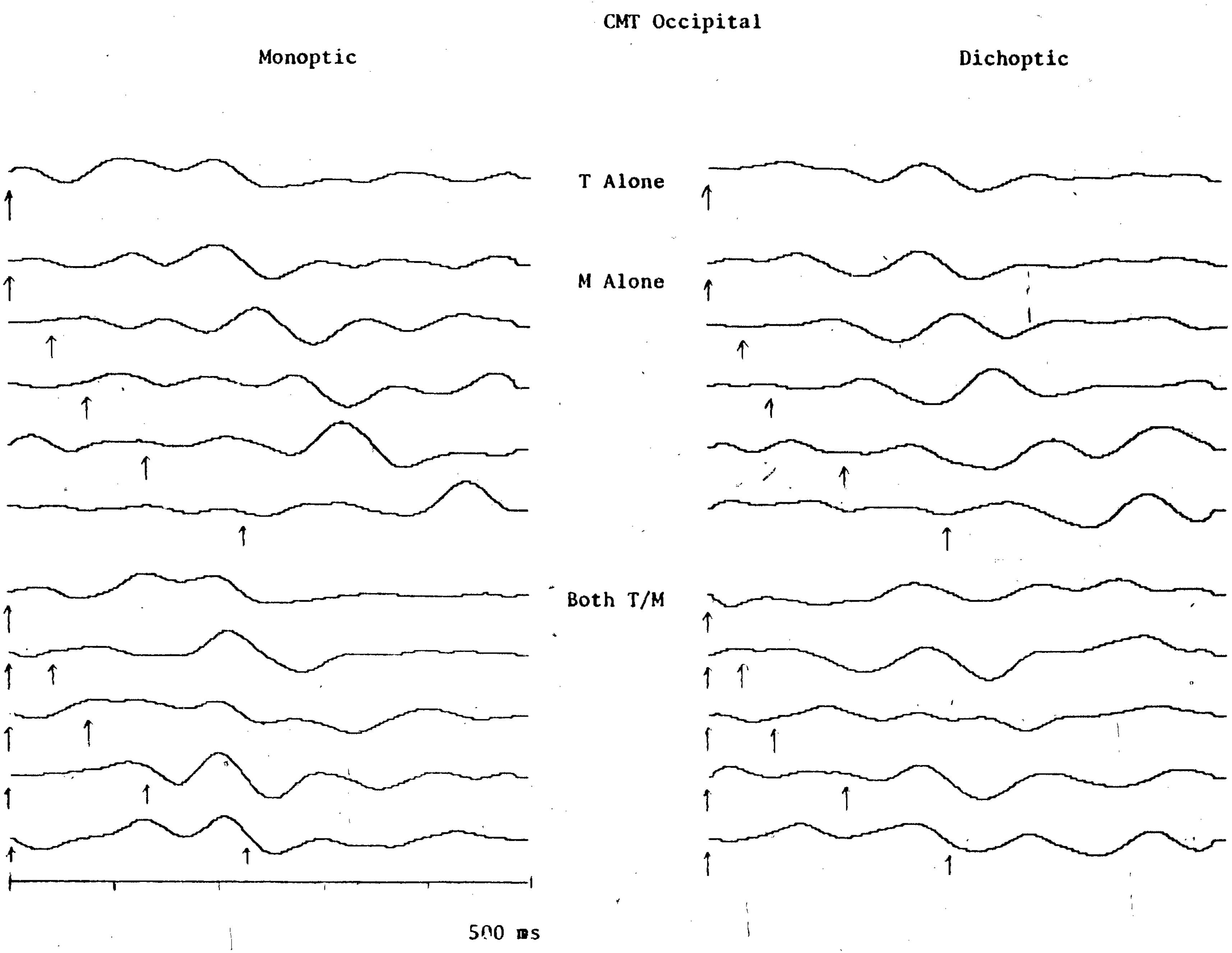
Unfortunately, neither summation or inhibition would predict the change that occurred in the positive peak in the mask alone response. However, maybe Jeffreys and Musselwhite (1986) are correct in assuming that the attenuation of the response to the mask is due to the adaptation from the preceding target stimulation. In a future experiment this may be tested by the examination of the VEP to a stimulus that succeeds another stimulus without invoking any visual masking. The first (adapting) stimulus may either spatially overlap the second stimulus or may be presented to another area of the retina to determine the extent to which there is adaptation. At this point in time, however, it appears that the VEP is more a sign than a code (see Uttal, 1965; 1967) with respect to the perceptual phenomena of visual masking.

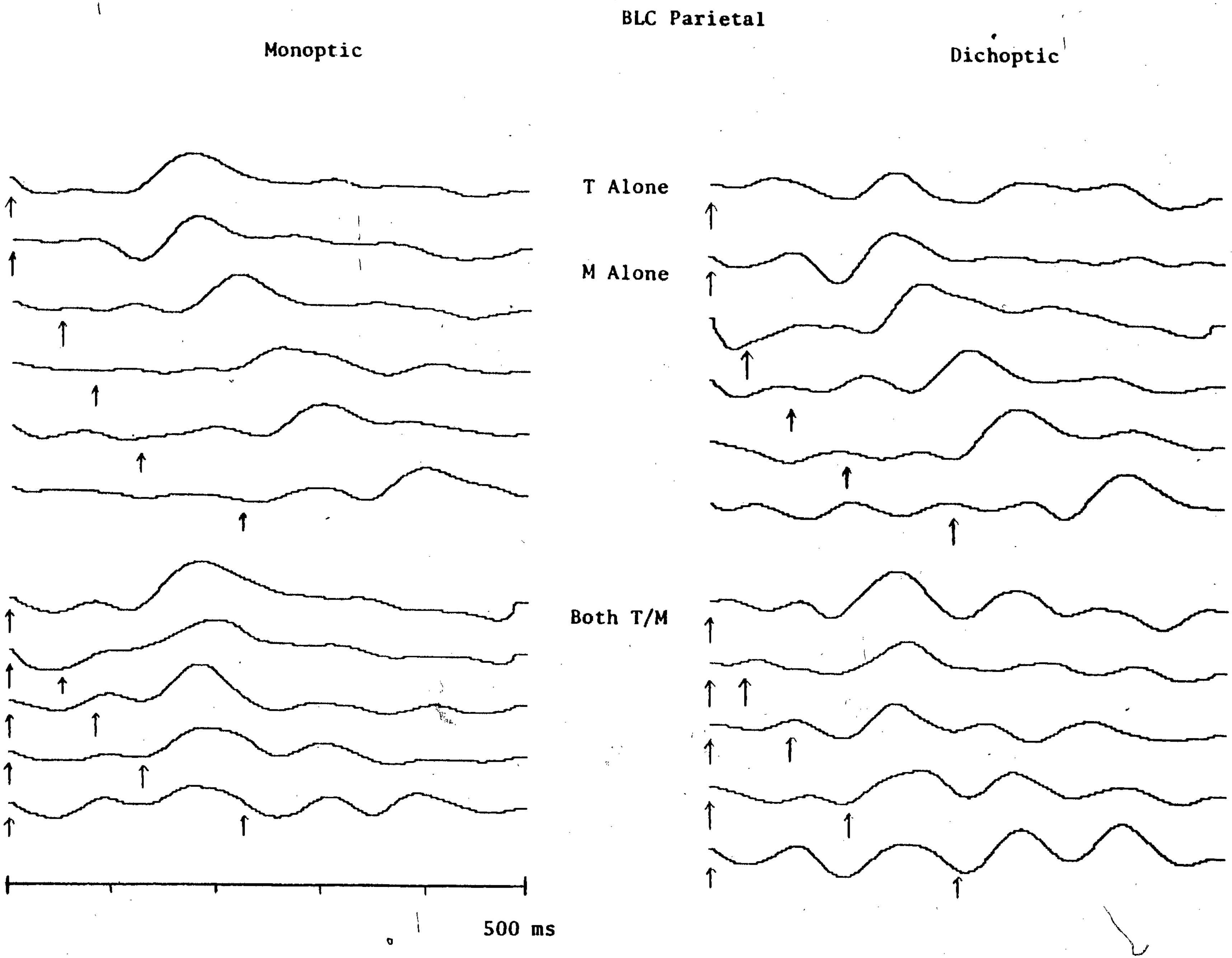
Appendix A. VEP Descriptive Data for BLC, ND and CMT. VEPs for monoptic (left) and dichoptic (right) for occipital (A) and parietal (B) locations. DVD occiptial (C) data included.


