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AGE DIFFERENCES AND EVOKED POTENTIALS IN
DICHOPTIC BACKWARD MASKING.

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AGE DIFFERENCES AND EVOKED POTENTIALS
IN DICHOPTIC BACKWARD MASKING

by

GAIL CRAMER

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

AGE DIFFERENCES AND EVOKED POTENTIALS
IN DICHOPTIC BACKWARD MASKING

Gail Cramer

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Physiological studies of age-related changes in perceptual and cognitive functioning have been unable to relate such changes specifically to nerve cell loss, neural conduction velocity, or EEG activation. Thus, deficits in the elderly on a wide variety of behavioral tasks have been attributed to slower central nervous system mediation.

Previous studies of visual masking point to the locus of masking in either central or peripheral nervous system processes. Turvey (1973) developed a model of visual information processing through studies of visual masking which characterized the central mechanism as a series of feature detectors operating upon outputs of peripheral systems which send signals at varying rates determined by the energy characteristics of the stimuli. Masking in the peripheral system is described by the relation: target stimulus energy multiplied by the minimum interstimulus interval necessary to escape masking equals a constant ($TE \times ISI_c = K$); while central masking can be identified by the relation: target stimulus duration plus the critical interstimulus interval equals a constant ($TD + ISI_c = K$). Interstimulus interval (ISI) is defined as the time from target offset to mask onset.

Dichoptic backward masking was investigated in Experiment I in 30 subjects between 16 and 26 years (mean age, 19.8 years) and 30 older subjects from 60 to 81 years (mean age, 67.9 years). A significant age difference ($p < .001$) in the ISI needed to evade masking was found; the old requiring 75, 77, and 79 msec longer than the young at target durations of 10, 20, and 30 msec. Although the confidence interval estimate was wide, the data were best described by the relation $TD + ISI_c = K$, indicative of masking originating in central processes according to Turvey (1973). Significant differences ($p = .01$) in Experiment I were also found between single letters, three letter words, and consonant trigrams used as target stimuli, all paired with a pattern mask constructed from pieces of the same type letters. The smallest difference was observed between the young and the old in the WORD groups, the largest, in the TRIGRAM groups. Evidence of the importance of the geometric characteristics of the mask to masking in theoretically central processing was obtained from six young subjects who experienced little or no masking in Experiment I. Retesting with a new mask constructed from longer line segments and different angles resulted in a 47% decrease in accuracy of target identification when $ISI = 0$.

Visual evoked potential amplitude was greater and latency shorter in the young subjects. The significant age difference observed in Experiment I was maintained in the summated evoked potential amplitude data collected in Experiment II ($p < .01$). Age difference in latencies to peak amplitudes were indicated by a significant interaction between

age groups and time segments of the summated waveforms ($p < .001$), and a significant age by masked versus unmasked conditions interaction ($p < .05$). Additionally, there was an association between perceptual and neural responses in the dichoptically obtained evoked potentials. Peak amplitudes were attenuated in response to stimulus conditions which produced perceptual masking. When no perceptual masking occurred, there was no attenuation of evoked potential amplitude. These results were obtained from both young and old subjects.

From the foregoing results plus results from controls using binocular presentations, it was concluded that both the psychophysical and evoked potential data were consistent with criteria for processes of central origin as the determinants of the differences between young and old subjects in dichoptic masking.

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Introduction

Turvey (1973) proposed a concurrent-contingent model of visual information processing with the purpose of separately identifying peripheral and central nervous system processes in vision through the use of visual masking experiments.

Since its introduction by Piéron (1925), the term "visual masking" has been used to denote situations in which two stimuli are presented successively or simultaneously; one reducing or eliminating the perception of the other. In general usage the term target stimulus (TS) is used to denote the test stimulus and the term masking stimulus (MS) is used for the mask which can precede (forward masking), occur together with, or succeed (backward masking) the TS. Typically the presentation of the two stimuli is separated by an interstimulus interval (ISI), measured from the end of the first stimulus to the onset of the second. The time between the onset of one stimulus and the onset of the next is referred to as stimulus onset asynchrony (SOA). When ISI is equal to zero, target duration (TD) equals SOA. If presentation of the two stimuli is simultaneous, both SOA and ISI equal zero. The use of backward masking as an analytic tool was proposed by Sperling (1963) on the assumption that processing took place in the interval between the presentation of the two stimuli. Two general interpretations of the masking phenomena are named "integration in which the two stimuli are thought to be integrated or summated by the nervous system, and

"interruption" in which the arrival of the second stimulus interferes with the processing of the first.

Integration theory of masking in its most economical form supposes a linear summation of TS and MS resulting in a response to their simultaneous perception (Erikson, 1966). The integration interpretation has been hypothesized by Turvey to describe the functioning of peripheral processes which can be identified by the following criteria:

(1) Masking arising in peripheral processes is energy dependent. The energy of the MS must exceed the energy of the TS for masking to occur.

(2) Data from masking experiments in which peripheral processes are responsible for the observed masking effects conform to a multiplicative relation between target energy and the minimum interstimulus interval necessary to evade masking (ISI_c): $TE \times ISI_c = K$.

(3) Masking is not determined by the geometric content of the MS.

The formulation of the peripheral relation was first suggested by Kinsbourne and Warrington (1962 a, b) in monocular, binocular, and dichoptic conditions, with random visual noise as mask. Their results indicated that all masking resulted from the same "central" interaction. Subsequent investigation by Turvey, however, revealed that masking only occurred in their studies when MS energy was greater than TS energy. Turvey was also unable to obtain dichoptic masking with random visual noise using equal energy stimuli except when TS was presented at threshold. Examination of other masking patterns led to the

conclusion that the most effective masking stimuli were similar to the TS in geometric configuration and located in the same area of the visual field as the TS letters. Additionally, his data indicated that masking of central origin was described by another relation, $TD + ISI_c = K$.

The second widely held interpretation of the masking phenomena is known as "interruption" which implies that processing of the TS is interrupted by the arrival of the MS. Interruption theories are appropriate only to situations of backward masking. The critical variable in masking arising centrally, according to Turvey, is SOA, or the time between onsets of the two stimuli. Central masking is also characterized by the criteria:

- (1) A TS can be masked by an MS of equal or lower energy.
- (2) The additive relation: Target duration plus the interstimulus interval necessary to evade masking equals a constant ($TD + ISI_c = K = SOA$), describes the masking function.
- (3) Central masking is dependent upon similarity of the figural characteristics (geometric content) of the stimuli.

Thus, if masking arises in peripheral processes, the two stimuli interact in the transmission channel (the peripheral system) presenting only one stimulus for central identification. If masking arises centrally, the stimuli are hypothesized to arrive separately in central mechanisms but the processing of the first stimulus is interrupted by the arrival of the second. The peripheral system as defined by Turvey includes

the retina, the lateral geniculate nucleus, and those cells of the striate cortex which have been shown to respond to changes in stimulus intensity (Vaughn & Gross, 1969; Short, Lieb, & Wilson, 1977). The central mechanism consists of a series of decisions performed on features of the stimuli as they are signalled from the periphery.

A schematic representation (redrawn from Turvey, 1973) of the concurrent-contingent model in the monocular viewing condition can be seen in Figure 1, where stimulus input to a particular location on the retina is represented by (I). A set of neural nets operating in parallel stages ($P_1 \dots P_n$) having different time constants ($d_1 \dots d_n$) dependent upon energy characteristics of the stimuli, store their outputs (O_{ij}) in central storage (S). Data stored in (S) either decay with time or are replaced by succeeding output from the periphery. Outputs of peripheral systems for the two eyes are stored in the same central storage units.

The central process ($C_1 \dots C_n$) is also characterized as a set of nets represented as a decision tree where (C_i) represents some decision point. Any central decision is contingent upon peripheral output in central stores. Input can proceed to the next decision ($C_i + 1$), can terminate in a final decision (O_k), or result in no decision (e). Lacking information in central stores, central nets can wait by looping at the input ($O_1 \dots O_n$) allowing an upper time limit exceeding that of the slowest operating time of a peripheral net, provided they receive inputs from their respective peripheral nets simultaneously or prior to the input branches from the preceding nets. Central nets are assumed to have equal time constants ($D_1 \dots D_n$).

Figure 1. Schematic representation (redrawn from Turvey, 1973) of the concurrent-contingent model describing the relation between peripheral and central nervous system processes in visual perception:

$I_1 \dots I_n$ = stimulus input

$P_1 \dots P_n$ = peripheral nerve nets

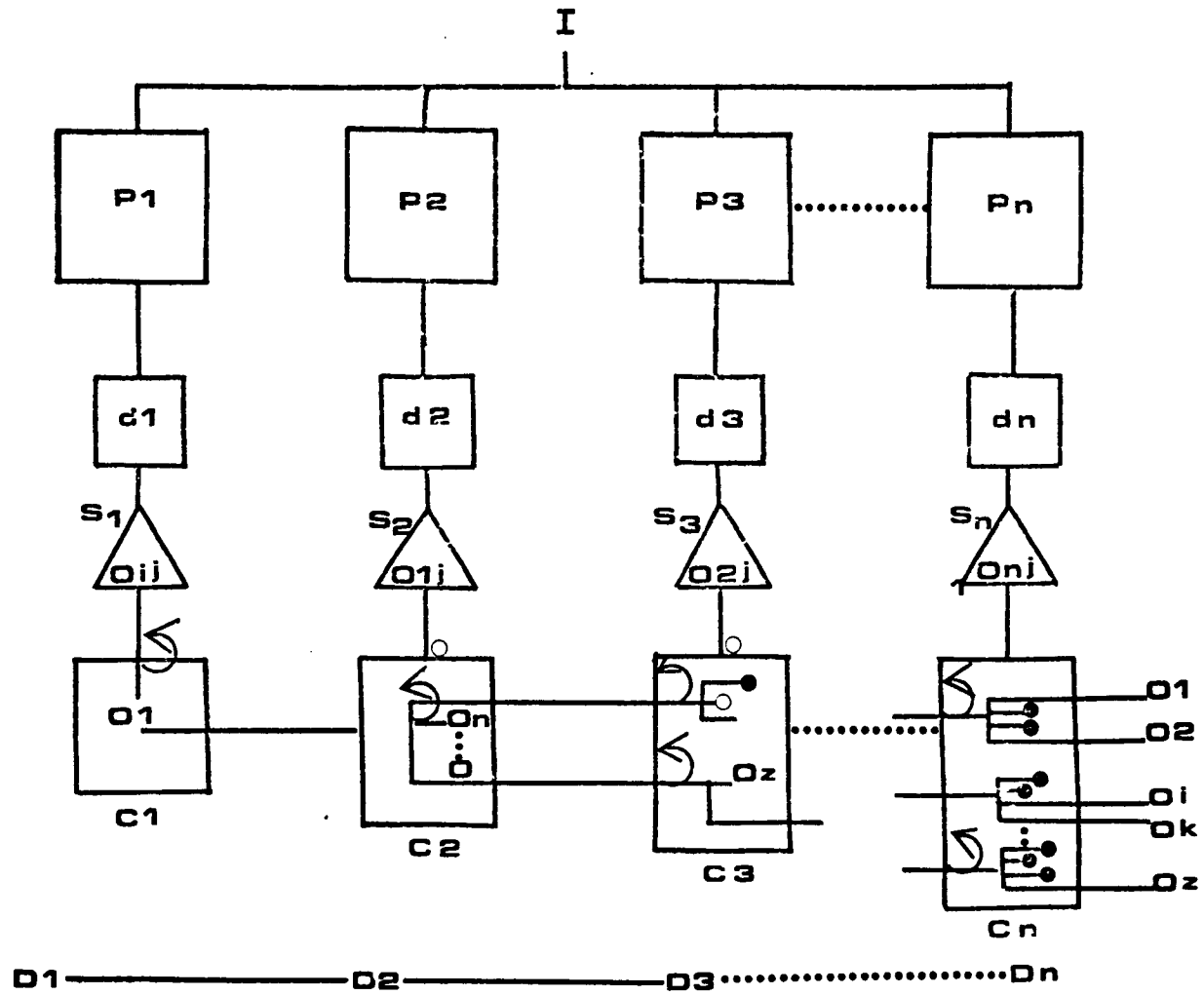
$d_1 \dots d_n$ = operating times of peripheral nets

$S_1 \dots S_n$ = central storage units

$O_{ij} \dots O_{ij}$ = output from peripheral nets

$C_1 \dots C_n$ = central nets

$D_1 \dots D_n$ = central operating times



When peripheral processing time is less than central processing time, central processing time is determined by the time constants of the individual stages. The model retains the traditional distinction between central and peripheral processes, but unites them functionally as a system of processing visual information.

Such a formulation, if valid, can be particularly useful in developmental and clinical research where the separation of structural and sensory deficits from identification and decision making functions of the nervous system is important. A review of past research on age-related deficits in perceptual and cognitive functioning revealed that physiological studies have been unable to relate age changes specifically to nerve cell loss, neural conduction velocity, or EEG activation. Such changes, therefore, have been widely attributed to slower central nervous system mediation (Botwinick, 1973).

Investigations of age differences utilizing visual masking studies have yielded confusing results. In a binocular backward masking study, Welsandt, Zupnick, & Meyer (1973), investigated pre-recognition (iconic) processing in seven age groups with mean ages of 5, 10, 16, 22, 35, and 55 years. They presented a single letter, E, H, K, or X for 8 msec as TS followed by an 8 msec MS. Twenty trials at each of seven ISIs (10, 25, 50, 75, 100, 125, and 150) msec were administered in addition to 20 trials with simultaneous presentation (SOA = 0). Results were compiled in terms of percent correct responses at each interval. The authors asserted: (1) they were studying "iconic processes"; the

icon referring to a retinal image which in any terminology is a peripheral process, (2) the importance of using "a centrally based masking paradigm" meaning the mask and target occupy the same area of the visual field. Both stimuli were presented for a duration of 8 msec; the target at a luminance of 4.3 mL and the mask at a luminance of 104 mL. Significant differences were found between the two youngest groups, the middle four, and the oldest group. The authors attributed the poorer performance of the children (mean age 5 years) to lack of experience in extracting information from the icon and that of the oldest group (mean age 55 years) to a slower rate of extracting information from the icon. In Turvey's formulation, mask energy exceeding that of the target is one of the necessary conditions for the establishment of masking arising peripherally. Additionally, the mask used by Welsandt et al. was a pattern mask consisting of a grid composed of criss-crossed diagonal black lines. If masking arises centrally, according to Turvey, the figural characteristics of the mask are of utmost importance; luminance differences have negligible effect. Thus the results of Welsandt et al. can say nothing as to the origin of the observed masking effects (and age differences indicated by them) Attention to the criteria outlined by Turvey could avoid confusion as to the locus of observed masking in similar studies.

Kline and Szafran (1975) investigated age differences using a monocular backward masking task, in which age differences in ISIs needed to escape masking were measured and attributed to changes in central

(defined as retro-chiasmal) processing time limiting the rate at which stimuli could be "cleared through the nervous system" (p. 307).

Walsh (1976) used Turvey's backward dichoptic masking experiments in which central interference was found (Turvey's experiments V through IX), as a basis for an age comparison of central processing. The results supported Turvey's model in that masking occurred with MS energy less than TS energy, and SOA ($TD + ISI_c$) was the variable which described escape from masking in both age groups, with the older people requiring a 24% longer ISI than the young to identify a masked target letter. Additionally, Walsh re-analyzed the data of Kline and Szafran in terms of Turvey's criteria for identification of peripheral and central processes and found that the visual noise mask used by Kline and Szafran was always presented at an energy level of at least three times that of the target stimulus, and the data closely fit the multiplicative relation between target energy and ISI. Thus, according to Turvey's formulation, the data of Kline and Szafran gave evidence for masking (and age differences) in peripheral rather than in central processes.

Herzog, Williams, and Walsh (1976) assessed the effects of practice across two age groups with mean ages of 66.5 years and 18.5 years using a dichoptic backward masking paradigm as did Walsh (1976). Five separate days of practice sessions resulted, for both groups, in reliable reductions in ISI_c required to escape masking. However, the magnitude of reduction was the same for both groups indicating that the amount of practice did not reduce previously demonstrated (Walsh, 1976) age diff-

erences in the speed of central processing. Since the improvement was equivalent in both age groups, the data suggest no impairment in the adaptability of central processes.

Experiment I Part A of the present study was an attempt to replicate under similar conditions Walsh's investigation of age differences in central perceptual processing using a dichoptic backward masking paradigm.

Part B further examined the figural characteristics of the masking stimulus used in Experiment I.