Monoptic
BLC Occipital
Dichoptic
T Alone
M Alone
Both T/M
500 ms

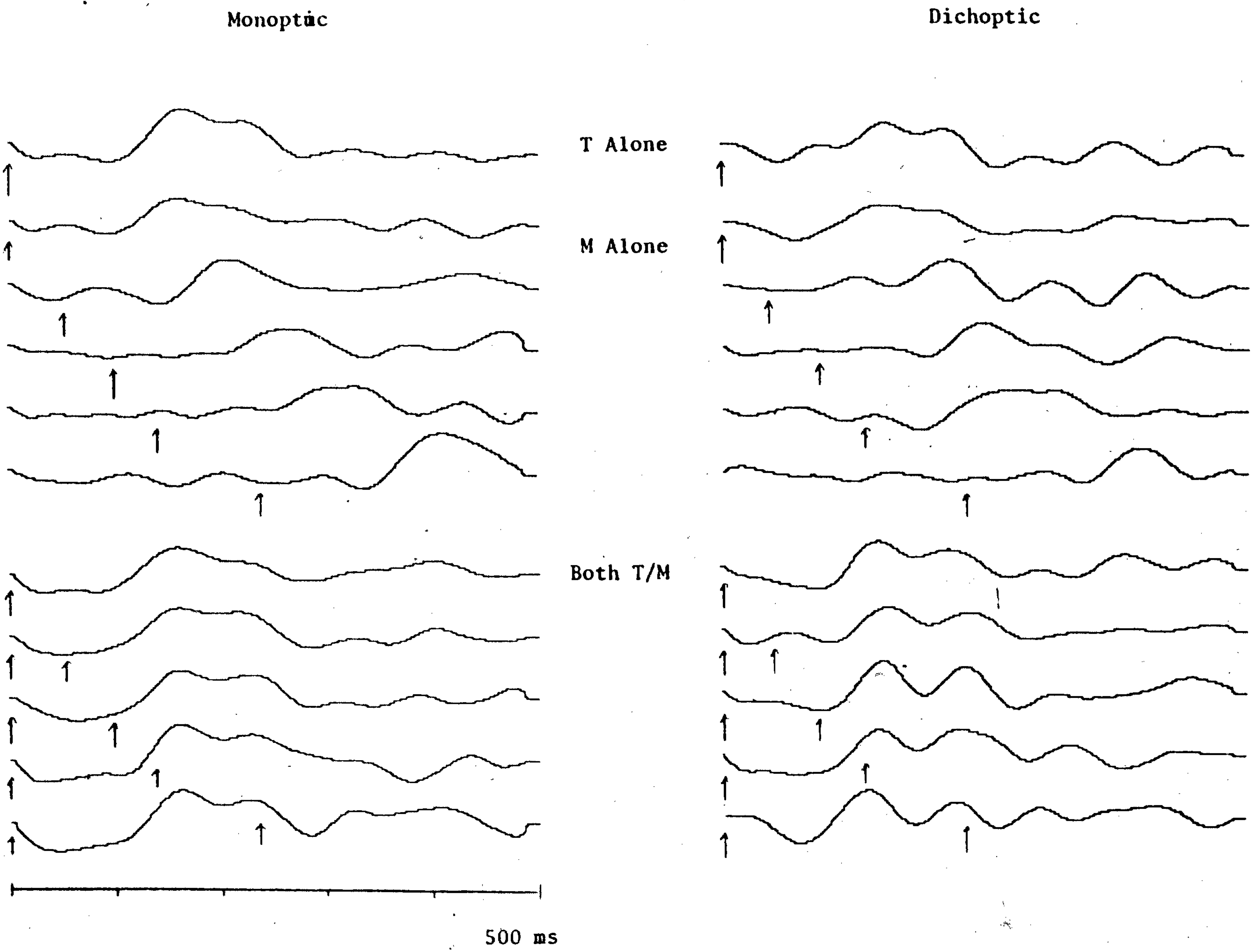

DVD Occipital
Monoptic
Dichoptic
T Alone
M Alone
Both T/m
500 ms


ND Occipital
T Alone
M Alone
Both T/M
500 ms

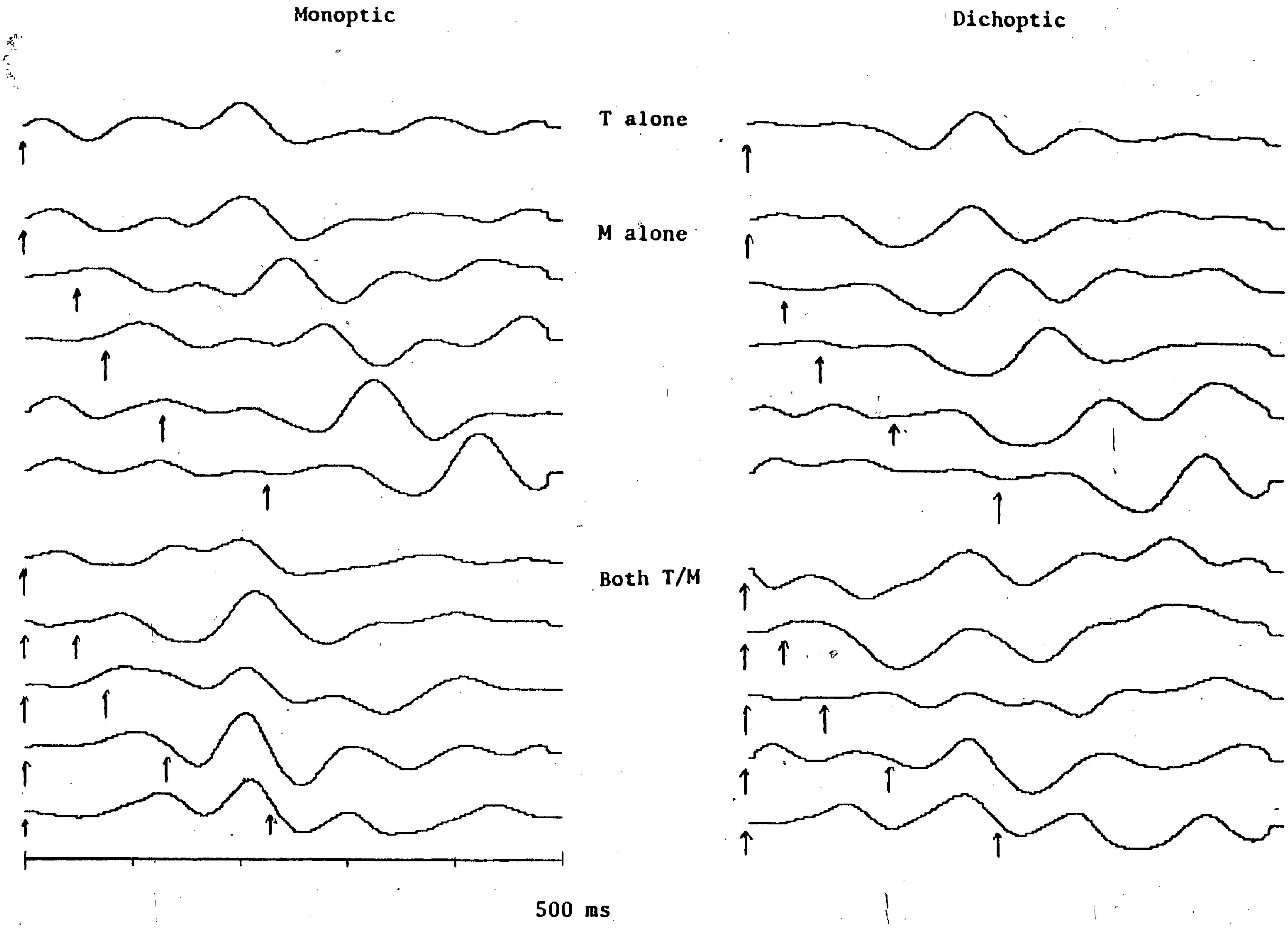

CMT Occipital
Monoptic
Dichoptic
T Alone
M Alone
Both T/M
500 ms


BLC Parietal
Monoptic
Dichoptic
T Alone
M Alone
Both T/M
500 ms

ND Parietal



CMT Parietal



Appendix B. Latencies for Large Positive Peak in Target Alone and Mask Alone Responses. Latencies in ms for both monoptic and dichoptic conditions for occiptial and parietal locations.

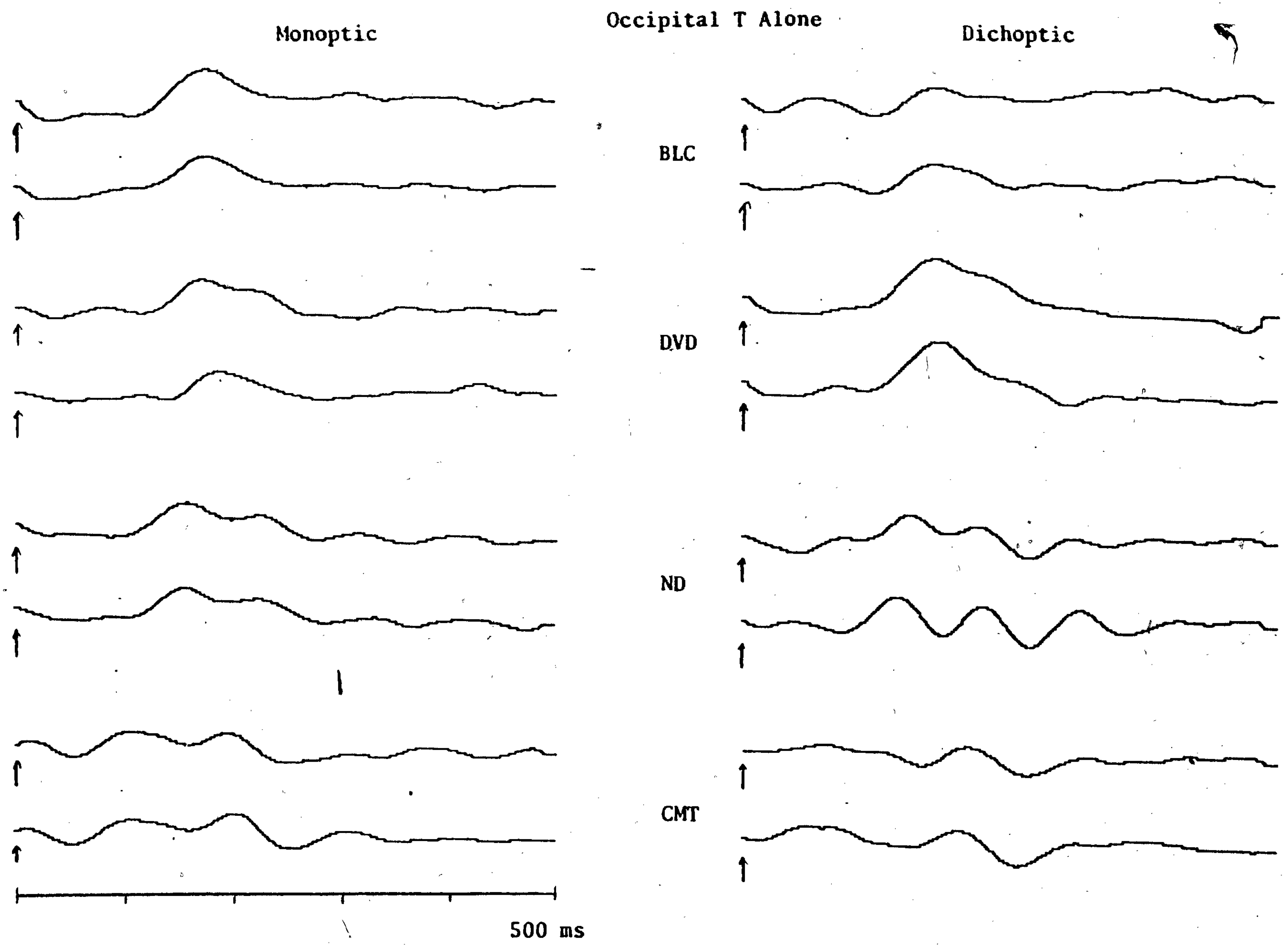
Ss:	BLC		DVD		ND		CMT	
	Monop	Dichop	Monop	Dichop	Monop	Dichop	Monop	Dichop
T Alone								
Occ	174	185	181	179	162	154	203	210
Par	178	187	184	182	166	157	206	212
M Alone (0)								
T/M SOA	0	0	0	0	0	0	0	0
Occ	175	172	181	180	150	141	202	205
Par	177	180	183	183	160	156	205	208
M Alone (1)								
T/M SOA	40	35	45	50	47	40	37	32
Occ	218	207	244	240	198	192	240	240
Par	218	208	241	240	208	218	244	242
M Alone (2)								
T/M SOA	80	70	90	100	95	80	75	65
Occ	259	246	277	289	237	232	277	276
Par	265	253	279	292	269	250	279	279
M Alone (3)								
T/M SOA	120	120	150	150	130	120	125	120
Occ	292	290	339	343	288	263	322	333
Par	295	300	339	341	327	291	324	335
M Alone (4)								
T/M SOA	220	220	250	250	230	220	225	220
Occ	404	398	451	446	401	379	441	424
Par	404	406	435	443	409	398	423	425

Appendix C. Reproducibility VEP Data: One Session. VEPs included:

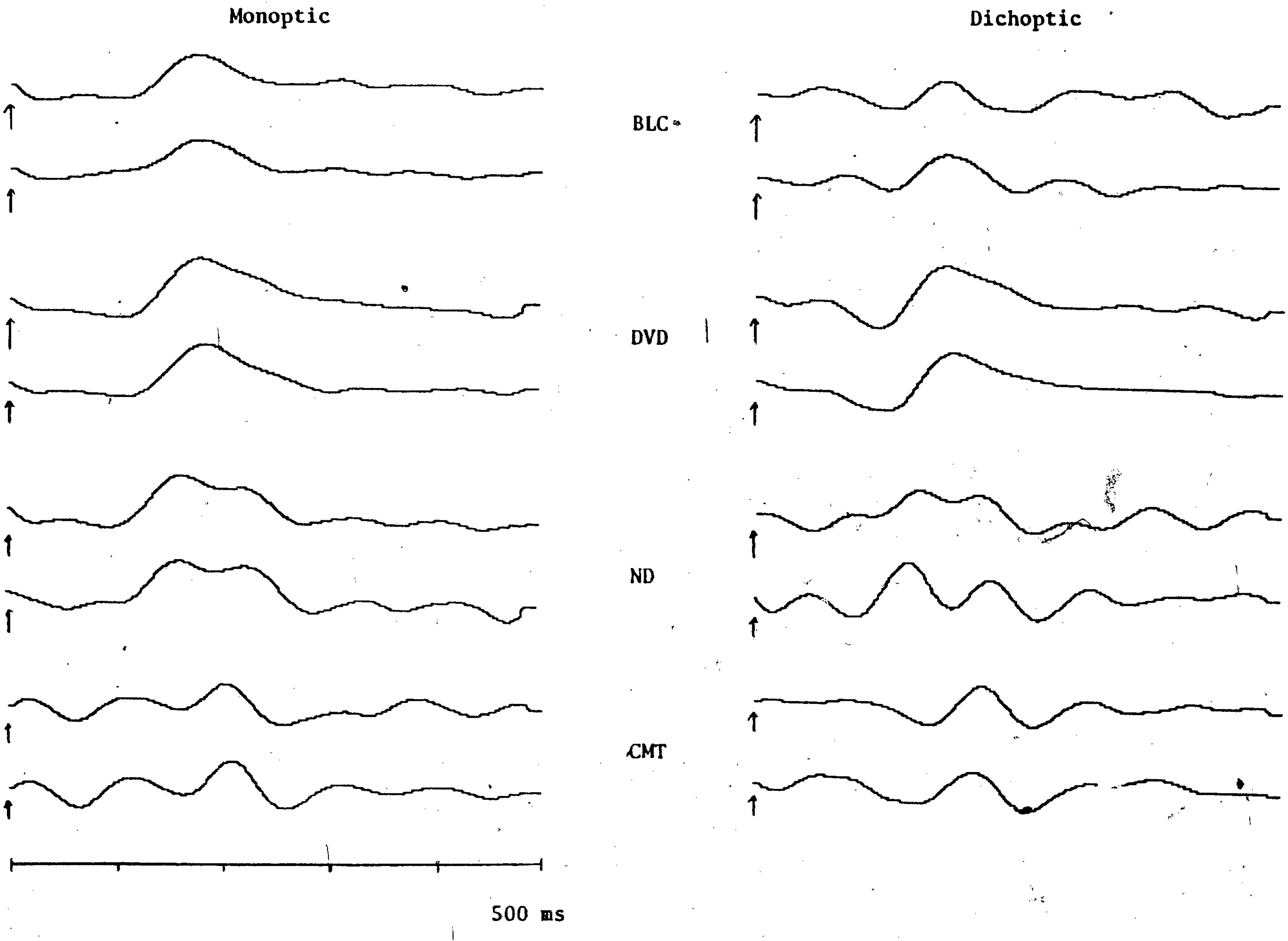
1) Multiple Target alone responses for all subjects for monoptic (left) and dichoptic (right) at the occipital (a) and parietal (b) locations

2) Multiple VEPs using Ss' 3 rd condition SOA for occipital (left) and parietal (right) during both monoptic (a) and dichoptic (b) conditions.

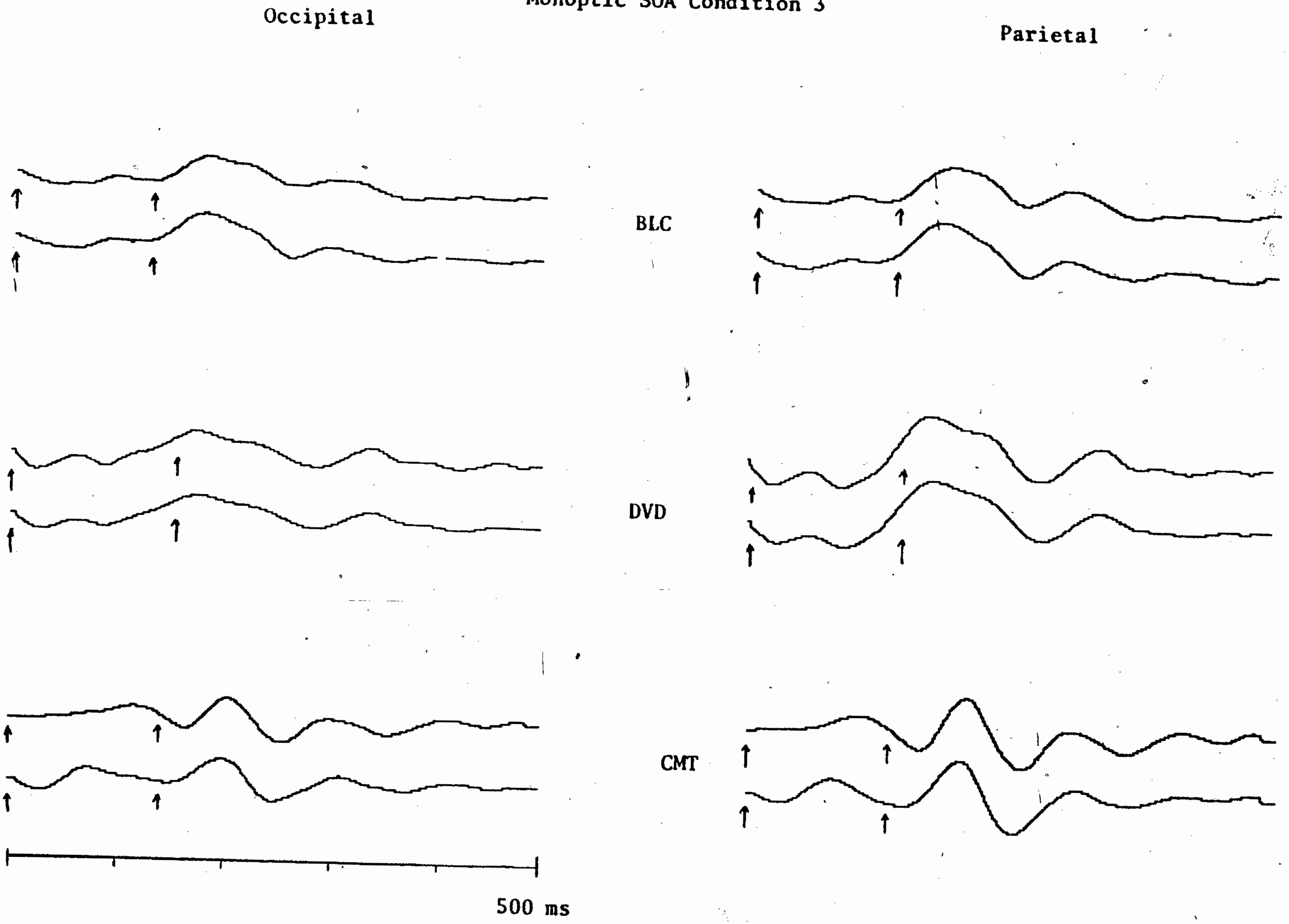
3) Multiple VEPs of the dichoptic condition for simultaneous stimuli presentation at a) occiptial and b) parietal locations.