Experiment II was designed to obtain visual evoked potential correlates of the psychophysical data gathered in Experiment I, again utilizing the dichoptic backward masking design for stimulus presentation.

General Method

Subjects

Sixteen Hunter College graduate and undergraduate students served as unpaid volunteers in pilot studies. Subjects who served in Experiments I and II were paid \$3.00 per hour for participation. The young subjects of Experiments I and II ranged in age from 16 to 26 years (mean = 19.8 years, SD = 2.9) and the old from 60 to 81 years (mean = 67.9 years, SD = 4.3). Twenty people over 60 years of age were excluded for failure to recognize a visual stimulus (LETTER, WORD, or TRIGRAM) within a maximum duration of 10 msec or because they demonstrated eye dominance. The procedure for determining eye dominance is explained in the Method section of Experiment I. The visual acuity of all remaining subjects, corrected with glasses, or uncorrected, was at least 20/25 as measured by a Snellen chart. Except for three high school seniors, all young people were Hunter College students. Volunteers over age 60 were recruited from the Caring Community Center of Greenwich Village, the Lenox Hill Senior Center, the Hunter College Association for Senior citizens, and Hunter College classes with an enrollment of older students. The mean educational level of the older group was 15.7 years (SD = 2.1). The mean educational level of the younger group was 14.9 years (SD = 2.9). See Appendix II.

Apparatus

A modified version of a previously described tachistoscope (Sperling,

1965), placed in an electrically shielded and sound attenuated booth was used for the presentation of stimuli. Flashes were presented through 7.6 by 7.6 cm apertures using GE fluorescent light sources (F14T12/DCWX). Ultra violet tubes (GE F8T5BLB) provided dim illumination between flashes (less than .1mL) and insured reliable flash durations. Homogeneous fields were maintained with a square of ground glass covering each stimulus aperture. Stimuli were viewed through artificial pupils 3 mm in diameter at a distance of 90 cm. Superimposition of fields was maintained with rhomboid prisms adjustable for interocular distance and convergence angle. A laboratory constructed stimulus changer consisting of a wheel with eleven slide holders, controlled by a switch panel from outside the booth, each switch corresponding to one of the eleven stimulus positions, was added to the test field (T) of the tachistoscope. A 20 second interval was necessary for complete randomization of stimuli. A chin rest with an attached microphone was fastened below the tachistoscope eye piece to help the subject maintain fixation and to enable him to respond verbally with a minimum of head movement. All luminance measurements were taken with a MacBeth Illuminometer. The readings were checked by a second observer whose judgements had been equated with a Pritchard photometer.

Procedure

Subjects were tested for visual acuity, given appropriate instructions for each experiment, practice trials, and 10 minutes of dark adaptation prior to experimental conditions.

Experiment I

Using a dichoptic backward masking paradigm, Walsh (1976) found a significant age difference in the interstimulus interval necessary to escape masking (ISI_C) with single letters as TS subtending a visual angle of 1.71 degrees vertically by 1.26 to 1.71 degrees horizontally, and a pattern mask formed from line segments subtending .22 degrees in thickness by 1.0 degrees in length placed evenly and centrally over the area of the visual field covered by the target letters. His older group, 2 males and 9 females with a mean age of 64.2 years (range 60 to 68 years), required an ISI_C of 22 msec, or 24%, longer than the young at each of three target durations to escape the masking effect. The younger group consisted of 3 males and 10 females from 18 to 23 years of age (mean age 19.5 years). Walsh's data conformed to the relation, target duration plus critical interstimulus interval equals a constant ($TD + ISI_C = K$), or SOA, suggested by Turvey (1973) to be indicative of masking at central rather than peripheral loci in the visual system.

The relevant variables in Experiment I of the present study were the critical interstimulus intervals (ISI_C s) at target durations of 10, 20, and 30 msec, and the target durations necessary for target stimulus recognition with ISI equal to zero (TD_C). Additionally, the differences in ISI_C and TD_C when single letters, three letter words, or consonant trigrams were used as target stimuli, were examined.

Previous research in cognitive processing in the elderly has shown older people to equal or surpass the young in tasks which tapped previously acquired "structure" (Kinsbourne, 1974) or in tasks involving concrete as opposed to abstract concepts (Arenberg, 1966). In studies of sequential blanking in which strings of stimuli are presented sequentially in spatially non-overlapping positions, Mayzner and Tresselt (1970) found that interleaving of two five-letter words resulted in 91% correct response to words displayed in the sixth through tenth place, and 87% correct response to words displayed in the first through fifth place (no blanking occurred). When random letters were interleaved with a five-letter word the word was correctly reported 88% of the time while the letters in first through fifth place yielded only 21, 6, 4, 8, and 12 % correct responses respectively. The authors concluded that not only geometric content, but word meaning could have powerful effects on sequential blanking. Therefore, it was hypothesized that in this study masking effects might be diminished when the target stimuli were well known three-letter words.

Turvey (1973) used both single letters and consonant trigrams as target stimuli. In his duration study, the mean ISI_c for four young subjects with a letter stimulus of 10 msec duration and a 10 msec pattern masking stimulus was 33 msec. Experiment VII of the same study utilized consonant trigrams as TS and a pattern mask of 50 msec duration. With TDs of 10, 20, and 30 msec pooled, the mean ISI_c of four young subjects was 109.5 msec. It was not clear whether

the longer mask duration or the trigrams were responsible for the greatly increased ISI_Cs. Turvey also emphasized the importance of there being similarity between the figural characteristics of the target and mask stimuli in order for successful masking of central origin to occur. It was predicted on the basis of the above findings that masking would be least with words as TS and greatest with trigrams.

Subjects

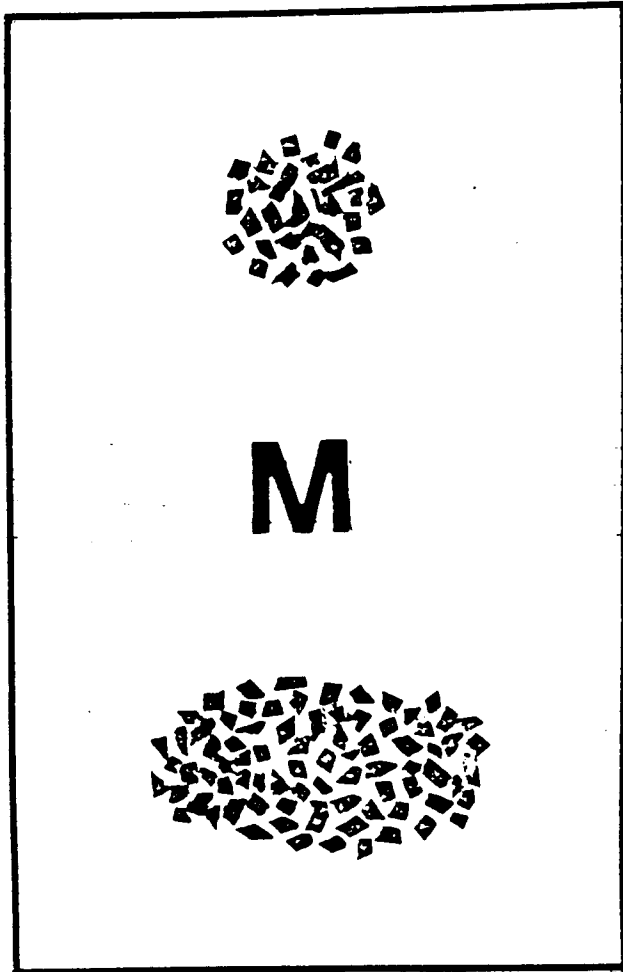
Thirty old adults (4 males, 26 females, 60 to 81 years, mean age 67.9 years) and 30 young adults (10 males and 20 females, 16 to 26 years, mean age 19.8 years) served as subjects. The older adults had a mean educational level of 15.7 years (SD = 2.1). The young group had a mean educational level of 14.9 years (SD = 2.9). Subjects who normally wore corrective lenses were tested with the lenses on. Prior to testing, subjects were asked if they were aware of any eye dominance effects and if the prescription for corrective lenses was the same for both eyes. If not, the subject was disqualified. Any subject who had difficulty seeing either the TS or the MS in practice sessions was also disqualified. Twenty older subjects were eliminated by these criteria. All the young subjects were retained.

Stimulus Materials

Test stimuli consisted of the single symmetrical letters of the alphabet, A, H, I, O, M, U, V, W, X, and Y; three letter words AIM, HAM, HIT, MAT, MIX, TOW, TOY, VAT, VOW, WAX, and WIN; and consonant trigrams, HMT, HVT, MHT, MHV, MHX, THV, VTW, VXT, VXW, WMX, and WVX. Welsandt, Zupnick, and

Meyer (1973) examined their group data for percentage of response to each letter at ISIs resulting in performance both above and below chance level. Two separate chi-square analyses of their data were non-significant, indicating no relation between an individual target letter and age group. The letters used in the present study were 1.25 cm black vinyl plastic, Super Stick Brand, # 406, subtending visual angles of .8 degrees vertical by .8 degrees horizontal. The thickness of the letters subtended .13 degrees of visual angle. For the words and trigrams, the separation between the letters was approximately .13 degrees. All the symmetrical letters of the alphabet were also used by Turvey (1973). Walsh (1976) omitted O and U because they were not formed from straight lines, although he did not discuss the rationale for the decision. All stimuli were centered on 7.6 by 7.6 cm glass slide plates. The masking stimuli were the pattern masks shown in Figure 2, the small one for single letters (PM1), the larger one for words and trigrams (PM3). The masks were constructed from pieces of the same type letters used as target stimuli cut in 2 mm segments (subtending .13 degrees of visual angle), placed randomly on glass covering the same area of the visual field as that covered by the target letters. PM1 covered an area 1.5 cm by 1.5 cm and subtended .95 degrees vertical by .95 degrees horizontal. PM3 covered an area of 1.5 cm by 4.0 cm and subtended a visual angle of .95 degrees vertical by 2.5 degrees horizontal.

Figure 2. PM1 (top) and PM3 (bottom) used to mask letters, words, and trigrams in Experiments I and II. The letter M is a sample of the size and type letters used.



Procedure Part A

The 30 subjects in each age group were further divided into WORD, LETTER, and TRIGRAM groups in the order in which they were accepted as subjects, alternating one young and one old. Six experimental groups, each containing ten subjects were formed. Subjects were assigned to stimuli in the following order: subjects 1-5 received LETTER stimuli, 6-10 TRIGRAM, 11-15 WORD, then WORD, TRIGRAM, LETTER, etc. until the 60 subjects had been assigned. Each subject received a different random presentation of the LETTER, WORD, or TRIGRAM stimuli through an experimenter controlled switch panel; each switch having a number corresponding to one of the eleven slide holders in the stimulus changer. Presentation of stimuli in Experiment I was dichoptic; the test stimulus always presented to the left eye and the masking stimulus always presented to the right eye. Because the stimulus changer could only be attached to one field of the tachistoscope, it was not possible to present the TS to either eye. Walsh always presented the TS to the right eye; Turvey used the left eye for some experiments, the right eye in others, and mentioned that in some subjects eye dominance could seriously affect masking results.

Each session began with a demonstration to the subject of the test stimulus alone, the mask stimulus alone, and both together, at varying interstimulus intervals. The subject was instructed to fixate on the center of the always visible superimposed square fields and was told

emphatically of the importance of keeping both eyes open at all times and remaining in a position in which the two squares appeared superimposed. He could adjust the eye piece for interocular distance and convergence angle to insure proper fixation. The residual glow from the light sources plus the ultra violet tubes provided dim illumination (less than .1 mL) between flashes. The subject was further instructed to report verbally the name of the LETTER, WORD, or TRIGRAM if he could recognize it in each flash. If not, to say "1" if the stimulus appeared to be a single flash, or "2" if it seemed to be a double flash. "No response" was not solicited but occurred at least once in 58 of the 60 subjects. Members of the WORD and TRIGRAM groups were asked to report any letters they saw whether or not such letters constituted the entire WORD or TRIGRAM. Practice trials were continued until each subject fully comprehended what was expected of him and was able to report several correct answers. An approximate estimate of each subject's ISI_c was obtained in these practice trials and used as the starting point for subsequent measurement of ISI_c . The experimental session consisted of three conditions:

Condition (1). Measurement of the recognition time of the test stimulus without the mask. Walsh (1976) found a mean letter recognition threshold in his older group of 2.59 msec versus 1.77 msec for the young. Such brief duration stimuli were not possible here because the equipment limited the briefest possible duration to 3 msec. If the subject could not identify a target in that duration, the duration

was raised in one msec steps until four correct responses were given. No preset number of trials was completed. Stimuli were presented on each trial in random order.

Condition (2). Measurement of the ISI_c (the interval at which a subject could identify a masked target, i. e., escape the masking effect). This condition was divided into three sections consisting of 22 trials in which the duration of the test stimulus was held constant at 10, 20, or 30 msec. To avoid order effects, the test durations were coded into six orders and randomly assigned to subjects with the constraint that 10 subjects, 5 young and 5 old, received each order. The codes were as follows: A = 10, 20, 30; B = 20, 30, 10; C = 30, 10, 20; D = 30, 20, 10; E = 20, 10, 30; F = 10, 30, 20. An approximate estimate of each subject's ISI_c was determined in practice sessions. ISI was begun at 0, 50, 100, or 150 msec and raised in 5 msec steps until one correct response was given and remained unchanged on the following trial. If the second response at the same duration was correct, the duration was lowered by 2 msec. If an incorrect response was given at the lower duration, the ISI was again raised by 2 msec on the next trial. If the response was correct, the duration was lowered by 2 msec until an incorrect response was given, at which time the duration was raised in 2 msec steps until at least two correct responses occurred. The ISI remained at that level until completion of the 22 trials. Walsh used a criterion of four correct responses. Some of the older subjects in this study were unable to report four successive stimuli even at durations well

above ISIs at which there was no masking. Fourteen (approximately 20%) of the 66 trials were catch trials; in these trials the test stimulus was not presented, permitting a response bias analysis of the data (Hodos, 1970). The intertrial interval was always 20 seconds given the operating time of the stimulus changer.

Condition (3). Measurement of the critical target duration (TD_c) with an ISI of zero msec. Target duration was started at the subject's recognition threshold as determined in Condition (1) and raised in 5 msec steps until a correct response was given, then lowered by 2 msec per trial until an incorrect response occurred, then raised in 2 msec steps until a criterion of at least four correct responses was reached. The duration remained at that level until the completion of 33 trials. Seven of the 33 trials (approximately 20%) were catch trials as in Condition (2). Thus 99 trials from each subject were available for analysis. As in Condition (2), the intertrial interval was always 20 seconds.

A measure of response bias or subject criterion was obtained through the use of a non-parametric index (Hodos, 1970) for use in detection and recognition experiments when the rigorous specifications of a signal-detection analysis are not practicable. The method is based on the geometry of the unit square and makes no assumptions about the statistical properties of sensory events associated with the presentation of signal and non-signal conditions. Percent bias is either plus or minus; plus indicating a conservative criterion, minus, a greater tendency towards risk.