Occipital T Alone
Monoptic
Dichoptic
BLC
DVD
ND
CMT
500 ms

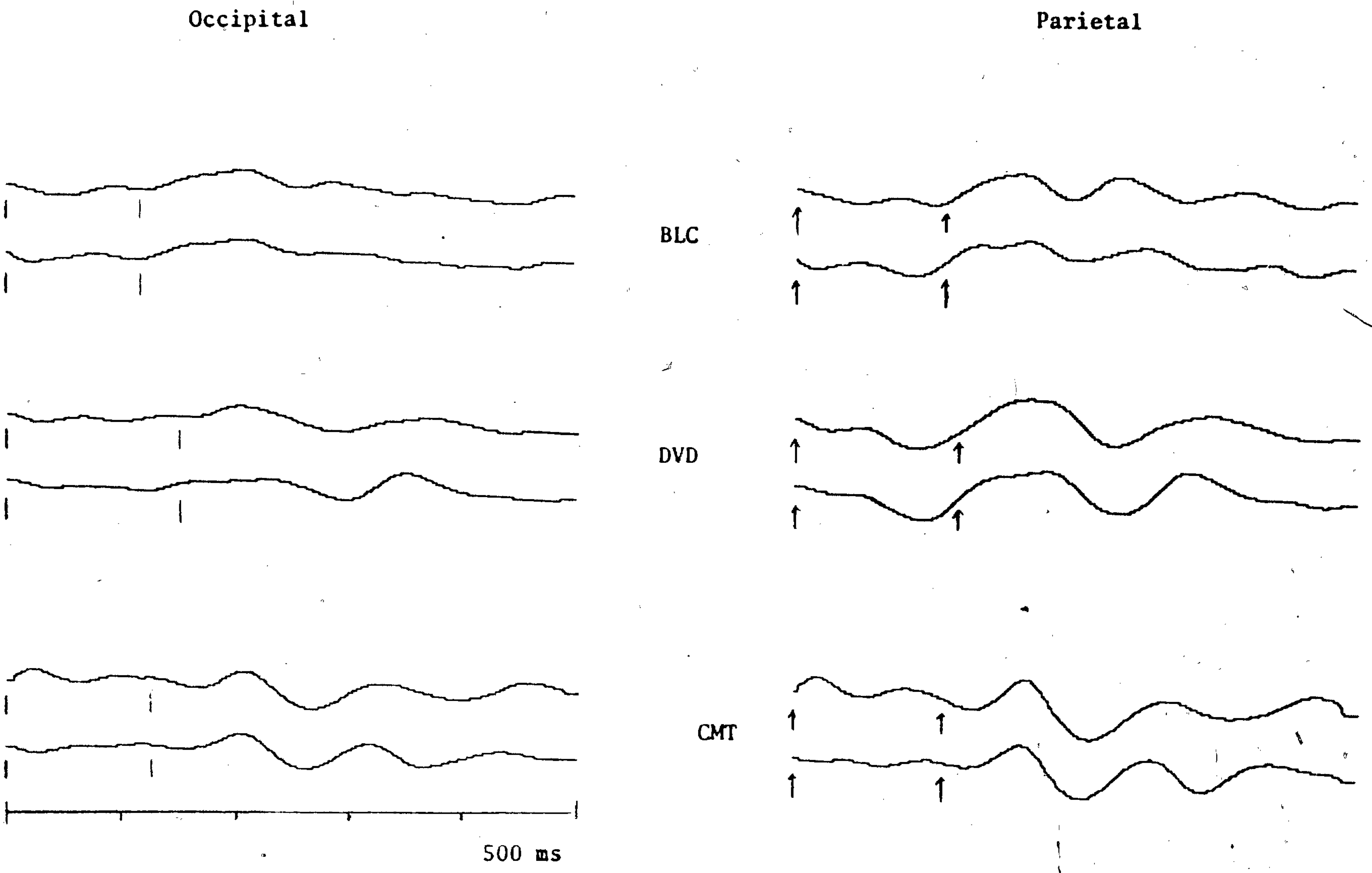
Parietal T alone



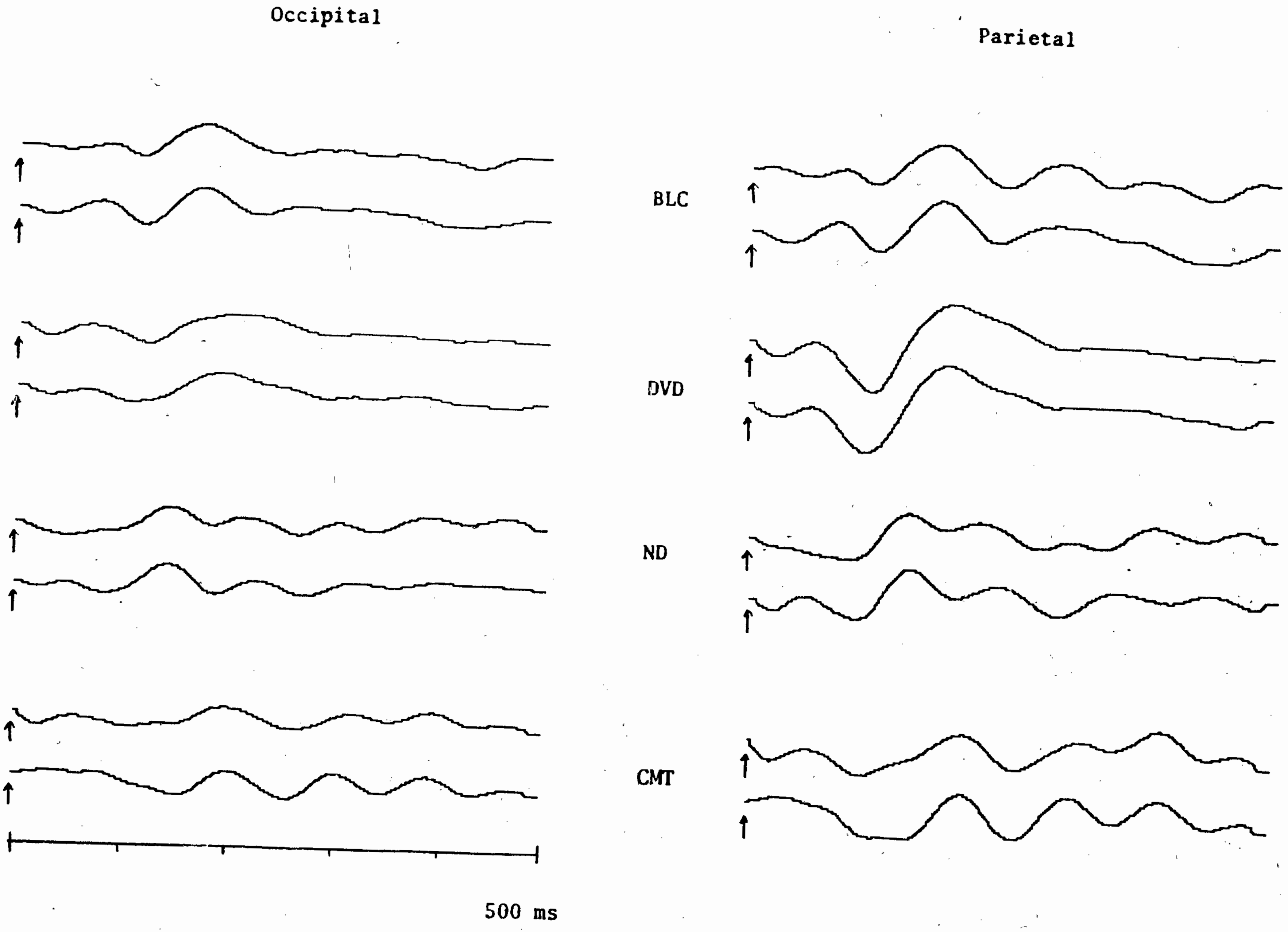
Monoptic SOA Condition 3



Dichoptic SOA Condition 3

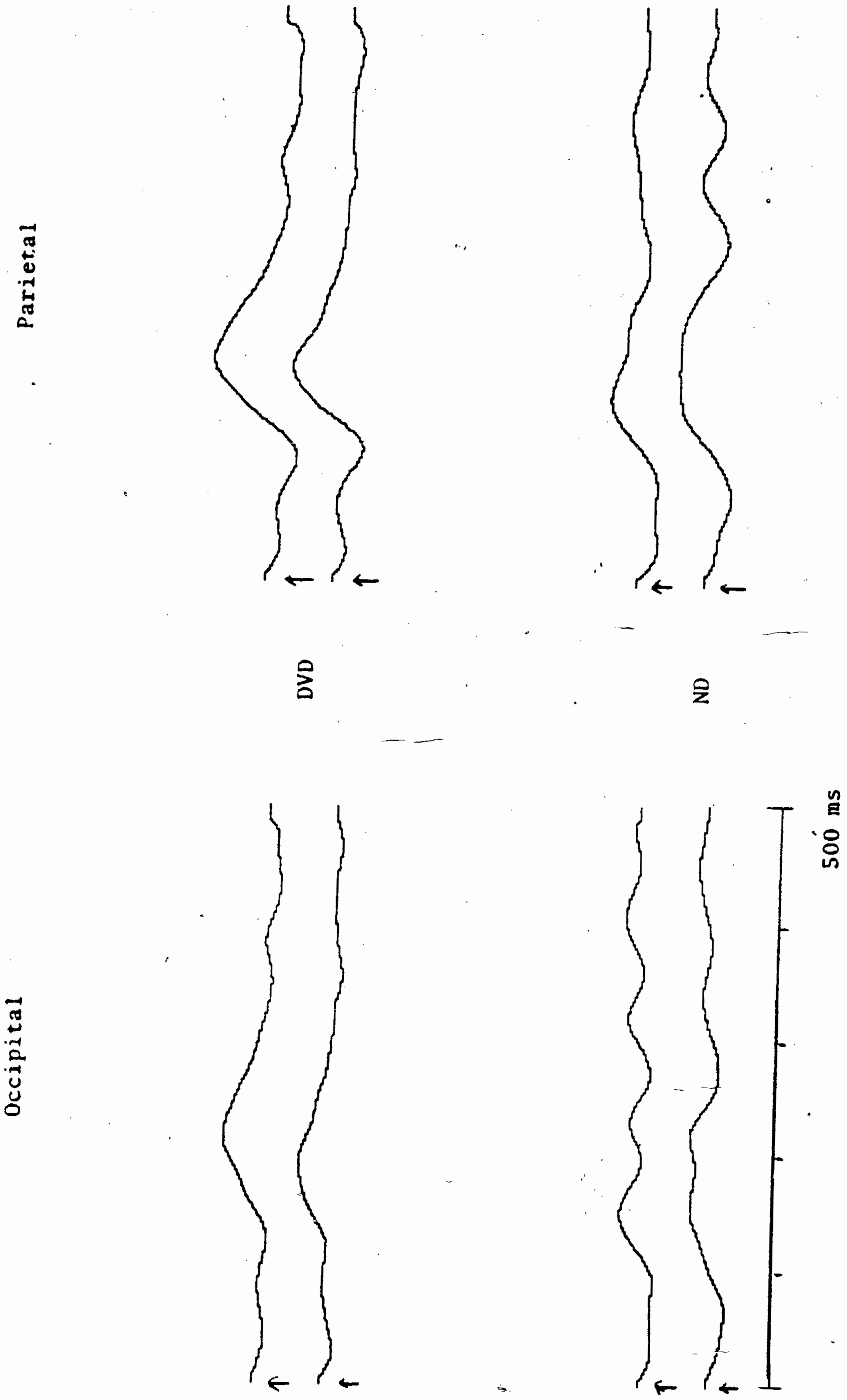


Dichoptic SOA Condition 0



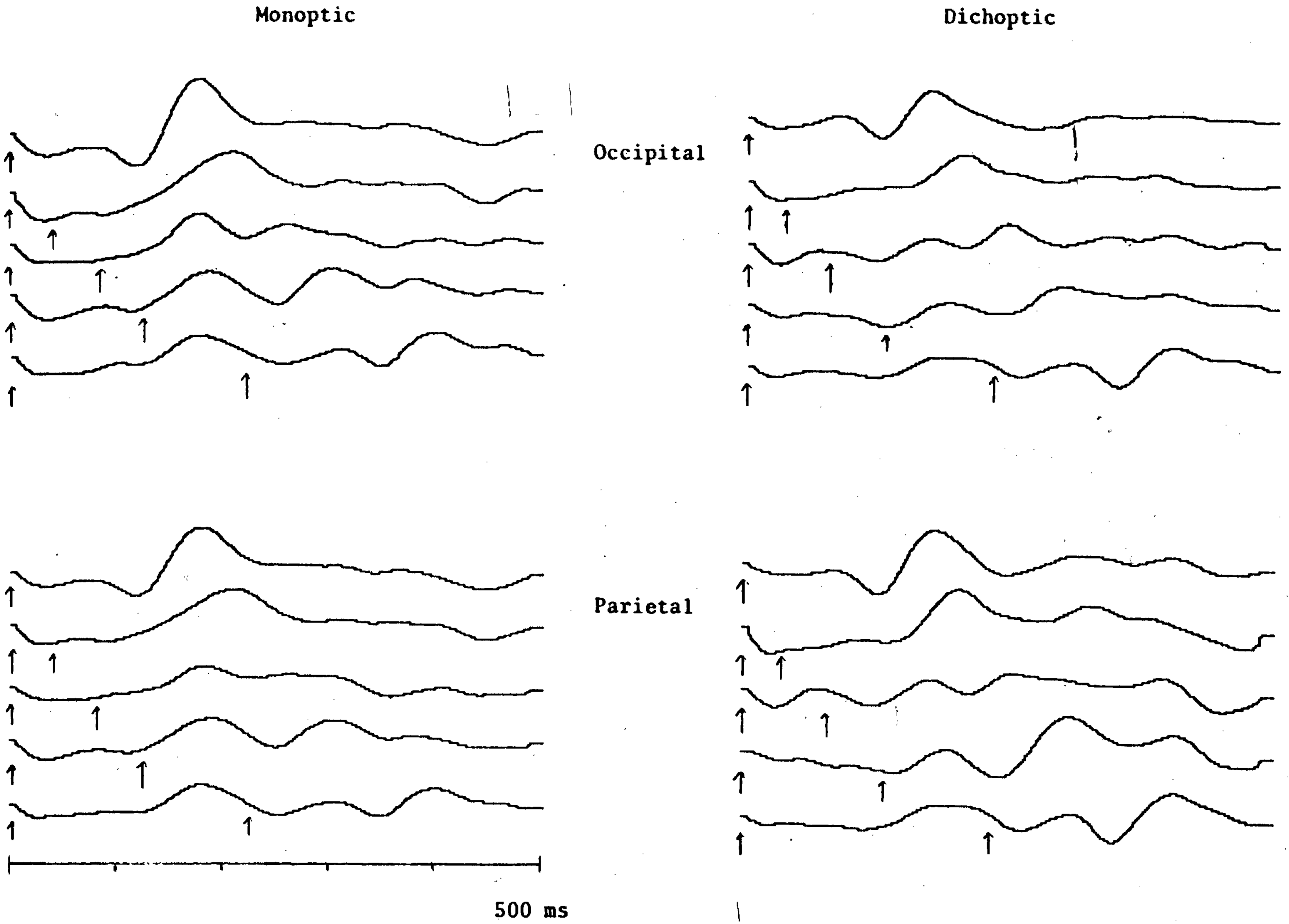
Appendix D. Reproducibility VEP Data: Two Sessions. Monoptic data recorded during 2 sessions using simultaneously presented stimuli at