Results and Discussion

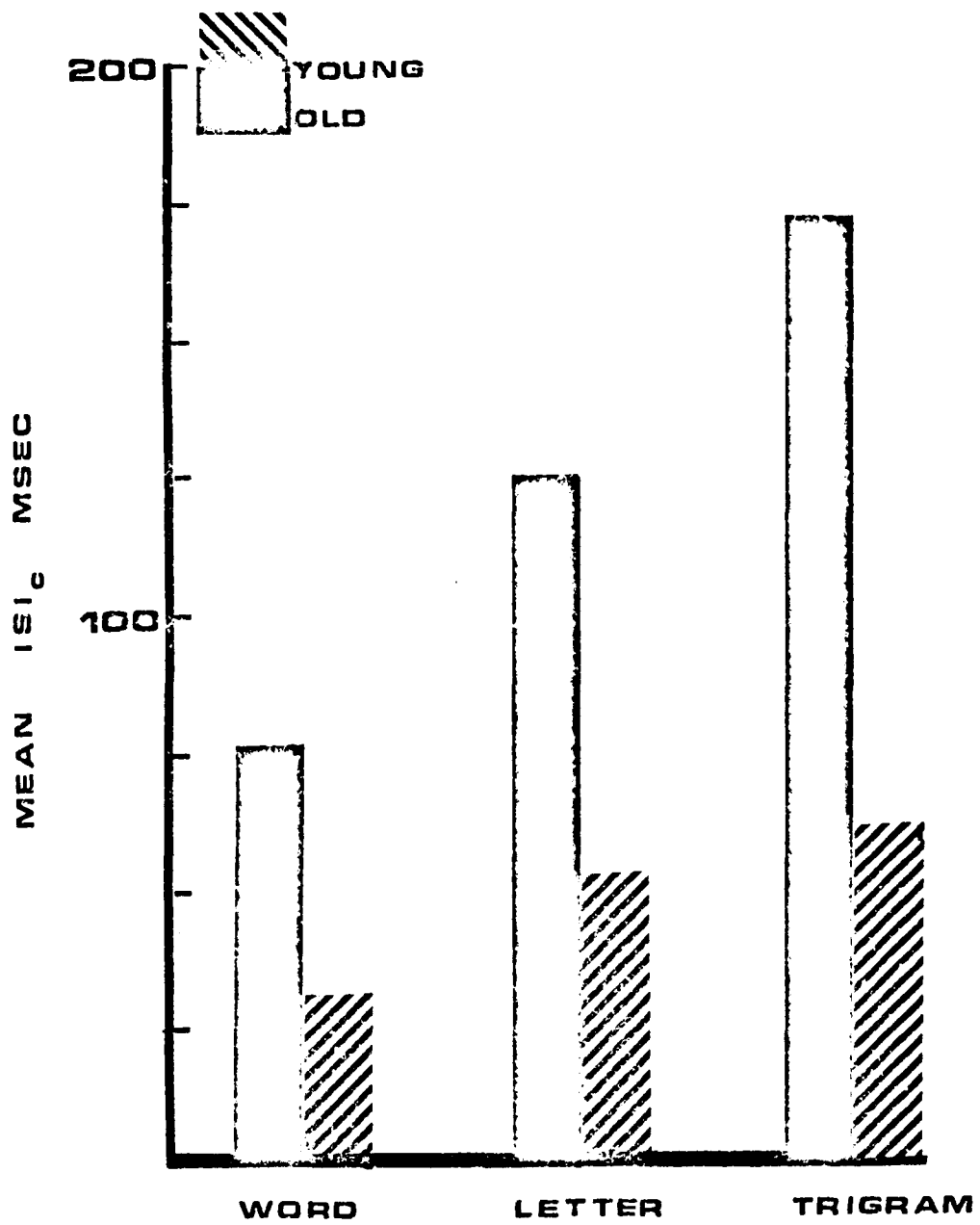
A fixed effects analysis of variance on subject groups (age) x conditions (WORD, LETTER, TRIGRAM) yielded a highly significant difference between the young and the old groups ($F = 23.53$, $df, 1, 54$, $p < .001$) and a significant difference between WORD, LETTER, and TRIGRAM conditions ($F = 4.99$, $df, 2, 54$, $p = .01$). The summary appears in Table 1. The interaction between age groups and WORD, LETTER, and TRIGRAM groups was not significant.

Figure 3 shows the relationship between age, target stimulus content, and ISI_c with target duration pooled. Walsh (1976) reported an age difference of approximately 22 msec between young and old at each of three target durations. With those durations pooled, the difference was 23.8 msec. The difference between the groups in the LETTER condition of the present study was 71.5 msec, almost three times that reported by Walsh. The mean age of Walsh's older subjects was 64.2 years, compared to 67.9 years here. Whether or not a difference of almost four years in that age range could account for the observed difference needs further study. It is more likely that stimulus characteristics were involved. Walsh presented his stimuli at .06 footcandles of illumination which is impossible to convert to mL (4.3 mL used here) without knowing the coefficient of transmission or reflectance. A representative reflectance of one test plate used in the MacBeth Illuminometer is .8, which would result in a luminance of 4.8 mL with a reading of .06 footcandles. This compares favorably with the

Table 1

Analysis of Variance Summary Table				
Source	df	MS	F	
Subject Groups (Age)	1	89,250.9	23.53	p < .001
Conditions (WORD, LETTER, TRIGRAM)	2	18,941.6	4.99	p = .01
Groups x Conditions	2	3,729.2	.98	
Within	<u>54</u>	3,793.4		
	59			

Figure 3. Relationship between age, stimulus content, and ISI_c with target duration pooled.



luminance used in the present study, but, of course, is pure speculation. Walsh also used a 5 second intertrial interval as opposed to 20 seconds here. This should not affect masking unless the longer interval had an adverse effect on attention or fixation variables related to individual subjects. Table 2 compares several stimulus parameters used in comparable experiments by Turvey (1973), Walsh (1976) and the present study.

Data from the Walsh study obtained with single letter target stimuli and a pattern mask of equal or less energy conformed almost exactly to the additive rule indicative of central masking. His younger group when viewing a target stimulus of 10 msec with a mask of 10 msec showed an ISI_c of 64.5 msec; with a TS of 20 msec, an ISI_c of 54.7 msec; and with a 30 msec TS, an ISI_c of 45.6 msec. Thus, in the formulation $TD + ISI_c = K$, the constant equalled approximately 75 msec and the critical target duration (TD_c), which should equal SOA, was 70.2 msec. Results from Walsh's older group revealed the same linear decrease in ISI_c over the 10, 20, and 30 msec TDs; the group requiring about 22 msec longer in every condition than did the young. The TD_c for the older group was 94 msec. The target duration data from Experiment I, Part A of this study are shown in Table 3. There was a consistent decrease (except in the LETTER group) in mean ISI_c with an increase in target duration. The mean decrease in ISI_c from 10 to 20 to 30 msec TD was 5.79 msec; less than the 10 msec predicted by the theory and

Table 2

Comparison of Stimulus Parameters in Comparable Experiments by Turvey, Walsh and Cramer

	Turvey (1973)	Walsh (1976)	Cramer
Letter size (Vertical)	.67 degrees	1.71 degrees	.8 degrees
(Horizontal)	.36 degrees	1.26 to 1.71 degrees	.8 degrees
Letter stroke width	.13 degrees	.22 degrees	.13 degrees
Number of letters used	11	9	11
Distance between letters (Trigrams)	.40 degrees	Walsh used only single letters	.13 degrees
Sequence of TS letters	counter-balanced blocks of different orders	random	random
Line length of mask strokes	no information given	1.0 degrees	.13 degrees
" width " " "	.13 degrees	.22 degrees	.13 degrees
Luminance of TS and MS at 10 msec duration	4 footlamberts (4.3 mL)	.06 footcandles (illuminance)	4.3 mL

Table 3

ISI _c Data Relative To Central and Peripheral Rules						
Age Groups with Stimuli Pooled - Stimulus Groups with Age Pooled						
	TD	Mean ISI _c	SD	TD + ISI _c	TD _c	TE x ISI _c
Young	10	52.16	34.27	62.16	42.50	521.00
	20	47.57	55.09	67.57		951.40
	30	39.10	43.02	69.10		1173.00
Old	10	128.43	82.80	138.43	116.27	1284.30
	20	124.67	82.31	144.67		2493.40
	30	118.30	79.18	148.30		3549.00
WORD	10	55.05	64.07	65.05	57.6	550.50
	20	54.05	67.11	74.05		1081.00
	30	51.45	62.27	81.45		1543.50
LETTER	10	84.05	75.36	94.05	75.05	840.50
	20	93.95	81.88	113.95		1879.00
	30	81.80	73.27	111.80		2454.00
TRIGRAM	10	130.85	86.46	140.85	105.50	1308.50
	20	111.85	88.97	131.85		2237.00
	30	102.85	79.15	132.85		3085.50

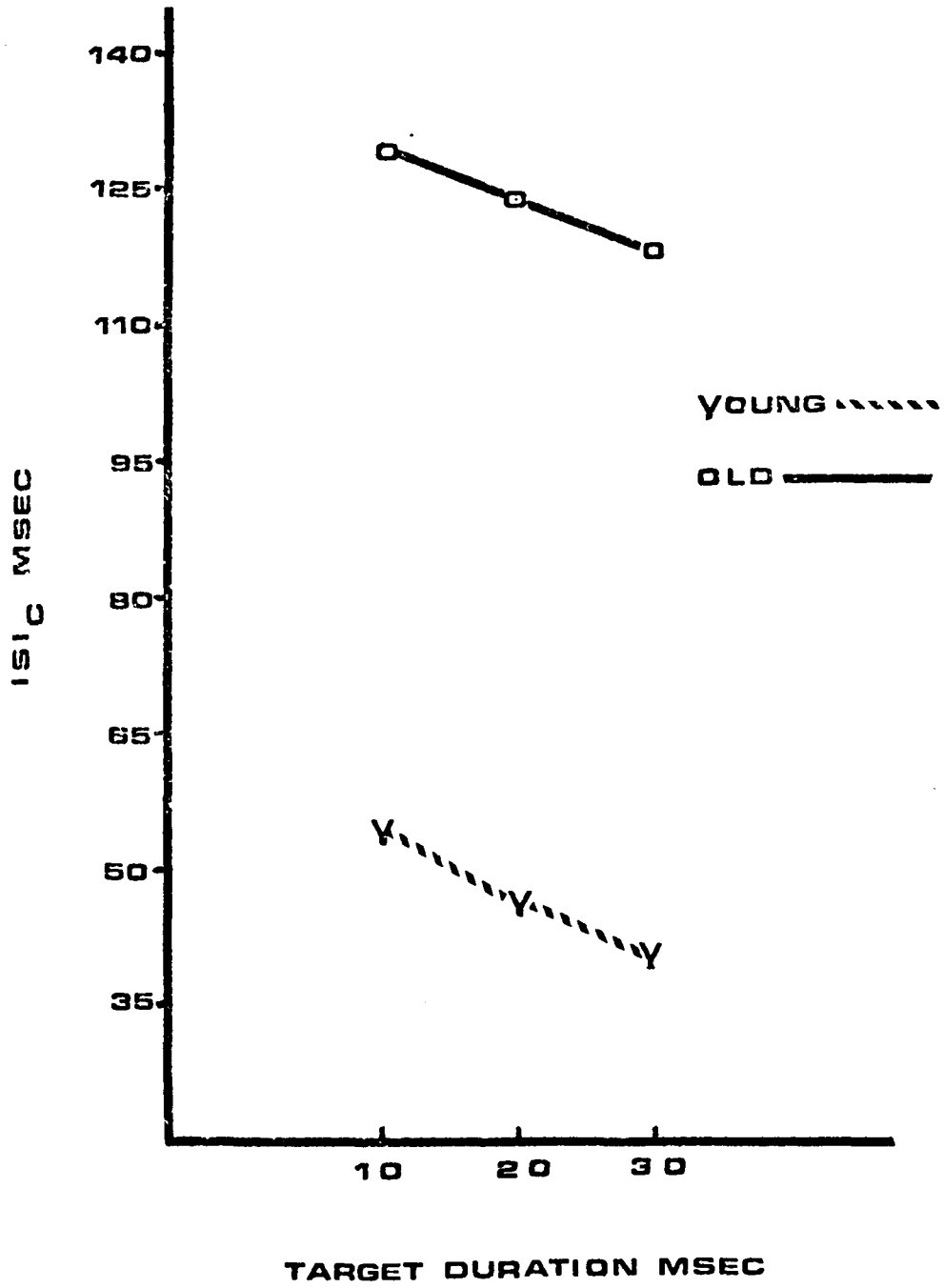
substantiated by Walsh. Columns 3 and 5 of Table 3 present the target duration data within the framework of the central relation ($TD + ISI_c = K$) and the peripheral relation ($TE \times ISI_c = K$). It is obvious that the data are reasonably approximated by the central rule, whereas there is a severe misfit to the peripheral relation. Since the model predicts the central relation to be a linear function with a slope of -1, ($TD + ISI_c = K$) i. e., $ISI_c = K + (-1) (TD)$, and the peripheral relation ($TE \times ISI_c = K$) (in this case, $TD = TE$), in a log transformation to also be a linear function with a slope of -1, i. e., $\log ISI_c = \log K + (-1) \log (TD)$, a linear regression analysis was performed on ISI_c s of all 60 subjects at TDs of 10, 20, and 30 msec. The data of all subjects was pooled since the model makes no predictions as to age differences or differences in target stimuli. The only relevant experimental question was whether or not the observed masking was taking place in central or peripheral processes. To test the hypothesis that the data fall within acceptable limits of a linear function with a slope of -1, the regression coefficient (\hat{b}) was computed for both central and peripheral relations. Error terms were computed from the sums of squares taken from the analysis of variance summarized in Table 1. A similar analysis was computed in log form to test the peripheral rule. A non-significant t statistic supports the hypothesis: $\hat{b} = -1$. In the case of the central rule, $t_{119} = .6317$ ns. (interval estimate = -0.5458 ± 1.193). In the case of the peripheral rule, $t_{119} = 2.81$ ($p < .01$) (interval estimate = $0.1257 \pm .5161$). Although the interval estimate for the central relation is wide, the

central rule as defined by Turvey is statistically supported by the ISI_C and target duration data. The peripheral relation is not.

Column 4 of Table 3 presents the critical target duration data (TD_C). The values theoretically should equal the constant produced by $TD + ISI_C = K = SOA$). In all groups the TDs were consistently lower by 25 to 30 msec than predicted by the model. This observation and the fact that ISI_C s at 20 and 30 msec target durations decreased by approximately 4 msec less than expected can possibly be explained by a similar phenomena to that described by Purcell, Stewart, and Dember (1969) related to the Broca-Sulzer effect. Specifically, when exposure duration increases and intensity is held constant, a stimulus consisting of black lines on a white ground may partially mask itself. The white surround becomes brighter and degrades the contours of the figure. Turvey (Experiments V and VII) explained some of his results in this context. The argument seems quite applicable to these data: at increased target durations of 20 and 30 msec, during measurement of ISI_C , luminance was held constant and more masking than was expected occurred. In measurement of TD_C , ISI was held at zero msec, and in most cases, TD was increased beyond the duration where the brightness effect was operative, resulting in critical target durations lower than SOAs.

Figure 4 presents mean ISI_C as a function of target duration for young and old groups. The functions are seen to be linear and almost exactly parallel, with a difference between the groups at 10 msec TD = 75.1 msec; at 20 msec TD = 77.1 msec; and at 30 msec TD = 79.2

Figure 4. Mean ISI_c as a function of target durations of 10, 20, and 30 msec for young and old subjects



msec. Thus, with target durations averaged over WORD, LETTER, and TRIGRAM groups, the age difference is approximately 50 msec greater than that reported by Walsh.

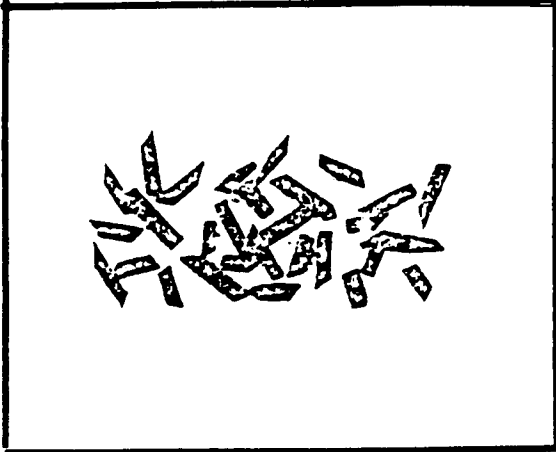
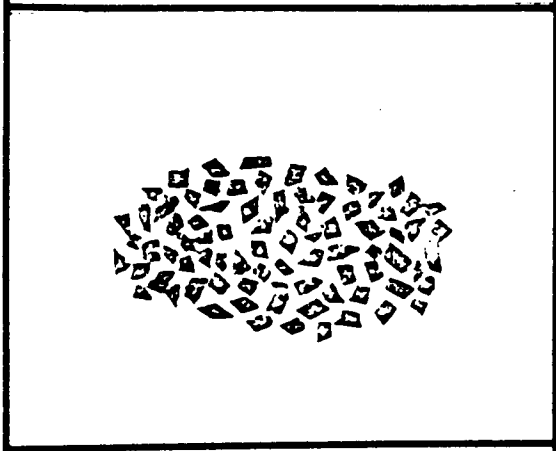
A possible explanation other than the Broca-Sulzer effect for some of the inexact ISI_c data is that five of the 10 young subjects from the WORD group and two from the TRIGRAM group experienced little or no masking, insuring an ISI_c of virtually zero. Further examination of the pattern mask (PM3) suggested that it resembled random visual noise almost as much as it did the target letters. Although Kinsbourne and Warrington (1962 b) reported dichoptic masking with random visual noise, Turvey (1973) was unable to do so except with TS presented at threshold. Part B of Experiment I was a follow-up control study undertaken to determine whether or not the figural characteristics of PM3 were causally related to the small amount of masking observed in seven young subjects in Part A. Figure 5 shows random visual noise as used by Turvey and Kinsbourne and Warrington (top), PM3 (center), and the New PM3 (bottom).