occipital (left) and parietal (right) locations for a) DVD; and b) ND.

Monoptic SOA Condition 0

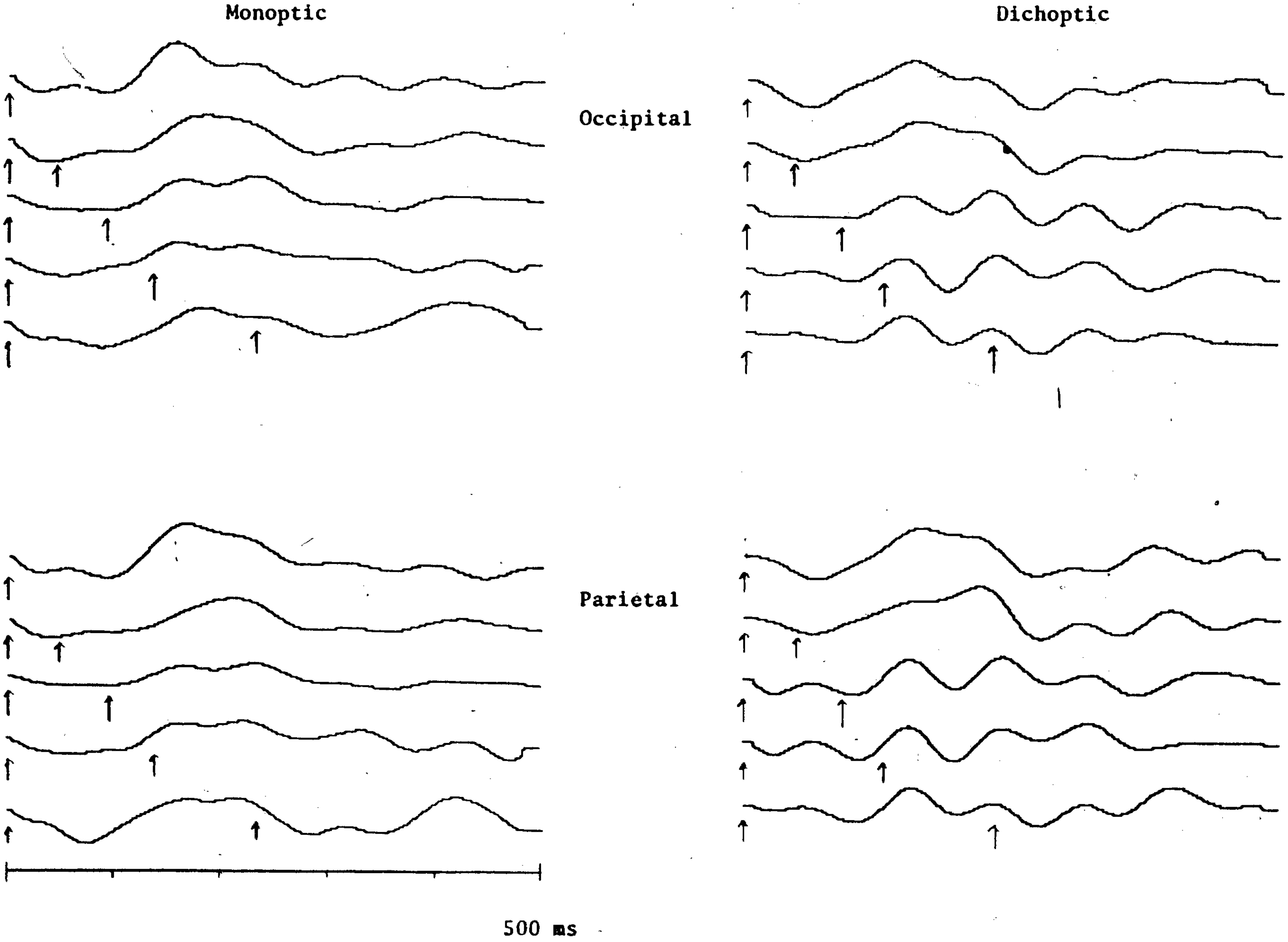


Appendix E. Waveform Computer Composites. Waveforms computed for both monoptic (left) and dichoptic (right) viewing conditions recorded at both occipital (upper) and parietal (right) electrode locations for A) BLC; B) ND; and C) CMT, including D) data for DVD occipital location for both monoptic and dichoptic conditions.