Procedure Part B

Five control conditions were as follows:

Condition (a). Twenty trials using WORD or TRIGRAM as TS and the original PM3 as mask, with $ISI = \text{zero msec}$, as a replication of Condition (2) Part A. The luminance of both the TS and MS was 4.3 mL as measured through the artificial pupils and focusing prisms.

Figure 5. Random visual noise (top), PM3 (center), and the New PM3 (bottom). The line segments of the New PM3 subtended .13 degrees of visual angle in thickness by .19 to .51 degrees in length. The overall mask subtended .95 degrees vertically by 2.80 degrees horizontally.



Condition (b). Twenty trials using WORD or TRIGRAM as TS, PM3 as mask, ISI = zero msec, but with mask luminance raised to 38 mL as measured through the pupils and prisms, or 190 mL without them. This was done because if masking were taking place in the peripheral system as defined by Turvey, raising the luminance of the mask would increase the masking effect.

Condition (c). Twenty trials with WORD or TRIGRAM as TS presented simultaneously with PM3, i.e., SOA = zero msec. Both were presented at a luminance of 4.3 mL as measured through the pupils and prisms. The reason for this condition was that if the original PM3 were capable of causing masking in these subjects, it would do so under conditions of simultaneous presentation of TS and MS.

Condition (d). Twenty trials with WORD or TRIGRAM as TS and the New PM3 as mask, with ISI = zero msec, and both TS and MS presented at a luminance of 4.3 mL.

Condition (e). Measurement of ISI_c using the New PM3 as mask. ISI was raised from zero in 10 msec steps until a correct response was given. On the following trial the duration was not changed. If a second correct response was given, the duration was lowered 2 msec per trial until an incorrect response occurred. It was then raised by 2 msec per trial until a criterion of four correct responses was reached.

Unlike Part A, no preset number of trials was completed.

Figure 6 shows percent correct response in the four conditions

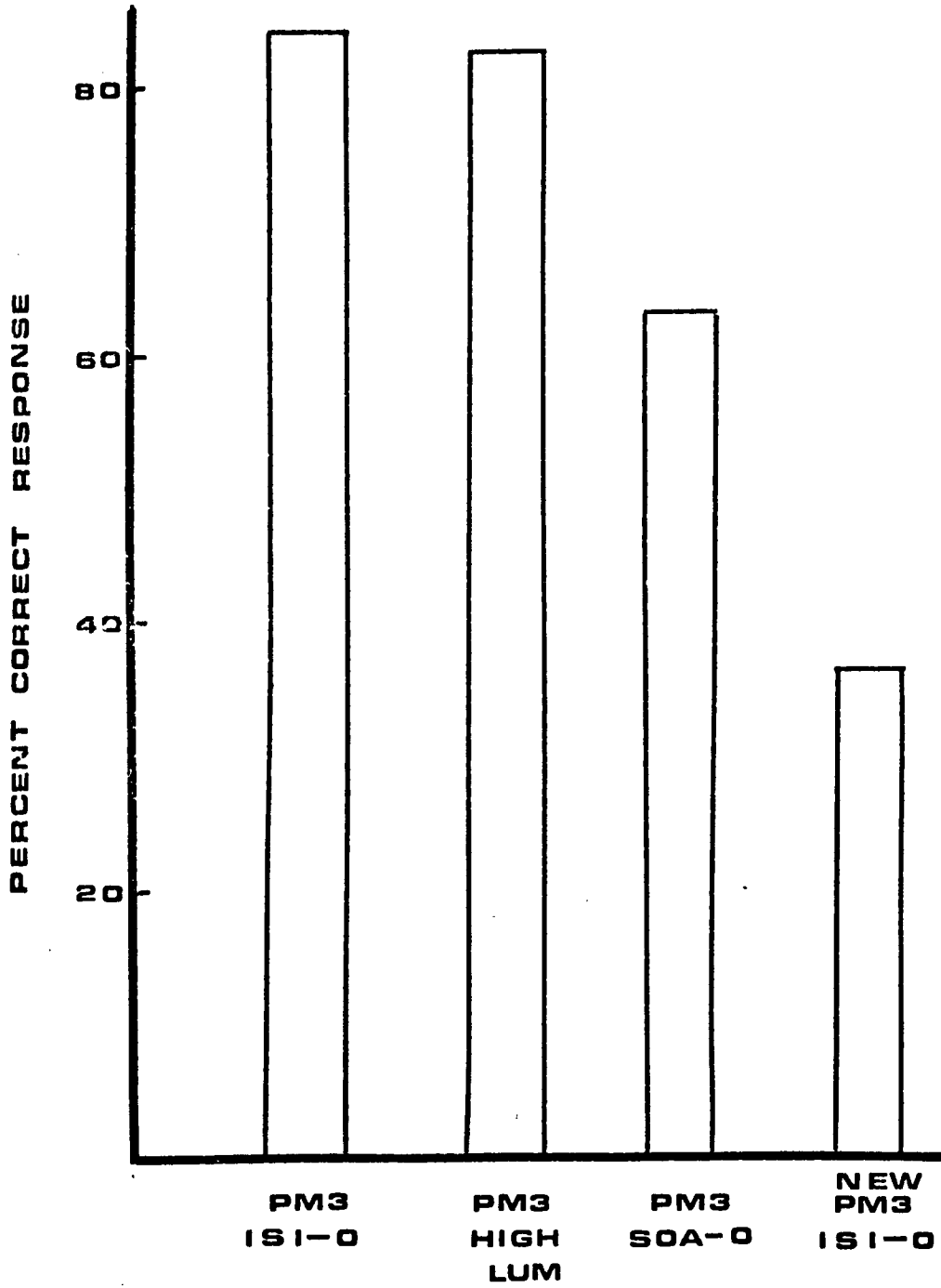
Figure 6. Percent correct response in four conditions of Part B,
Experiment I.

(a) The original PM3 as mask, TS = 10 msec, MS = 10 msec, ISI = 0 msec.

(b) The original PM3 as mask with its luminance raised to 38 mL as measured through artificial pupils and focusing prisms. Other conditions same as in (a).

(c) SOA = 0 msec. Other conditions same as in (a).

(d) The New PM3 as mask. Other conditions same as in (a).



of Part B. Condition (a) was essentially a replication of Condition (2), Part A, in which these subjects were able to identify a masked (with PM3) target of 10 msec duration with an ISI of zero msec. In Condition (a) of Part B, the mean percent correct identification of the six subjects was 84%, again with a 10 msec target, a 10 msec mask, and an ISI = 0, with PM3 as mask. Raising the luminance of the mask (Condition (b)) decreased the percentage of correct responses by 1%. If masking were originating in the peripheral system as defined by Turvey, increased luminance of the mask would increase the masking effect. In Condition (c) with SOA = zero msec, percent correct response decreased by 21%, showing that the original PM3 had some masking capability in these subjects. Use of the New PM3 in Condition (d) decreased the percent of correct responses by 47.5%. Only one subject did not experience a greater degree of masking with the New PM3. Lack of masking in that one case may have been caused by eye dominance effects which developed during the experiment. Herzog et al. (1976) reported several instances of this occurring in subjects who did not show dominance effects when given a pre-experimental eye dominance test. The mean ISI_c of the group with the New PM3 as mask was 82.6 msec (SOA = 92.6 msec). The mean SOA of these same subjects in Condition (2) of Part A was 10 msec.

Turvey's explanation for failure to obtain dichoptic masking with random visual noise, was that visual noise, because of its unstructured

nature, was behaving like a homogeneous flash of light. It is well known that forms cannot be masked by light (Kahneman, 1968). Turvey maintains that the greater the similarity between target and mask, the greater the probability that masking will occur, provided that masking is of central origin. Mayzner and Tresselt (1970) suggest that inputs with varying geometric properties are dispatched to different cortical locations sufficiently spaced so that the inhibitory fields of the later arriving stimuli do not interact with excitatory fields of earlier inputs. Why this effect was evident in only a few subjects is not clear. The only possible explanation in terms of any known factor about these particular subjects was that they all had excellent visual acuity (20/15 or better). Certainly most subjects, particularly in the older group, experienced a great deal of masking with PM3 as mask. There appears to be no established procedure for the construction of pattern masks in terms of line lengths and orientations. A systematic study of such parameters is recommended.

Table 4 gives the response bias percentages of all subjects in the WORD, LETTER, and TRIGRAM groups from Part A. All subjects were conservative; the old no more so than the young. Young subjects in the WORD group showed a greater tendency towards conservative responses than the old (+ 90.9 versus + 78.2 respectively). This tendency was reversed in the TRIGRAM group; the old responding more conservatively than the young. Interestingly, in both old and young in the LETTER groups, the conservative bias was greatly

Table 4

Response Bias Data for the Young and Old Groups in the WORD, LETTER, and TRIGRAM conditions

	WORD		LETTER		TRIGRAM	
	Condition	% Bias	Condition	% Bias	Condition	% Bias
YOUNG	10 msec	+ 82.5	10 msec	+48.2	10 msec	+59.6
	20 msec	+ 100.0	20 msec	+31.1	20 msec	+70.3
	30 msec	+100.0	30 msec	+33.3	30 msec	+60.7
	TD _c	+81.1	TD _c	+46.3	TD _c	+56.4
		$\bar{X} = +90.9$		$\bar{X} = +39.7$		$\bar{X} = +61.8$
OLD	10 msec	+ 87.8	10 msec	+31.5	10 msec	+85.1
	20 msec	+83.9	20 msec	+48.8	20 msec	+86.8
	30 msec	+76.8	30 msec	+32.7	30 msec	+86.1
	TD _c	+64.4	TD _c	+31.5	TD _c	+76.0
		$\bar{X} = +78.2$		$\bar{X} = +36.1$		$\bar{X} = +83.5$

reduced indicating that an increased tendency to guess in these groups may have contributed to the greater discrepancies observed in the ISI_C data in the LETTER condition.

Table 5 lists WORDS, LETTERS, and TRIGRAMS in alphabetical order with percent correct response to each. The numbers in parentheses refer to the rank of percent correct responses to each stimulus for young and old subjects. There appeared to be no orderly relation between letter preference and age, supporting the findings of Welsandt et al. (1973) which indicated that no systematic relation between age and letter preference existed. A Spearman rank order correlation coefficient computed on the ranks of the single letters yielded an r of .518 which was not significant. Correlation coefficients computed separately for the WORD and TRIGRAM groups were also non-significant, again suggesting no relation between age groups and ease of recognition of particular WORDS or TRIGRAMS. The letter A, with 69% correct response, and the words AIM and VOW, both with 86% correct response ranked first with the younger group, whereas the letter O and the word TOY ranked first with the older subjects, with 59% and 69% correct respectively.

The number of partial reports of letters appearing in the first position in WORDS or TRIGRAMS was 233, 28% of the times the letter appeared in that position; 169, or 18% in the second position; and 162, or 27% in the third position.

Table 5

Percent Correct Response to Each LETTER, WORD, or TRIGRAM

Numbers in Parentheses Indicate Rank of Each Stimulus for Young and Old

	LETTER		WORD		TRIGRAM			
	% Correct Old	% Correct Young	% Correct Old	% Correct Young	% Correct Old	% Correct Young		
A	45 (3)	69 (1)	AIM	49 (4)	86 (2)	HMT	20 (7)	59 (3)
H	38 (8)	60 (3)	HAM	42 (8)	77 (10)	HVT	37 (1)	61 (2)
I	37 (10)	28 (11)	HIT	40 (9)	79 (7)	MHT	26 (2)	57 (6)
M	45 (2)	64 (2)	MAT	46 (5)	74 (11)	MHV	23 (4)	54 (9)
O	59 (1)	52 (5)	MIX	35 (11)	81 (3)	MHX	26 (3)	53 (10)
T	41 (6)	48 (9)	TOW	39 (10)	81 (5)	THV	14 (10)	66 (1)
U	40 (7)	40 (10)	TOY	69 (1)	78 (9)	VTW	22 (5)	58 (4)
V	44 (5)	50 (7)	VAT	43 (7)	80 (6)	VXT	16 (9)	58 (5)
W	45 (4)	50 (6)	VOW	51 (3)	86 (1)	VXW	11 (11)	56 (8)
X	37 (9)	53 (4)	WAX	52 (2)	78 (8)	WMX	21 (6)	57 (7)
Y	27 (11)	49 (8)	WIN	44 (6)	81 (4)	WVX	18 (8)	53 (11)

Table 6 lists the single letters again alphabetically, and gives the number of correct responses to each from both young and old when the letter appeared in first, second, or third position in a WORD or TRI-GRAM which was not recognized in its entirety. These letters and positions represent partial correct responses. The numbers in parentheses refer to the number of WORDS or TRIGRAMS in which the letters appeared in that position. The letters were ranked, after dividing the number of reports by the number of times the letter appeared, and separate correlation coefficients were computed for each position. For the letter in position 1, the correlation was not significant, indicating no orderly group preference for a particular letter. For position 2, $r = .71$ ($p < .05$) one-tailed ($N = 8$), with the letters M and A being reported most frequently in both groups. In position 3, $r = .93$ ($p < .05$) one-tailed ($N = 5$). In third position the letter T was the most frequently reported in both groups with W a close second.

The partial report data are of interest in terms of Sperling's (1960) investigations of short term memory. In a 50 msec presentation of a five-letter array, there was almost complete recall of letters appearing in the first position and less than 50% recall of letters appearing in the fifth position. Sperling interpreted this as supporting a theory of sequential (serial) processing of the iconic image. The present data, however, support a model of parallel processing since the percentage of letters reported in third position was approximately equal to the

Table 6

Number and Percent of Partial Reports of Each Letter and its Position in WORD or TRIGRAM

Numbers in Parentheses Indicate Total Number of WORDS or TRIGRAMS in which Letter Appeared in that Position

	Position 1				Position 2				Position 3					
	Old		Young		Old		Young		Old		Young			
	Number of Reports	%	Number of Reports	%	Number of Reports	%	Number of Reports	%	Number of Reports	%	Number of Reports	%		
A (1)	8	6	0	0	(4)	14	12	12	10	(0)	-	-	-	-
H (4)	29	24	12	10	(3)	13	11	11	9	(0)	-	-	-	-
I (0)	-	-	-	-	(4)	12	10	1	1	(0)	-	-	-	-
M (4)	32	27	23	19	(2)	18	13	15	13	(2)	8	6	3	3
O (0)	-	-	-	-	(3)	6	5	6	5	(0)	-	-	-	-
T (3)	15	13	8	5	(1)	10	8	4	3	(6)	49	41	24	20
U (0)	-	-	-	-	(0)	-	-	-	-	(0)	-	-	-	-
V (5)	41	34	26	22	(2)	18	3	-	-	(2)	19	16	9	8.5
W (4)	22	18	17	14	(0)	-	-	-	-	(4)	10	33	7	8
X (0)	-	-	-	-	(2)	-	-	-	-	(2)	22	18	11	9
Y (0)	-	-	-	-	(0)	-	-	-	-	(0)	-	-	-	-
Totals	147	18	86	10		105	11	64	7		108	18	54	9

percentage of those reported in first position. Turvey (1973), isolating central processes in a monocular study found that at longer PM3 duration (25-500 msec) subjects reported the first letter of a trigram more often than the other two. Subjects often commented that they did not have time to read the third letter. At PM3 durations of 10 msec or less, however, errors were more evenly distributed across positions. The model is of value in that it can support both the concepts of serial and parallel processing at different stages in the flow of information.