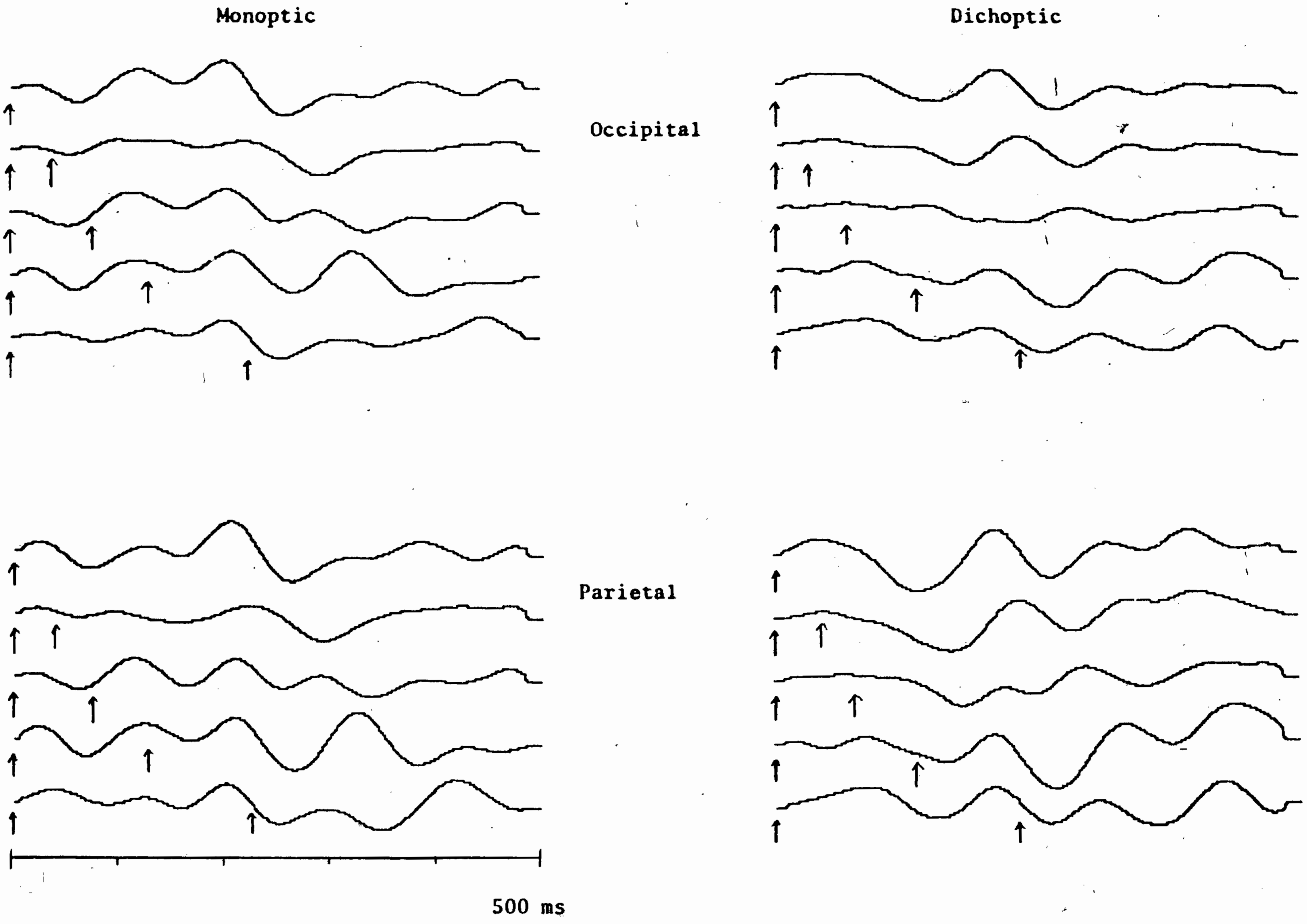
BLC Composite Waveforms



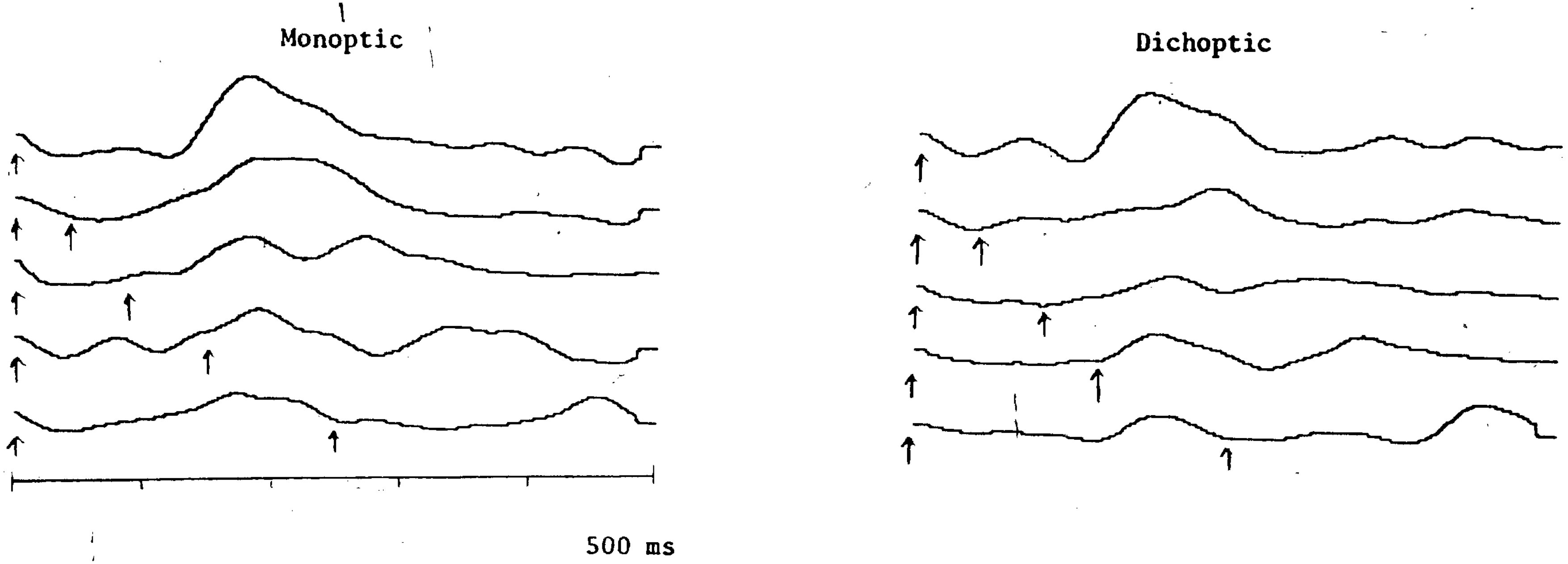
ND Composite Waveforms



CMT Composite Waveforms

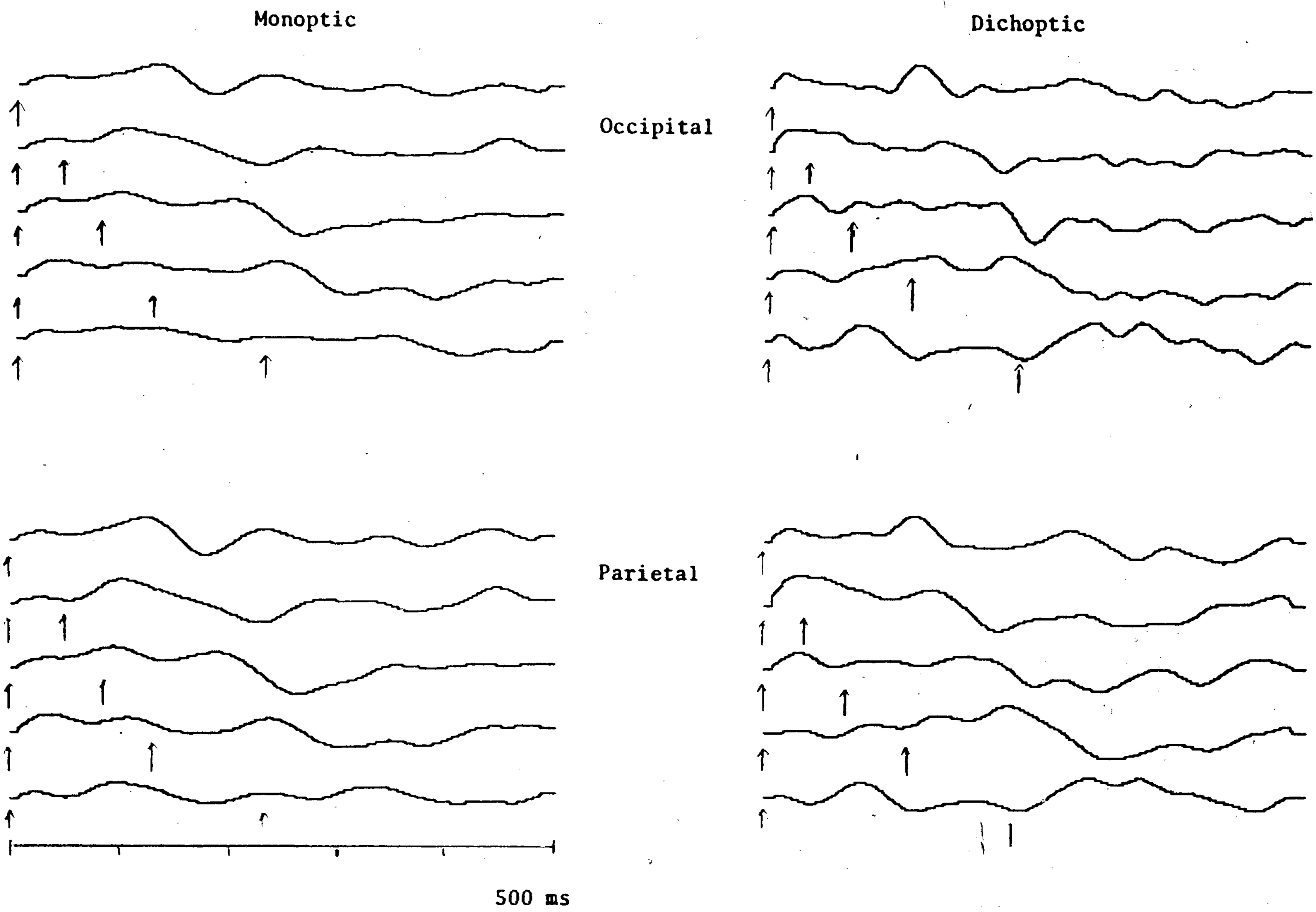


DVD Composite Waveforms
Occipital

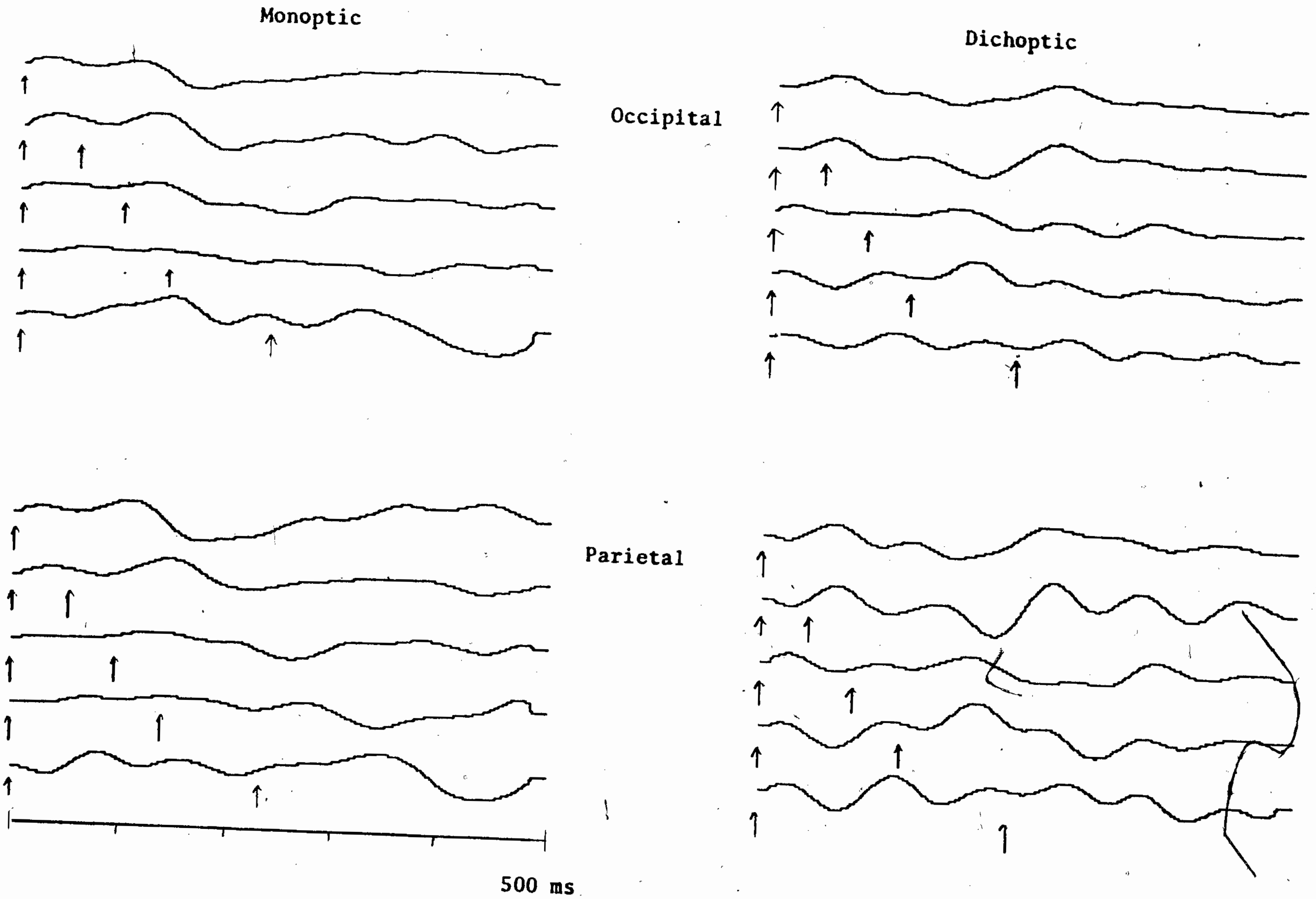


Appendix F.* Waveform Residuals. Waveforms computed for monoptic (left) and dichoptic (right) viewing conditions recorded at both occipital (upper) and parietal (lower) locations for A) BLC; B) ND; and C) CMT, including D) occipital data for DVD.

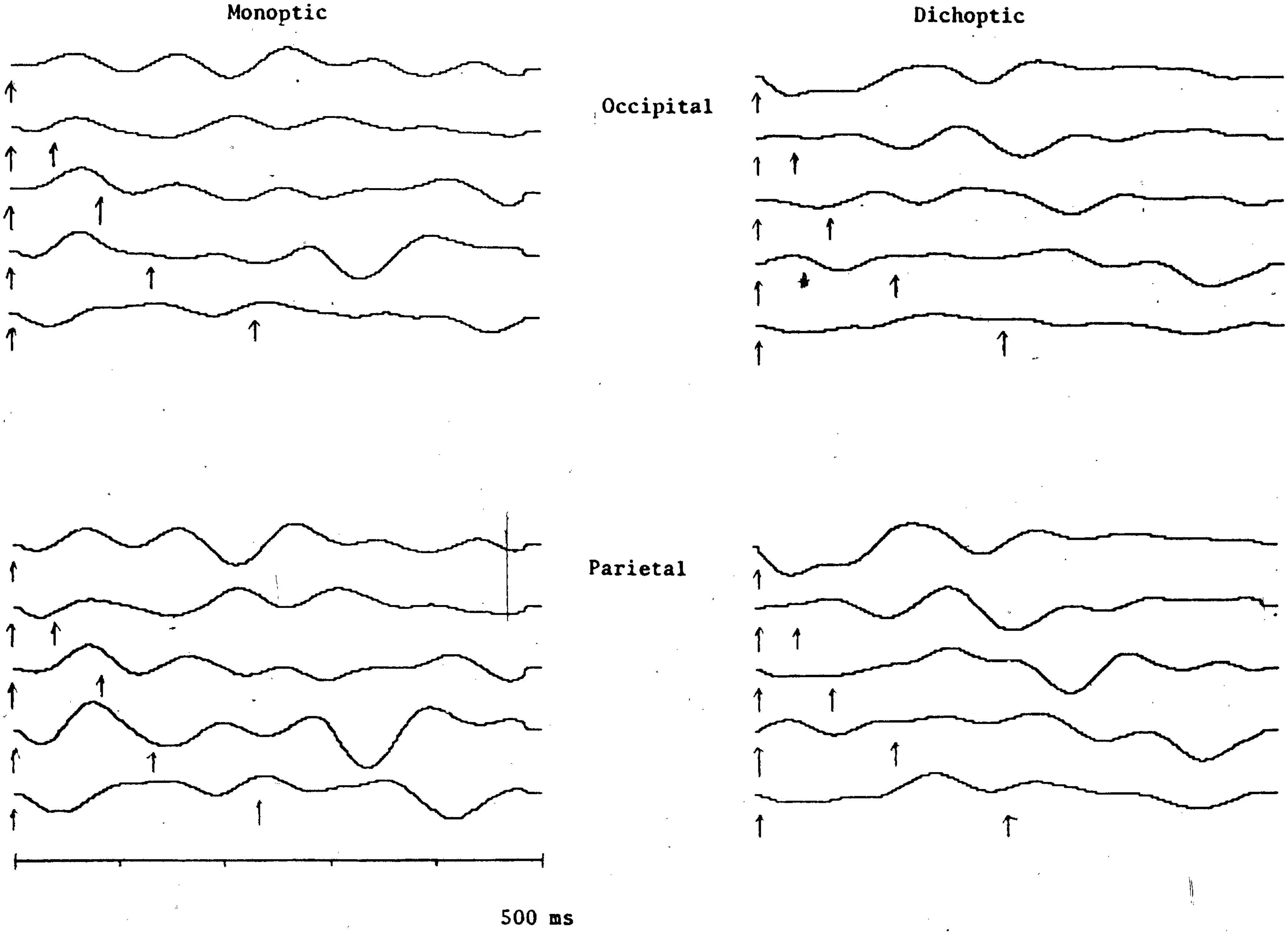
BLC Residual Waveforms



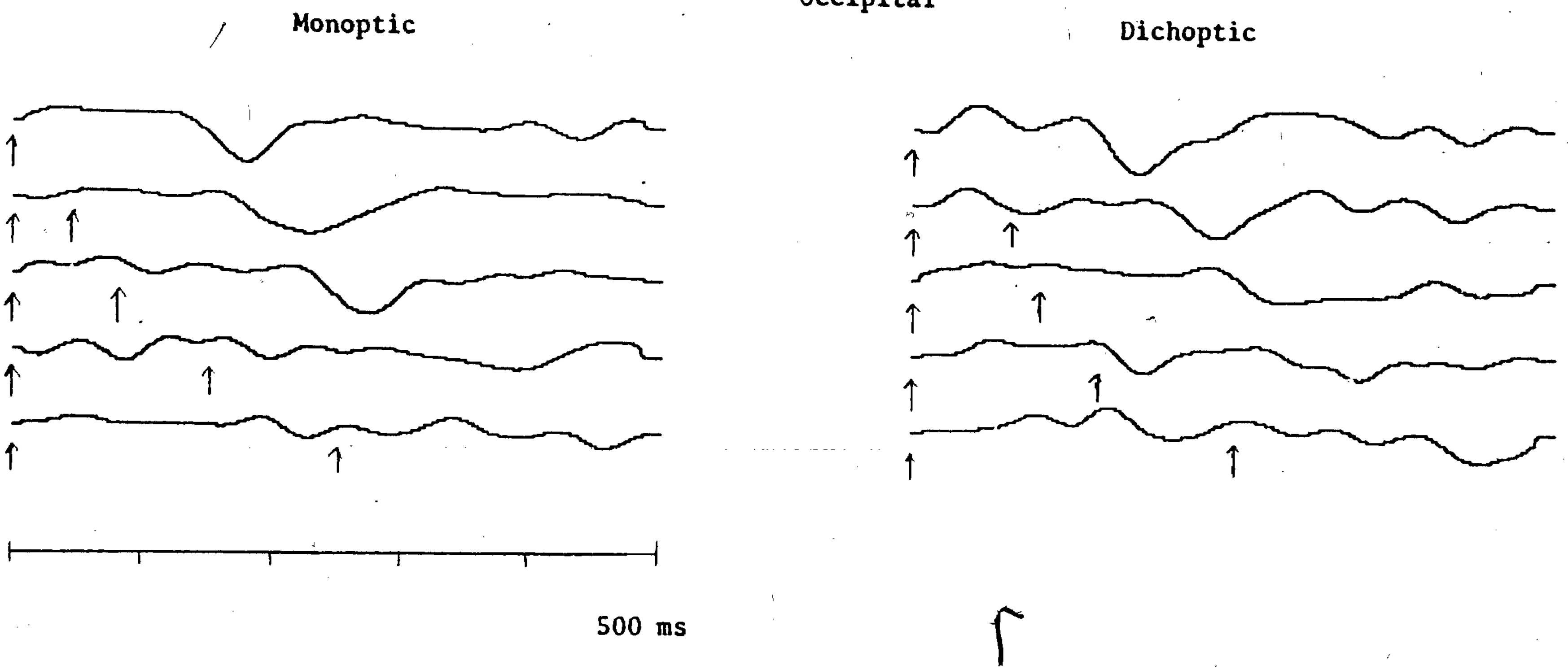
ND Residual Waveforms



CMT Residual Waveforms



DVD Residual Waveforms
Occipital

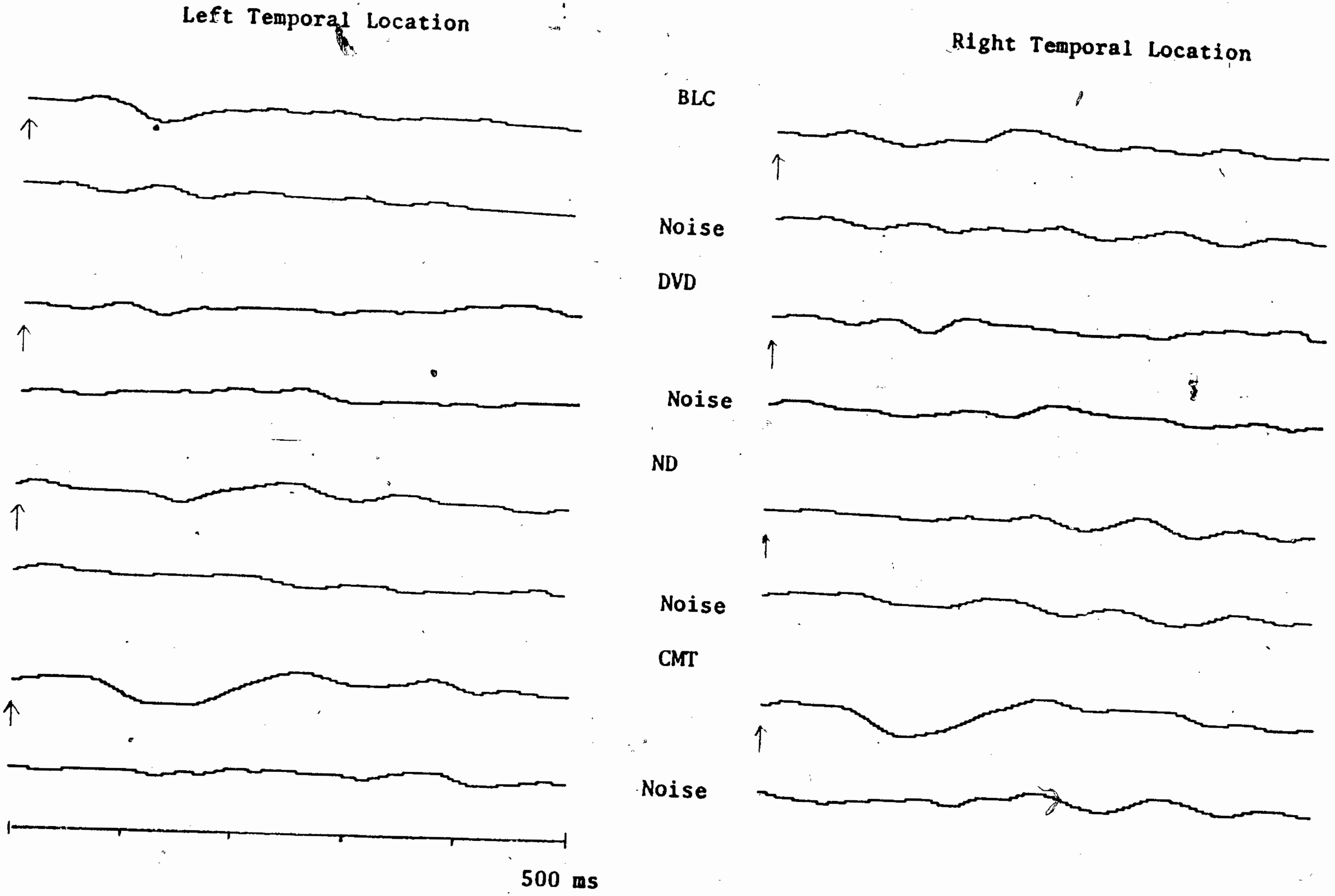


Monoptic

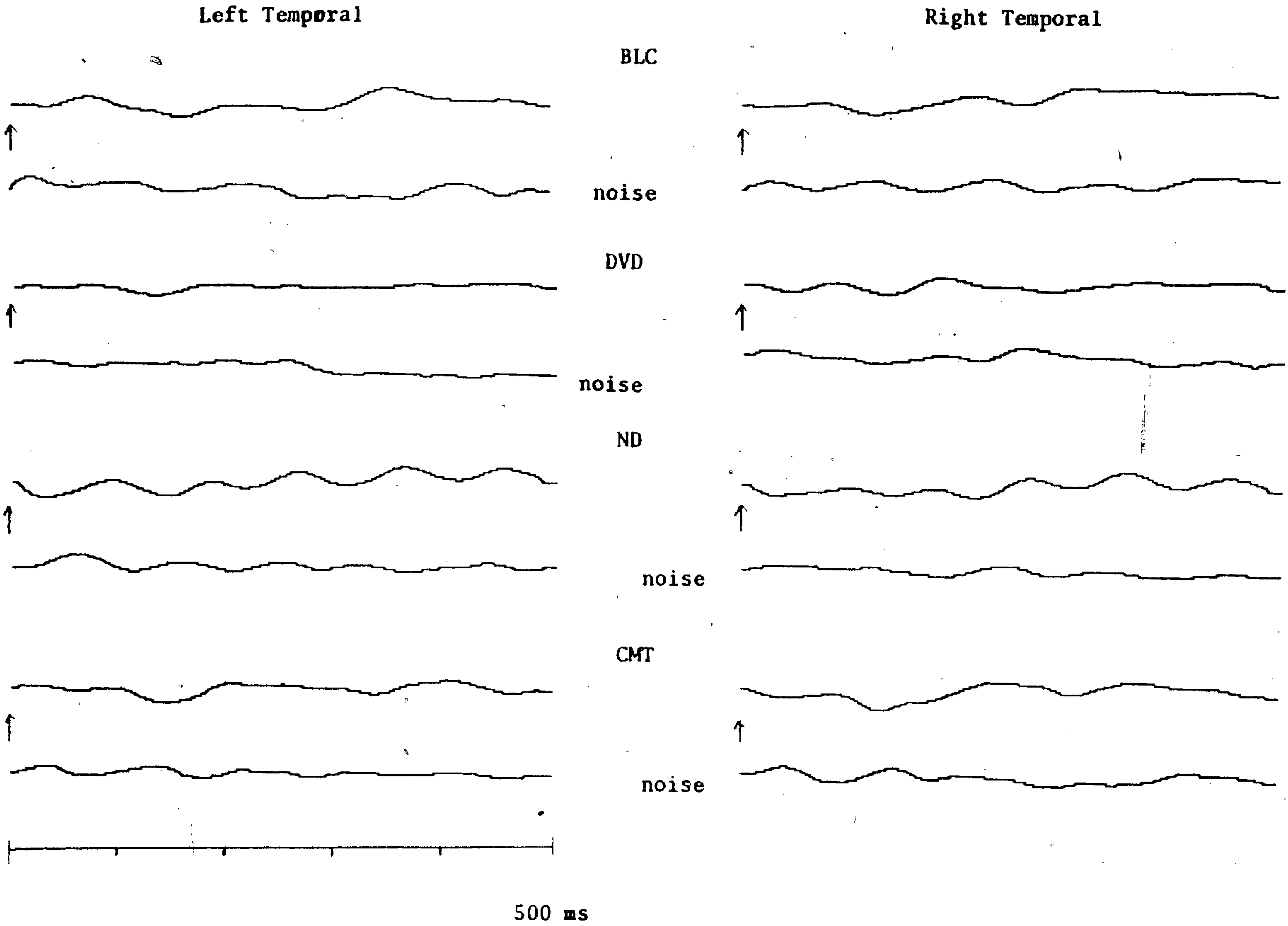
Dichoptic

Appendix G. VEP Pilot Data Recorded at Temporal Electrode Placements. Conditions include A) monoptic and B) dichoptic viewing recorded at left