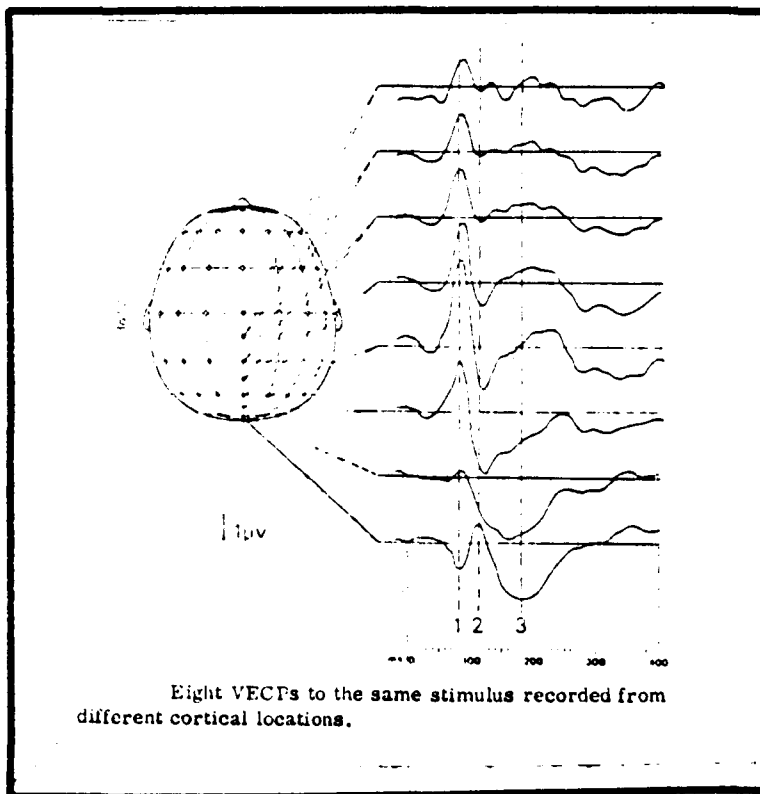
Experiment II

Recent development of computers capable of storing and adding re-current electrical signals generated by presentation of external stimuli has made possible the detection of cortical evoked potentials with scalp electrodes. Signals unrelated to the stimulus (noise) tend to average out as true signals are summed with stimulus repetition. It is generally assumed that the averaged evoked potential obtained from the scalp represents the summated activity of a large number of cortical cells; the response of these cells dependent upon stimulus and subjective variables. One stimulus variable relevant to the present study is stimulus intensity; increases in intensity are known to produce more complex waveforms with greater amplitudes and shorter latencies. Extremely intense stimulation, however, can reduce amplitude to the noise level (Perry & Childers, 1969). In terms of the concurrent-contingent model, greater stimulus energy increases the speed of peripheral processing which would therefore shorten the latency of the central response. Perry and Childers (1969) have also studied the relationship between evoked potentials and the maintenance of scotopic levels of adaptation. Over 100 flashes of bright light at the rate of four flashes per second produced only .5 log units of light adaptation. Thus in the typical experimental situation, visual stimulation could not raise the total adaptation level significantly toward the photopic range. Rate of stimulation in studies of visual evoked potentials is usually on flash per second or less. Rates of more than three per second result in response overlap; the earliest components of responses to rapidly presented stimuli can be seen at 5 to 10 msec which is faster

than the transmission time from receptor to cortex, showing that the early components are actually tails of the previous response. Slow rates of stimulation tend to increase between subject variability, and in some cases have been shown to increase amplitudes of both positive and negative peaks. Rate of stimulation in the present study was extremely slow; each flash pair occurring only once every 10 seconds. Females have been reported to give visual evoked responses with larger amplitudes and shorter latencies than males (Perry & Childers, 1969). Evidence from studies of eye dominance has not been conclusive, although some have reported larger evoked responses from the right occiput than from the left. Larger evoked responses occurred in the right hemisphere of some subjects who participated in binocular pilot studies for the present investigation (Appendix I). No differences in response from the two hemispheres was observed in dichoptic studies (Experiment II). Habituation can be controlled, particularly with naive subjects, with short breaks in the experimental session. Figure 7 shows visual evoked potentials recorded from different cortical locations (Kinney, 1977). Different electrode placement can affect amplitudes and latencies of the various components.

Attempts to identify universal components of the visual evoked potential (VEP) have not been successful (Kinney, 1977). There are several morphologic descriptions in common usage which can be helpful, particularly in identifying early components (less than 100 msec) of the VEP. Cigánek (1961 a, b,) identified a primary complex with waves I, II, and III at 40, 53, and 75 msec, and a secondary complex

Figure 7. Visual evoked potentials recorded from different cortical sites (Kinney, 1977).



formed by waves IV, V, VI, and VII at 95, 115, 130, and 190 msec. Gastaut and Regis (1964) described a visual potential having the same morphologic characteristics as Cigánek's but have enumerated the waves II, III, IV, Va, Vb, Vc, and VI which correspond to the I- VII classification of Cigánek. Gastaut and Regis found only 20% of subjects to present a photic potential complete from the I-VI wave, but the IV-VI waves were present in every visually evoked potential.

Vaughn (1969) suggested a method of separately identifying and analyzing the sensory and motor elements of sensorimotor sequences, and the central correlates of perceptual and cognitive processes in human subjects. The term "event related potentials" (ERP) was proposed to define the class of potentials having stable time relationships to definite stimulus events. The general class (ERP) was further categorized into (I) sensory evoked potentials (II) motor potentials (III) long-latency potentials related to complex psychological variables, (IV) the steady potential shifts, and (V) extra-cranial potentials. More than one class is generally present in any experimental situation, thus the temporal, spatial, and morphological features of the ERP assist in its characterization. A standard format for defining variations in amplitude, latencies of peaks, and presence or absence of components found under different experimental conditions was proposed. It consisted of an abbreviated designation of (1) electrode placement (2) component polarity (3) component peak delay (latency) in msec and (4) component amplitude in uV measured from the baseline. Thus a visual potential could be denoted as O_1/C_z : P (33, 1. 2); N(80, 4. 5); P(120, 7. 2); N(175, 2. 4); P(230, 16. 1). O_1 indic-

ating active electrode over occipital area and C_z a vertex reference.

Of particular relevance to the present study is a recent increase in the investigation of evoked responses to patterned stimuli. Spehlman (1965) found visual evoked potentials to blank stimuli to be consistently lower in amplitude and shorter in latency than those in response to patterned stimuli. John, Herrington, and Sutton (1967) examined the relation between the perceptual content of a stimulus and the evoked potential by manipulating size and orientation of geometric forms. Specifically, they investigated the responses to (1) a blank visual field versus a field containing a geometric shape, (2) one shape versus a different shape of equal area, (3) two identical shapes of different area, (4) the words "square" and "circle" printed with capital letters equated for area were compared. Waveforms elicited by a blank field differed from those in response to a geometric form; different shapes of equal area elicited different responses; similar shapes of different area elicited similar responses; different words equated for letter area evoked different responses. Different responses elicited by stimuli of different shape but equal area could not reasonably be attributed to differences in the amount of physical energy, thus they were thought to be caused by the stimulation of different retinal cells. However, large size differences in forms of the same shape produced similar responses in spite of the retinal area stimulated. The authors concluded that the evoked potential differences were more related to shape than to size of the stimulus elements and appeared to demonstrate a physiological correlate of per-

ceptual, rather than sensory processes.

Harter and White (1968) reported decreased amplitudes in both positive and negative peaks when stimuli were progressively blurred. Reitveld, Tordoir, Hagenouw, Lubbers, and Spoor (1967) found that amplitude and latencies, particularly of the second large component, increased with the presentation of patterned stimuli; the amount dependent upon the size of the stimulus pattern. White (1969) using four stimulus patterns, including a checkerboard, a horizontal grating, a set of concentric circles, and a set of radial lines found the checkerboard patterns consisting of check sizes subtending 10 degrees of visual arc resulted in the largest amplitude evoked potentials from all subjects tested. The waveforms showed consistent negativity at about 100 msec and marked positivity at 180 msec. Isolation of the contribution of contour from the pattern was achieved through the insertion of a minus 10 diopter concave lens in front of the subject's eyes and subtracting via the computer the same number of responses from all waveforms. The remaining trace was thought to represent the contribution of contour to the final average. What remained was a diphasic wave, negative at 100 msec and positive at 150 to 160 msec following stimulation. The degree of clarity of the image was found to be directly related to the amplitude of the wave.

Armington, Corwin, and Marsatta (1971) found larger response amplitude to checks than to stripes of intermediate spatial frequencies. Moskowitz, Armington, and Timberlake (1974) used a monocular study

of alternating stimuli with herringbone patterns to investigate the effects of sharp versus rounded off corners. Response amplitude was found to be greatest when stimuli had 90 degree corners, least for 135 degree corners, and intermediate for 45 degree corners. Curves and rounded patterns evoked larger amplitude responses than did 180 degree patterns. Latencies to sharp corners were shorter than latencies to rounded and straight patterns.

Visual evoked potentials in relation to aging were studied by Schenkenberg (1970). He recorded responses to flashes of light from frontal, occipital, and central sites, in subjects aged 5 to 77 years and found the cumulative amplitude to decrease by more than half from the youngest to the oldest age groups. The subjects were divided into eight age groups with 20 subjects in each group. The displayed averages consisted of a mean of 20 subjects. The greatest decreases were found in the early components (20-100 msec) and in the 200-300 msec range. Latencies to peaks beyond 100 msec often increased by 20 msec or more. This last result was also reported by Straumanis, Shagass, and Schwartz (1965), and by Dustman and Beck (1969). Shagass (1968, 1972), however, reported increasing amplitudes and latencies with age, favoring the conclusion that central mechanisms were involved as well as peripheral, since involvement of only peripheral mechanisms would not lead to simultaneous increases in both latency and amplitude (Diamond, 1964). A simple peripheral process should yield a decrease in latency with an increase in

amplitude.

Response to paired stimuli (Shagass, 1968) was shown to be smaller in amplitude to the second of a pair than to the first, and with increasing age the latency to recovery of a full amplitude response to the second stimulus was longer. Shagass (1972, pp. 87-106) attributed this effect to a loss of inhibition in neural function with age.

Bergamini, Bergamasco, Mombelli, and Gandiglio (1965) have shown that pupil diameter can influence averaged evoked potential amplitudes and latencies. It is well known that pupillary diameter decreases with age (Leopold, 1965). This constriction is partially controlled in the present study with the use of artificial pupils, which equalize retinal illuminance in all subjects.

Experiment II was designed to obtain visual evoked potential correlates of the psychophysical data gathered in Experiment I. The critical interstimulus interval between the masking flash and the test flash as determined in Experiment I was used as the basis for stimulus presentation conditions in Experiment II. Intervals which were well beyond the masking threshold for all subjects were also used. Data of interest were the latencies of peak amplitudes following stimulus presentation at intervals in which perceptual masking occurred and at longer intervals in which no perceptual masking occurred.

Data on the amplitudes, latencies, and shapes of evoked waveforms in response to binocular presentation of stimulus materials used in Experiment I as distinguished from the dichoptic presentation of stimulus

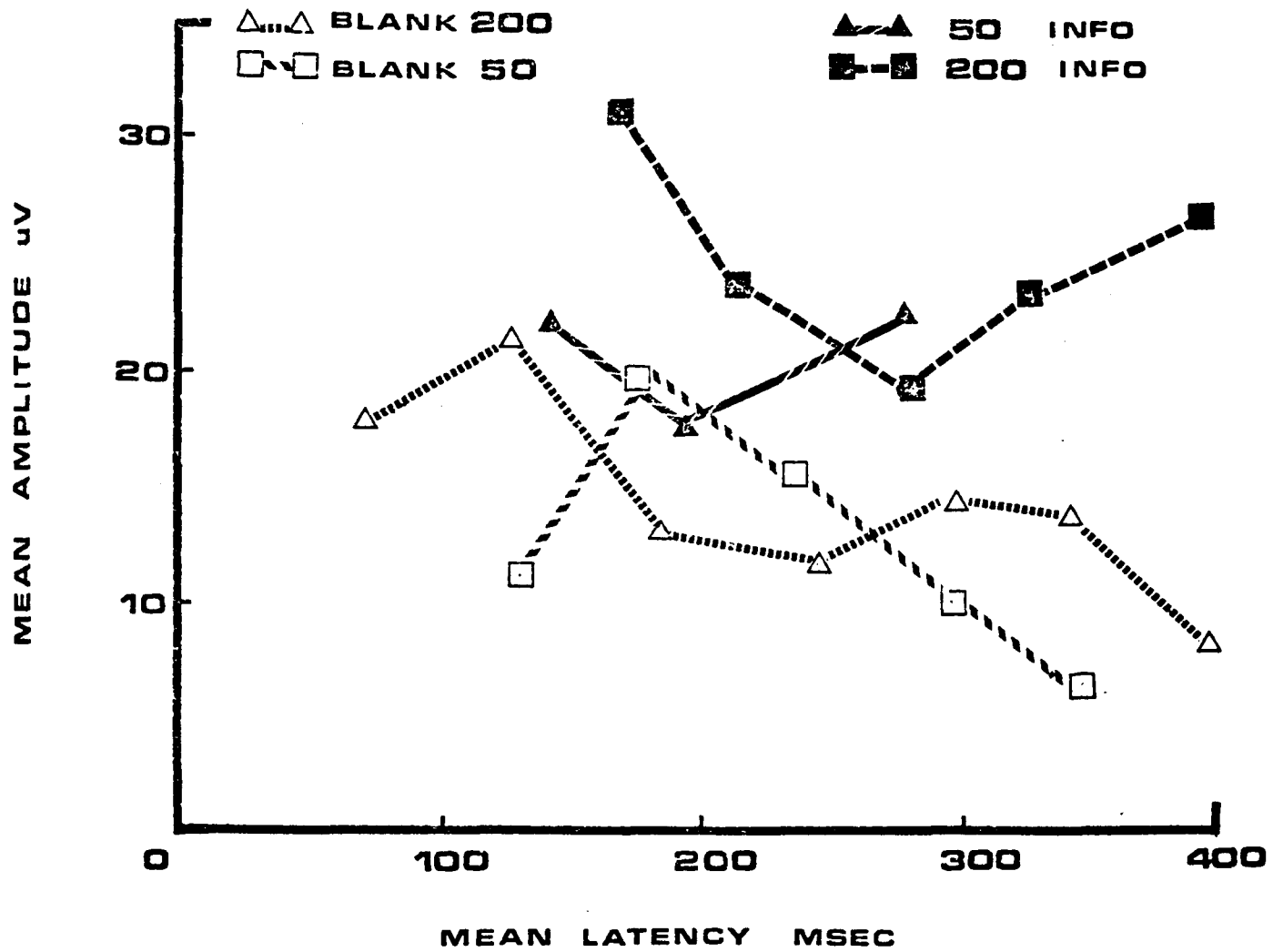
materials used in Experiments I and II, were obtained in preliminary pilot studies on 16 Hunter College graduate and undergraduate students 4 males, 12 females, with a mean age of 25.1 years (range 19-38). All had 20/20 vision as measured by a Snellen chart with or without corrective lenses. The exact procedure and all traces are shown in Appendix I. In general, the results showed an excellent signal to noise ratio, and similar traces were obtained from left and right hemispheres, with some showing a slight increase in amplitude from the right. Binocular presentation was used in this preliminary work because it allows peripheral (retinal) interactions between stimuli to occur, whereas the dichoptic presentation used in Experiment II does not.

Figure 8 shows the relation between mean amplitude and mean latency from six young subjects in conditions of binocular presentation of paired flashes of light with interstimulus intervals of 50 and 200 msec, and paired informational (patterned with the trigram TYU + PM3) with the same interstimulus intervals. Comparisons of one versus two blank flashes, and comparisons of blank with patterned flashes were in agreement with existing literature in that latencies to blank flashes were shorter and amplitudes lower than those to the patterned stimuli.

Subjects

The subjects were all drawn from those of Experiment I. Three young men (22 to 26 years, mean age 24.0 years), seven young women (18 to 26 years, mean age 22.2 years), and ten older women (65 to 78 years, mean age 70.1 years) participated. Both the young and old groups included three subjects from each of the LETTER, and TRIGRAM

Figure 8. Mean amplitudes and latencies of P-N components of evoked potentials in conditions of binocularly presented paired blank flashes and paired informational flashes with ISIs of 50 and 200 msec. The informational condition consisted of the trigram TYU and the appropriate pattern mask (PM3).



groups, and four from each of the WORD groups (two of the young men had been WORD subjects and one had been a LETTER subject. There were no male TRIGRAM subjects). All subjects showed masking in Experiment I.

Apparatus

The equipment described in the General Method section was again utilized for the presentation of stimuli. In addition, Grass gold cup electrodes were placed on the scalp of each subject 2.5 cm above theinion, and 2.5 cm to the left of the midline for left hemisphere recording and 2.5 cm to the right of the midline for right hemisphere recording. Both were referred to vertex and grounded to ipsilateral mastoid bones. Signals were fed into Grass Model P511E/EF/F AC preamplifiers set to pass frequencies between .1 and 100 Hz (half amplitude points) and were averaged by a digital PDP 8/I mini-computer using the Lab 8 Advanced Averager programs LB-1117C-PB and U18 C-PB. Averaged waveforms were photographed with a Tektronix Oscilloscope Camera, Model C-27, using Polaroid Type 47 film. PM1 and PM3 (Figure 2) were used to mask WORD, LETTER, and TRIGRAM stimuli. The New PM3 was not used as these potentials were to be correlates of the psychophysical data obtained in Experiment I.