temporal (left) and right temporal (right) locations for all Ss.

Pilot Data Temporal Monoptic

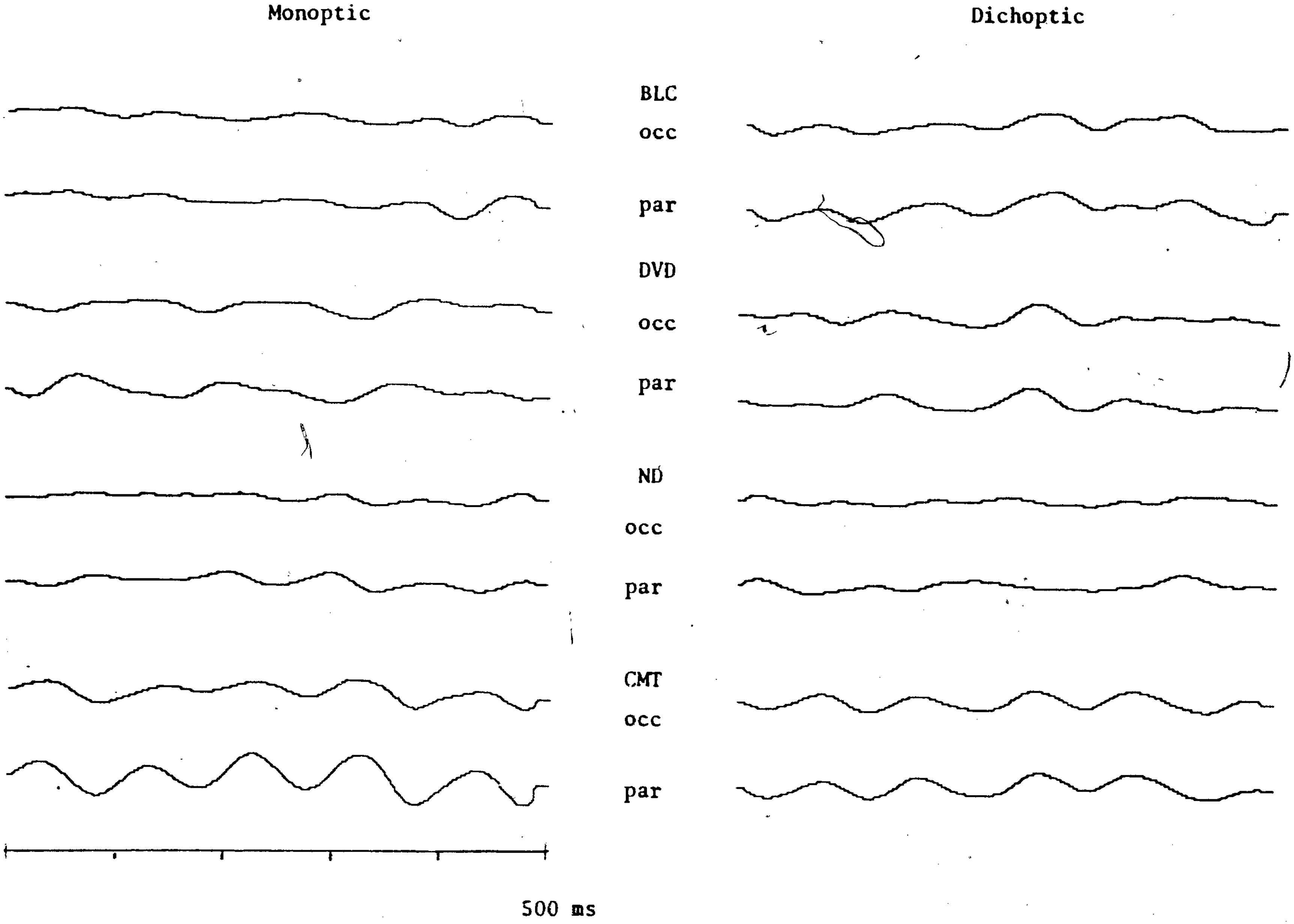


Pilot Data Temporal Dichoptic



Appendix H. VEP General Noise Levels for all Subjects. Conditions include monoptic (left) and dichoptic (right) for a) BLC; b) DVD; c) ND; and d) CMT recorded at both electrode locations.

General Noise Levels



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