Procedure

Following electrode attachment, each subject was instructed to remain physically motionless and to try just as hard to identify the LETTER, WORD, or TRIGRAM as he did in Experiment I but to omit

the verbal response, since overt vocalization could contaminate the visual evoked potentials with muscle potentials.

Condition (1). Noise control averages consisted of measurement of basic EEG activity in which stimuli were presented but viewing was blocked with black masking tape covering the artificial pupils. These data were taken on nine of the young subjects and on five of the older subjects. A 40 watt overhead lamp remained on in the booth. Subjects were instructed to silently count backwards by sevens from 500 to -3. Pilot studies (Appendix I) had shown excellent signal to noise ratios in similarly recorded averages. Noise control data were taken in Experiment II only if the subject was thought able to tolerate an extra fifteen minutes in the experimental situation before the main conditions were initiated.

Condition (2). Evoked potentials were recorded with a target duration of 10 msec, a mask duration of 10 msec, and an ISI of zero msec; conditions which resulted in perceptual masking for the subjects used here. Both target and mask were presented at a luminance of 4.3 mL as measured through the eye piece prisms and artificial pupils.

Condition (3). With target duration at 10 msec, mask duration at 10 msec, ISI was increased to 150 msec for the young subjects; 250 msec for the older subjects. These conditions resulted in no perceptual masking. In all conditions of Experiment II the intertrial interval was reduced to 10 seconds, necessitating a modification of complete randomization of stimuli on any given trial. A succeeding stimulus could not

be more than five steps away from its predecessor, as opposed to any of the eleven possibilities available in Experiment I. Both target and mask were presented at a luminance of 4.3 mL as measured through prisms and artificial pupils.

Results and Discussion

Figures 9 and 10 show individual traces from three young and three older subjects with averaged waveforms from the masked and unmasked conditions superimposed. The overall amplitude can be seen to be less in the masked condition (2). Except for subject ODL, the positive peak at approximately 200 msec (P2) is particularly attenuated. After onset of the mask in unmasked condition (3), in which no perceptual masking occurred, the waveforms were flatter in all cases than when perceptual masking occurred, indicating no separate neural response to the mask.

Summarizing the individual traces, Figure 11 plots the median amplitude and latency of P-N components for old and young groups in masked and unmasked conditions. Except for the range below 130 msec in the young and above 350 msec in the old, perceptual masking resulted in evoked potential amplitude attenuation in both groups. In the masked condition (2) the point of highest amplitude for the young people occurred at a latency of 130 msec and for the older subjects at 295 msec, although a peak of nearly the same amplitude was seen at 140 msec. Both functions were characterized by two prominent peaks of high amplitude; the two separated by 75 msec in the younger group and by 150 msec in the older group. Since stimulus onset was identical for both groups in the masked condition, it can be ruled out as a causal factor in the observed difference. The data imply that

Figure 9. Evoked responses from three young subjects in masked condition (2) and unmasked condition (3) superimposed for each subject. Vertical lines indicate stimulus onset. Negativity is downward. m = masked, um = unmasked.

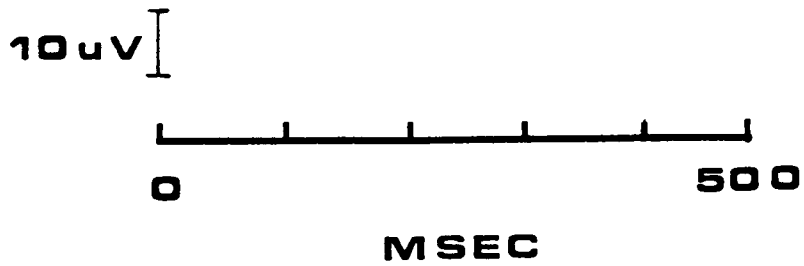
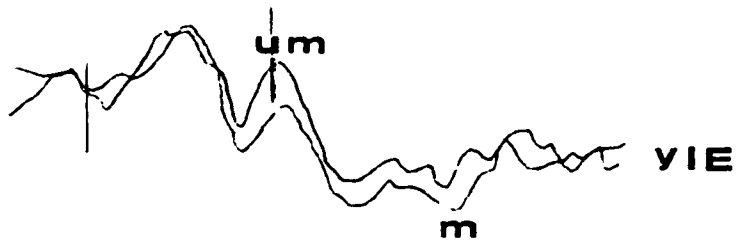
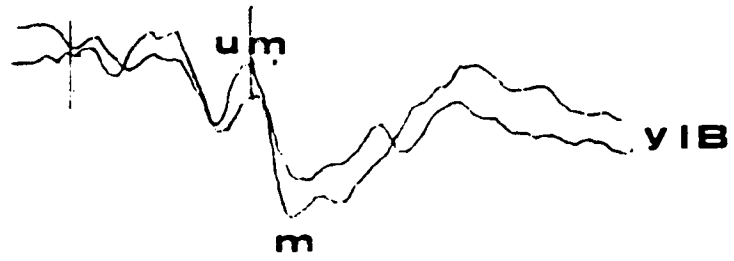
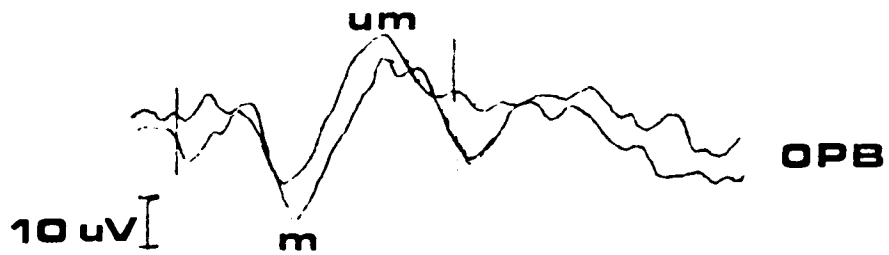
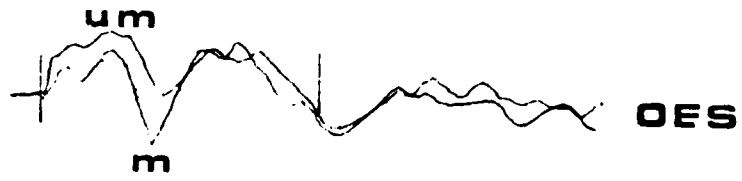
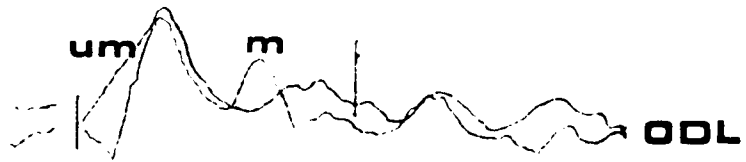


Figure 10. Evoked responses from three older subjects in masked condition (2) and unmasked condition (3) superimposed for each subject. Vertical lines indicate stimulus onset. Negativity is downward.
m = masked, um = unmasked.

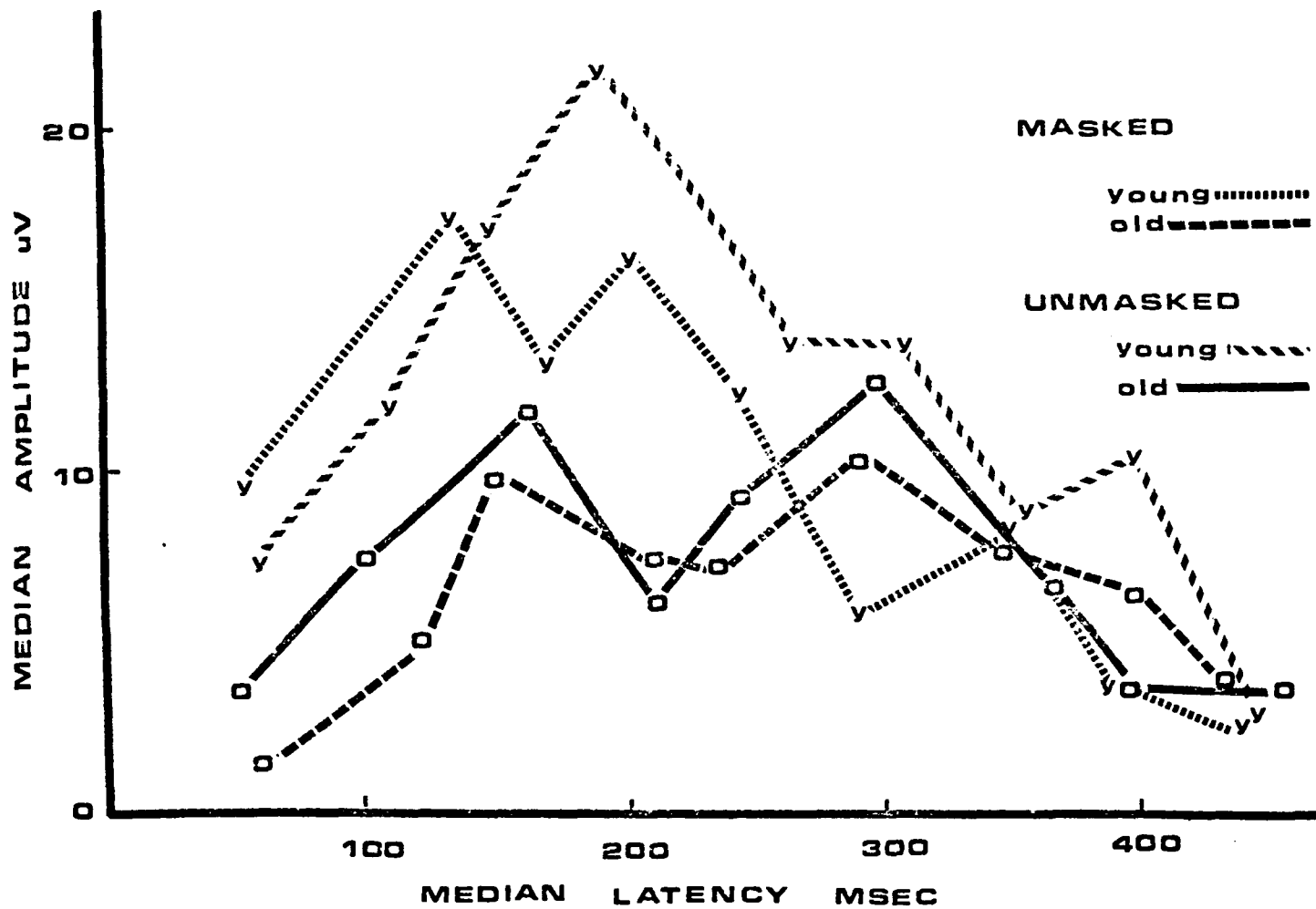


10 μ V



MSEC

Figure 11. Median amplitude and latency of P-N components of evoked potentials for young and old subject groups in masked and unmasked conditions.



although only one stimulus was perceived, there was a separate neural response to each of the two stimuli, and that the latencies of these responses were longer for the old than for the young; by 15 msec to the first, by 100 msec to the second. In the unmasked condition (3), the function for the older group retained the two prominent peaks with a mean increase in latency of approximately 20 msec to the first stimulus and about 5 msec to the second accompanied by an increase of about 3.6 uV in amplitude. The point of highest amplitude occurred at 55 msec after mask onset. In contrast, the function for the younger group exhibited only one high amplitude peak occurring 45 msec after onset of mask with an increase of 6.6 uV in amplitude over the high point in condition (2). Thus the neural response occurred at 195 msec after onset of TS with apparently no separate response to the mask. It is possible that PM3 in this case, as for some subjects in Experiment I, was eliciting a neural response similar to what would be expected from a random noise pattern or from a homogeneous flash of light.

MacKay (1968) studied evoked potentials in response to monocular and dichoptic masking using random visual noise and blank fields as stimuli. Perceptually, the noise field could be blanked (masked) by the blank field in the monocular condition up to an interstimulus interval of 10 to 20 msec depending on the relative brightness of the two stimuli. Dichoptically, however, the blank field was suppressed by the noise field "over several tens of msec and several log units". Using bipolar horizontal electrode placement to the left of the midline, MacKay found

the evoked response to dichoptic stimulation markedly resembled the random noise trace recorded monocularly. There was no evidence of the presence of the blank flash. The response to the blank flash, when recorded singly had a strikingly different morphology. In this case, the perceptual and evoked responses were found to coincide. MacKay suggested that whatever "switching" mechanisms are responsible for the observed suppression, their loci must be more peripheral than those of the pattern specific component of the evoked potential, and further, that the neural mechanisms which result in the evoked responses to blank and to patterned stimuli are independent.

The binocular pilot conditions obtained in the present study (Appendix I) support this view of independent mechanisms governing the electrophysiological responses to blank and to patterned stimuli. Binocular evoked responses to single blank flashes showed essentially the same morphology as the monocular responses to blanks presented by MacKay. As the interstimulus interval was lengthened the one prominent peak became two, a result which concurs with other research (Wicke, Donchin, & Lindsley, 1964). The addition of pattern, however, in the binocular condition did not change the shape of the waveform, it merely increased amplitudes and latencies of prominent peaks, a result which can be interpreted as showing both central and peripheral involvement (Diamond, 1964). Thus the "independent" mechanisms suggested by MacKay could be peripheral and central components of the visual system as discussed by Turvey (1973).

The relationship between perceptual judgement and electrophysiological response is not yet clearly established. Schiller and Chorover (1966) reported no changes in visual evoked potentials accompanying brightness reduction in metacontrast. They concluded that the evoked potential was not always correlated with alterations in subjective brightness. Vaughn and Silverstein (1968) found attenuation of evoked potential amplitude accompanying brightness reduction when stimuli were presented foveally but not with parafoveal stimulation. They attributed the results of Schiller and Chorover to stray light impinging on the retina resulting from parafoveal stimulation. The attenuation reported by Vaughn and Silverstein occurred about 200 msec after presentation of the initial stimulus.

Lehman and Fender (1967) found visual evoked responses were reduced in amplitude if a flashing target was structured (dots, cross, or grid) instead of uniformly illuminated and that the evoked potential amplitude was decreased if the other eye viewed a steadily illuminated rather than a dark field. The observed effects were attributed to increased complexity of the display absorbing more cortical capacity; leaving less to participate in the evoked response.

Changes in the visual evoked response to backward masking of letters by letters, grids of dots by each other and by letters, and letters by grids, using equal energy stimuli were studied by Andreassi, De Simone, and Mellers (1976). Figure 12 reproduces traces from three conditions of their experiment. In conditions B and C backward masking occurred in perceptual reports; the evoked response in the 200 msec range was attenuated. No perceptual masking occurred in Condition A. Note the

Figure 12. Evoked responses from Andreassi et al. (1976). In condition A perceptual masking did not occur. In conditions B and C backward perceptual masking did occur.

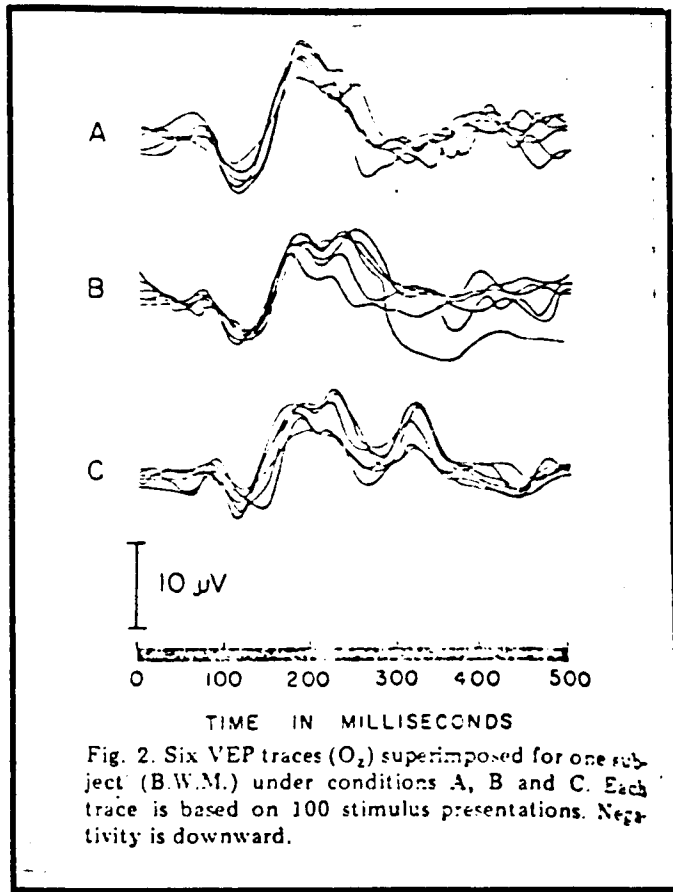


Fig. 2. Six VEP traces (O₂) superimposed for one subject (B.W.M.) under conditions A, B and C. Each trace is based on 100 stimulus presentations. Negativity is downward.

similarity in latency, waveshape, and amplitude reduction particularly in functions for the young group shown in Figure 11 representing the masked and unmasked conditions of Experiment II in the present study. Andreassi et al. also found that backward masking occurred with like stimuli accompanied by significant decreases in amplitude of the evoked potential. Conversely, backward masking did not occur with unlike stimuli nor did a decrease in evoked potential amplitude. In a previous study, (Andreassi et al., 1971) found that presentation of equal intensity stimuli presented sequentially resulted in masking but no evoked potential changes occurred. They attributed this to the possibility that brain areas other than the visual cortex were involved in the masking effect. Such an interpretation is consistent with Turvey's (1973) discussion of central and peripheral factors, in which "central" may well refer to processing areas beyond the striate cortex.

Figures 13 and 14 represent median amplitude as a function of evoked potential component in conditions (2) and (3) respectively. The components were derived from the most positive and the most negative values within each 100 msec of the waveform. All four functions were predominantly negative. The only positive point in condition (2) occurred in the younger group in the 200- 300 msec range. The function for the older group showed increasing positivity through the 300-400 msec range. Fender and Santoro (1977) describe computerized analysis and display techniques used to identify the origins of visually evoked scalp potentials. Contour mapping algorithms display the time behavior of equipotential scalp surfaces during visual stimulation. Using a vertex reference, traces from

Figure 13. Median amplitude as a function of evoked potential components. Each N-P peak represents the mean of the most negative and the most positive values of ten subjects within each 100 msec time segment in the masked condition (2).

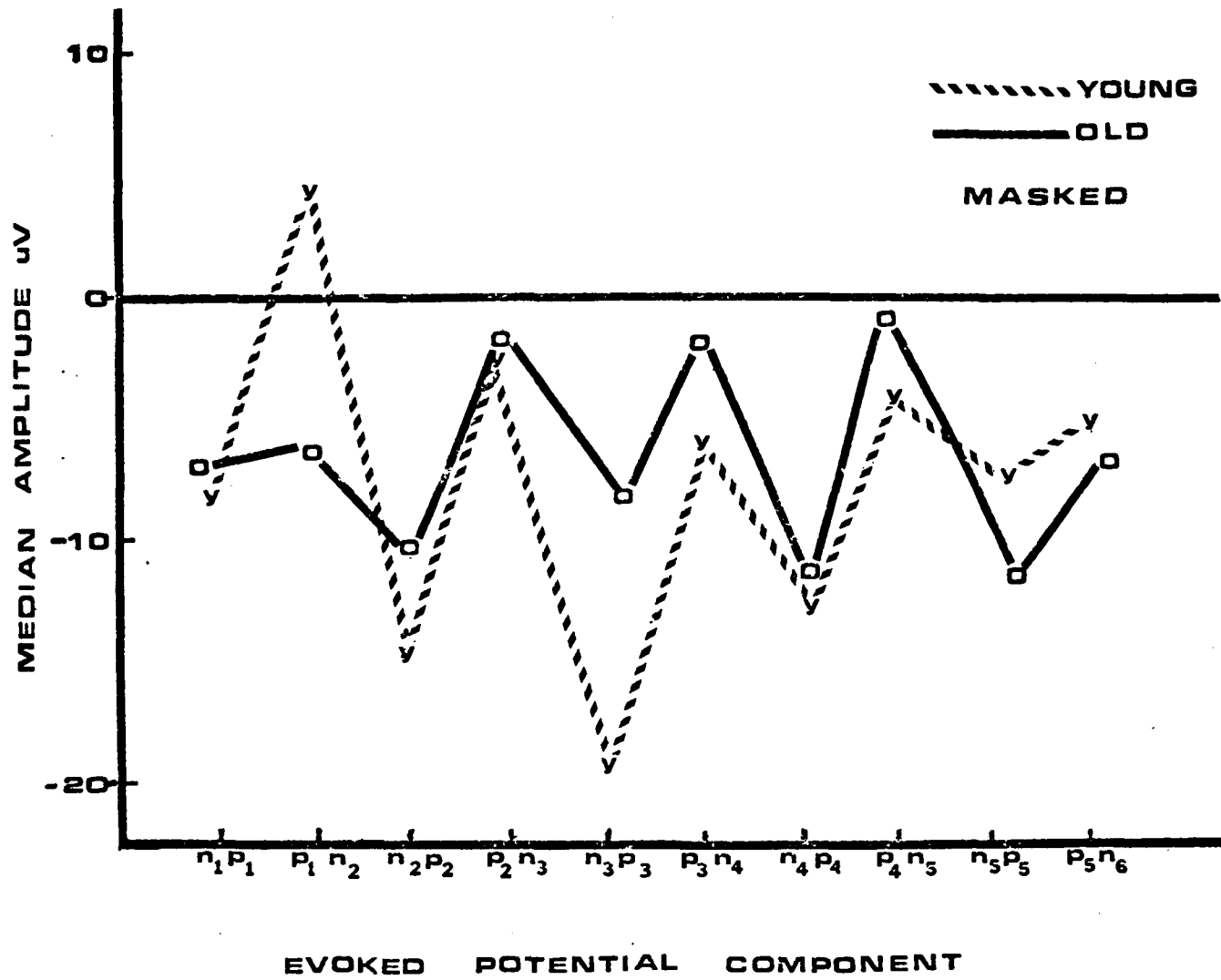
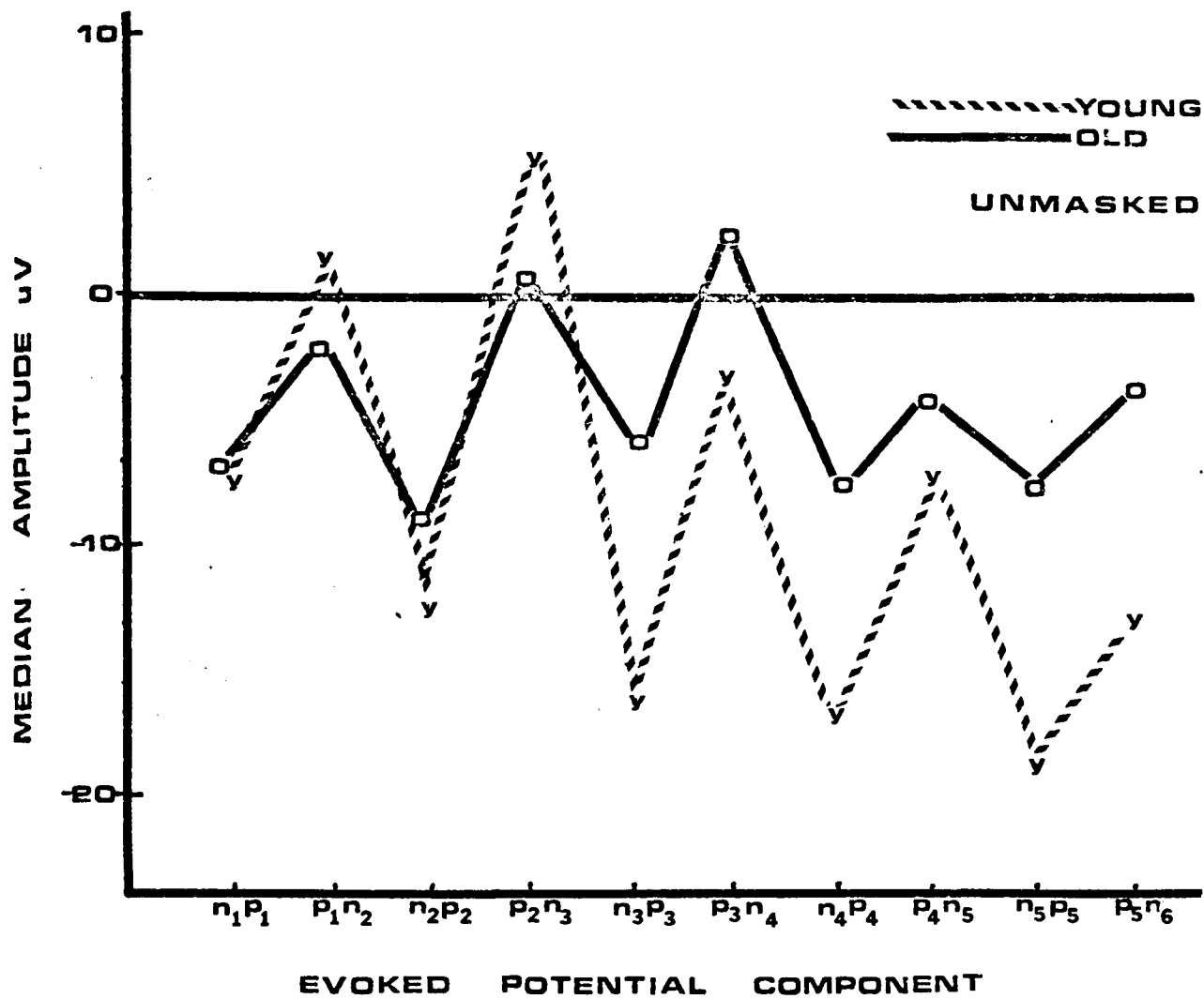


Figure 14. Median amplitude as a function of evoked potential components. Each N-P peak represents the mean of the most positive and the most negative values of ten subjects within 100 msec time segments in the unmasked condition (3).



42 scalp locations were shown. The distribution of scalp potentials 120 msec after a flash event shows two large negative areas over the occipital regions with a positive crest at the midline. At 170 msec the right hemisphere became increasingly positive, while the left hemisphere became more negative. At 180 msec, electrical activity was increasingly influenced by other factors (concurrent auditory stimuli, etc.)

A similar map (Rémond, 1965) shows activity from the occipital area in response to binocularly viewed flashes to be primarily negative to approximately 80 msec, positive until about 200 msec, with smaller areas of negativity occurring at about 200 and 260 msec. After 285 msec the area became almost completely negative.

When comparison of waveforms is difficult because of variability in amplitude components or variability in their latencies, it has been suggested (Perry & Childers, 1969) that summation of the waveforms is a preferable method of analysis. The summated waveforms are divided into time segments which are then analyzed using traditional statistical techniques.

Table 7 shows results of analysis of variance on subject groups x conditions (masked, unmasked) x time segments (50-225 msec, 225-450 msec). The individual data point values in the two segments were summed. All statistical computations in Experiment II were performed on the digitalized data from the computer print-out on only the left hemisphere responses.

Significant differences in summated evoked potential amplitude were found between the old and the young groups ($F = 11.77$, $df, 1, 18$, $p < .01$),

Table 7

Analysis of Variance Summary Table			
Source	df	MS	F
Age Groups	1	1212.90	11.77 p<.01
Conditions (masked, unmasked)	1	176.13	5.25 p<.05
Time Segments (50-225, 225-450 msec)	1	683.86	6.51 p<.05
Age Groups x Conditions	1	169.95	5.06 p<.05
Age Groups x Time Segments	1	1723.29	16.42 p<.001
Conditions x Time Segments	1	343.20	8.70 p<.01
Age Groups x Conditions x Time Segments	1	2.14	
Subjects/Age Groups	18	103.07	
Conditions x S/Groups	18	33.52	
Time Segments x S/Groups	18	164.97	
Conditions x Time Segments x S/Groups	18	39.43	
	<hr/>		
	79		

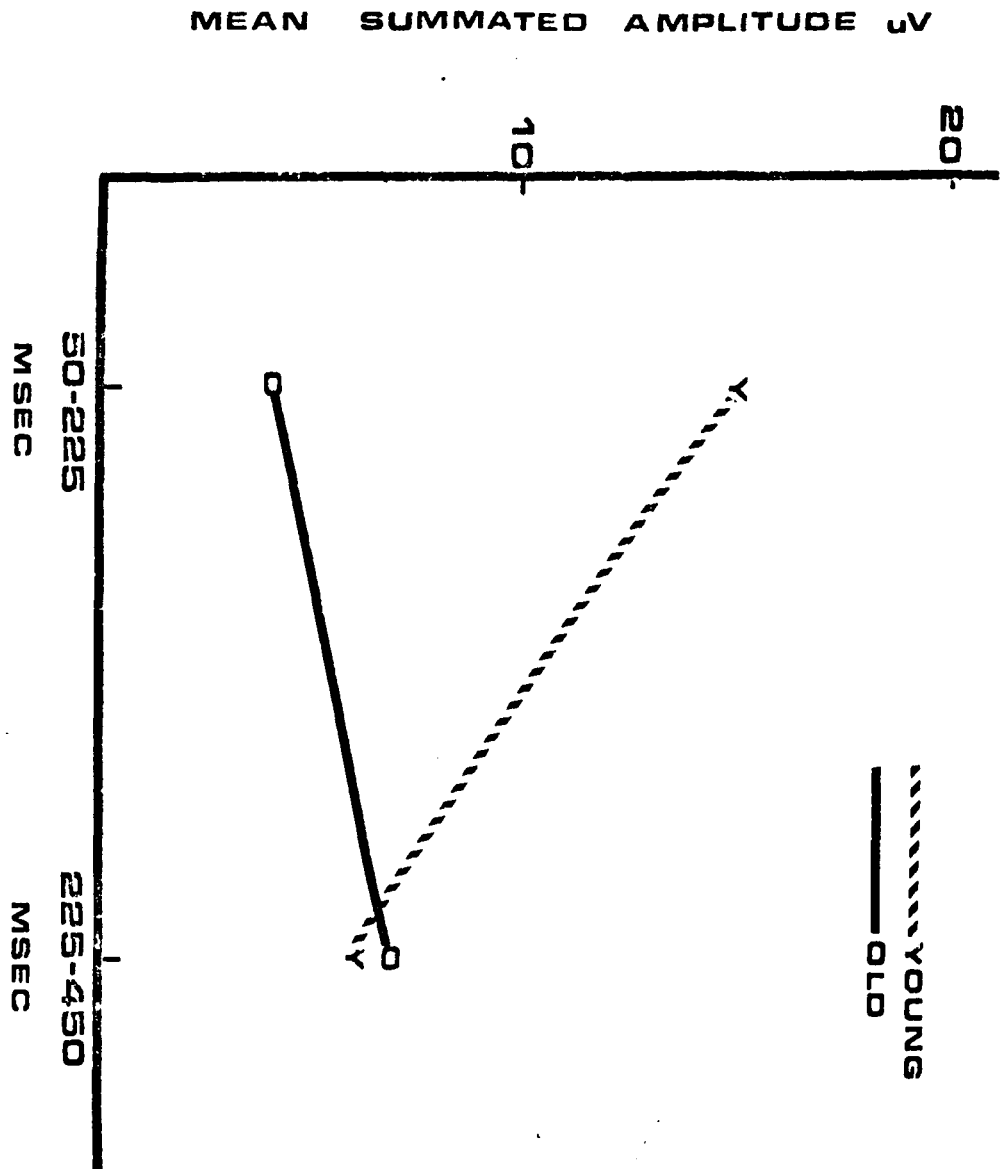
between summated amplitude in the masked and unmasked conditions ($F = 5.25$, $df, 1, 18$, $p < .05$), and in the interaction between conditions and subject groups within conditions ($F = 5.06$, $df, 1, 18$, $p < .05$). Differences in amplitudes in the time segments also proved to be significant ($F = 6.51$, $df, 1, 18$, $p < .05$) as was the interaction between subject groups and time segments ($F = 16.42$, $df, 1, 18$, $p < .001$). Finally, the interaction between conditions and time segments also showed significance ($F = 8.70$, $df, 1, 18$, $p < .01$).

The age difference observed in Experiment I ($p < .001$) was maintained in the group difference in summated amplitude of evoked response ($p < .01$) in Experiment II. Additionally, the highly significant subject groups x time segments interaction ($p < .001$) and the interaction of groups x conditions ($p < .05$) seen in Table 7 indicates latency differences to peak amplitudes between the young and the old.

A decrease in cumulative amplitude of evoked response from the elderly particularly in the 200-300 msec range has been reported previously by Schenkenberg (1970), Straumanis, Shagass, and Schwartz (1965), and by Dustman and Beck (1969). Shagass has also found the response to the second of a stimulus pair to be smaller than the first. Shipley and Hyson (1977) have reported increasing amplitude attenuation in response to an increasing number of sequentially presented stimuli. A pair of flashing lights was increased to three, four, etc. up to ten, resulting in a continuous decrease in overall amplitude of the waveforms.

Figure 15 shows the mean summated amplitude as a function of time segments for young and old groups averaged over both conditions. It is

Figure 15. The mean summated amplitude as a function of time segments 50-225 msec and 225-450 msec for both young and old groups averaged over masked and unmasked conditions.



clear that the greatest amplitude occurred for the young people in the first half of the average and decreased sharply in the second segment. In contrast the older group showed an increase in amplitude in the second half of the total waveform.

Figure 16 represents the mean summated amplitude as a function of time segments for the masked and unmasked conditions with data from subject groups pooled. A much greater difference in amplitude from first to second half of the waveform is seen in the masked condition. However, amplitude in the unmasked condition, contrary to expectation, also showed a decrease in the later segments.

Figure 17 shows the subject groups x conditions x time segments interaction.

The age difference in Experiment I was in the critical interstimulus interval necessary to escape the masking effect. If masking in this case can be assumed to be of central origin, it is tempting to ascribe the evoked potential differences to slower central nervous system processing in the elderly; but this is not necessarily the case. In Turvey's concurrent-contingent model, central processing is dependent (contingent) upon input from the periphery. If this input is delayed because of structural limitations in the aging visual system, central processing will begin at a later time in older subjects than in younger ones viewing equivalent stimuli. Therefore longer latencies to peak amplitudes could or could not indicate slower central mediation.

It is well known that opacities in the vitreous body reduce the amount of light reaching the receptors of older subjects (Weale, 1963). Trans-

Figure 16. The mean summated amplitude as a function of time segments 50-225 msec and 225-450 msec for masked and unmasked conditions averaged over subjects.

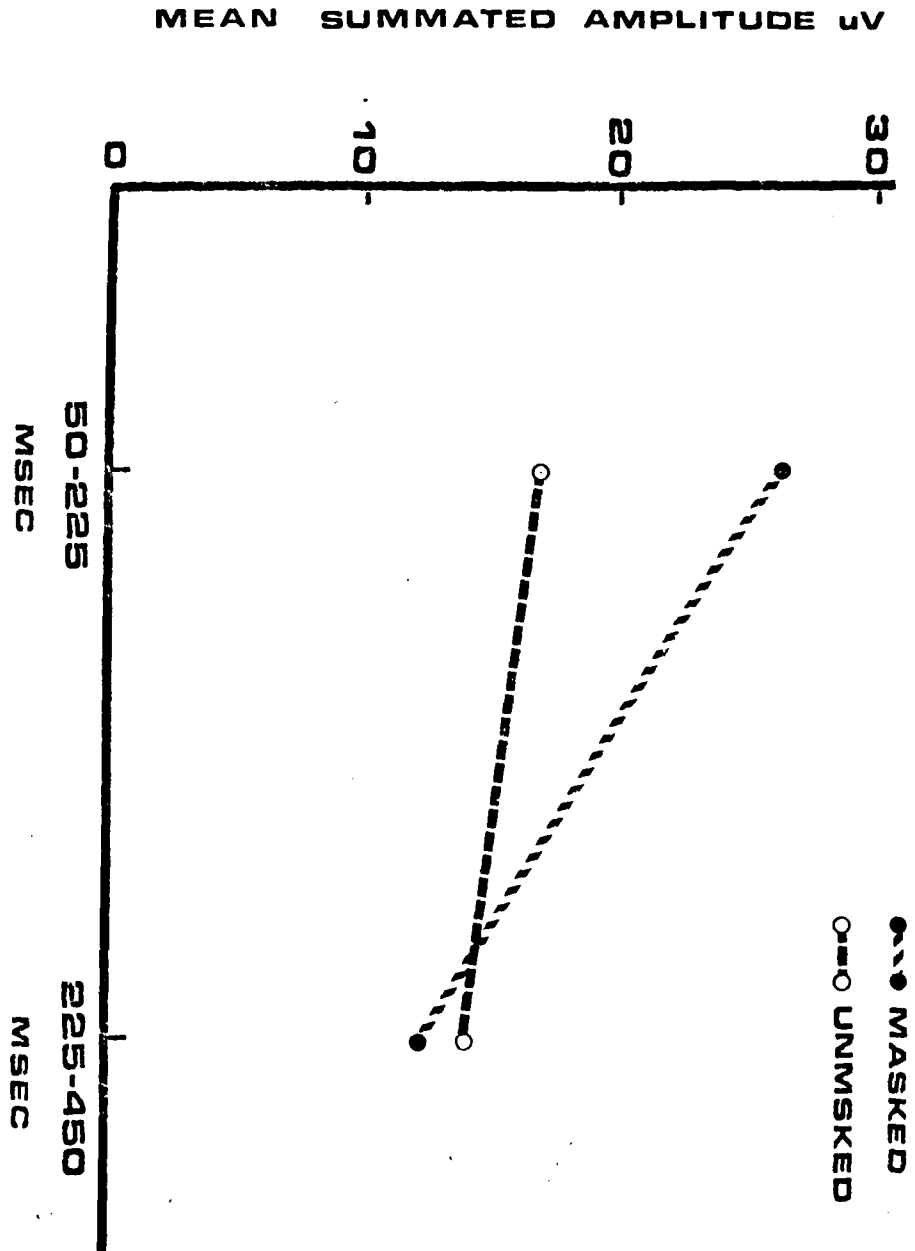
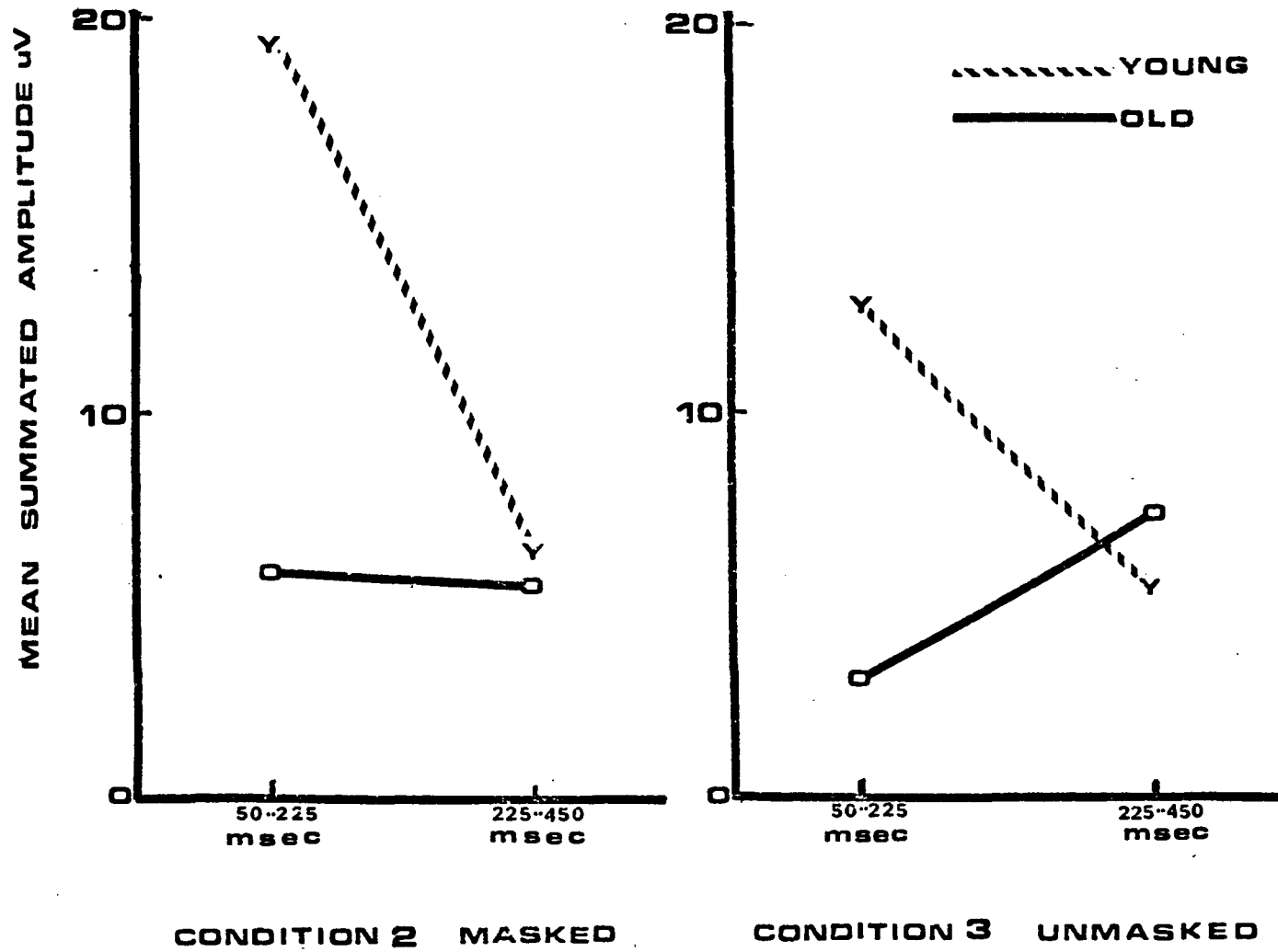


Figure 17. Subject groups x Conditions x Time Segments interaction.



parency of the lens is diminished by accumulation of inert tissue (Leopold 1965), and water loss leads to shrunken fibers. These changes interfere with the transmission and refraction of light, raising the absolute threshold for vision. Said and Weale (1959) showed that with increasing age the lens becomes more opaque particularly with relation to short wavelengths. The ultra violet tubes used in this experiment to maintain ionization of the fluorescent lamps added a slight lavender tinge to the stimulus light. Birren, Casperson, and Botwinick (1958), using a white light source, found that only one third of the light reaching the retina of a twenty year old subject would arrive at the retina of a person aged sixty. Erikson, Hamlin, and Brietmeyer (1970) measured the time required to identify a target (a gap in a Landolt ring). With constant illumination and target size, and with the use of artificial pupils, a group of subjects 50-55 years of age took 200 msec to achieve the same level of performance as subjects 30-35 years of age reached in 20 msec. Similar results were reported by Abel (1972) and Reading (1972). These researchers explain their results at least partially, in terms of the amount of light reaching the retina. In a second experiment, Erikson et al. (1970) adjusted the time and intensity values so that the total energy of each combination of presentation time and stimulus intensity was held constant. The time intensity reciprocity relationship broke down at about 146 msec in all age groups but the slope of the decay function for the oldest group was less than for the young. The authors suggested that the older people could trade time for intensity for longer periods than the young people.

Turvey's conceptualization of the visual system and his development

of the concurrent-contingent model provide a framework in which apparently discrepant findings in both psychophysical and physiological areas can be re-examined from a different perspective and perhaps be found not so discrepant after all. The data of Kinsbourne and Warrington (1962 a, b) described by the authors as indicative of a "central" interaction being the basis of all masking phenomena, became the departure point for Turvey's subsequent re-definition of "peripheral" processes which allow the transmission of information through a series of recodings from receptor to cortex and include the cells of the striate cortex which respond to stimulus intensity. Turvey's experiments give ample evidence that masking observed monoptically and dichoptically is not necessarily attributable to the same process. In short, the peripheral system is energy dependent; the central system is time and content dependent. If MS energy is greater than TS energy, the mask will overtake the target in monocular or binocular presentation, interact with it in the peripheral system, and deposit one stimulus different from either of the original two in central stores. This type of interaction has typically been described by the "integration" theory of visual masking. If MS and TS are of equal energy, masking can only occur if the time interval between onsets of the two stimuli (SOA) is short enough for the second arriving stimulus to interrupt the processing of the first and if its geometric content can replace or sufficiently degrade the content of the first so that it will not be perceived. Walsh's (1976) re-analysis of the Kline and Szafran (1976) data on age differences in "central" processing pointed out the same misunderstanding evidenced by Kinsbourne and Warrington. What were reported as age differences in central processing were, by

Turvey's definition and criteria, a peripheral effect. The Welsandt et al. (1973) investigation of age differences in iconic processing similarly confounded the energy, time, and content variables.

Results of experiment I of the present study support the concurrent-contingent model in that:

- (1) Masking was obtained with equal energy TS and MS.
- (2) The different pattern masks resulted in different amounts of masking in the same subjects.
- (3) The data conform, although with wide confidence intervals, to the rule $TD + ISI_c = K$ or SOA, suggested by Turvey to indicate masking of central origin.

Experiment II was undertaken for the purpose of obtaining visual evoked potential correlates of perceptual masking obtained in Experiment I.

Results showed:

- (1) Significant age differences ($p < .01$) were obtained in the summated amplitude measure.
- (2) Perceptual masking was accompanied in both groups by amplitude attenuation from 130 msec to 450 msec in the younger group, and from the onset of TS to 350 msec in the older group. Similar attenuation of evoked potential amplitude has been reported by Vaughn and Silverstein (1968) whose results were obtained during metacontrast suppression with no spatial overlap of TS and MS, and by Andreassi et al. (1976) using stimuli with partial overlap. In the present study the mask occupied the same spatial area as the target. Since stimulus presentation was dichoptic, and the psychophysical results conform to a central formulation as defined by Turvey, an explanation

of masking in terms of an "interruption" hypothesis is applicable to the data. The arrival of the second stimulus interfered with the processing of the first resulting in an attenuation of evoked potential amplitude. Andreassi et al. (1976) using sequential stimuli with some spatial overlap, explain the effect at least partially, in terms of the activity of excitatory fields produced in the visual cortex by the arrival of early stimuli being diminished by inhibitory action produced by later arriving stimuli. This of course is a neural concomitant of the "interruption" hypothesis of perceptual masking. Apparently, recording with scalp electrodes is too gross a measure to assess the affects of spatial overlap or non-overlap of sequentially presented stimuli since the evoked potential results of the present study concur with those of both Vaughn and Silverstein (1968) and Andreassi et al. (1976) who used complete or partial overlap of TS and MS.

(3) At ISI s too long to produce perceptual masking, evoked potential amplitude was not attenuated. The averaged waveforms for the older group retained the two prominent peaks of high amplitude observed in the masked condition. The ISI for the group was 250 msec, apparently long enough to eliminate any interaction of excitatory and inhibitory fields generated by the two stimuli. In contrast, only one peak of high amplitude (positive at about 200 msec) occurred in the younger group. Although no perceptual masking occurred with an ISI of 150 msec, it appears that any inhibitory cortical activity caused by the pattern mask at that interval was not strong enough to interfere with excitatory activity produced by the target stimulus.

Evoked potential correlates of masking studies in which MS energy greatly exceeds that of TS energy, (exemplified by Wicke, Donchin, & Lindsley, 1964) conform to an "integration" theory of masking. At brief ISIs there appears to be only one neural response to the combined stimuli. As the interval is lengthened, a separate response to each stimulus is clearly observed in the waveform. Results of pilot work (Appendix I) in the present study in which MS was of greater energy than TS, support this interpretation. The same kinds of criteria, therefore, appear to affect both psychophysical and evoked potential results: energy characteristics of TS and MS (peripheral interaction in Turvey's terminology), and SOA, or time differences between onsets of the two stimuli, and geometric content of TS and MS, corresponding to central interactions as defined by Turvey.

Appendix I

Appendix I

Appendix I represents pilot control data on evoked responses to binocular viewing of single flashes of light, double flashes of light at ISIs of 50 and 200 msec, and double flashes with the letters TYU as TS and PM3 as MS at ISIs of 50 and 200 msec.

Method

Subjects

Sixteen Hunter College graduate and undergraduate students, 4 males 12 females (mean age 25.1 years, range 19 to 38 years) served as subjects. All were unpaid volunteers. All had 20/20 vision as measured by a Snellen chart with or without corrective lenses.

Apparatus and Stimulus Materials

The apparatus was the same as that described in the General Method section, except that the stimulus changer was not used. Informational stimuli consisted of the black letters TYU 1.25 cm tall subtending .8 degrees of visual angle vertically by .8 degrees horizontally. The thickness of the letter strokes subtended .13 degrees and the separation between the letters was approximately .13 degrees. A pattern mask (PM3) shown in Figure 2 was constructed from identical letters cut in 2 mm segments, subtending .13 degrees of visual angle, placed at random orientations on clear glass. The entire mask subtended .95 degrees of visual angle vertically by 2.1 degrees horizontally.

Procedure

Tektronix EKG electrodes were attached at the active position 2.5

cm above the inion and 2.5 cm to the left of the midline for left hemisphere recording and in the same position to the right of the midline for right hemisphere recording. Both were referenced at vertex with Beckman silver/silver chloride disk electrodes and grounded to ipsilateral mastoid bones. Subjects were instructed to fixate on a red fixation cross in the center of the stimulus aperture, always visible at a luminance of less than .1 mL. All stimulus viewing was binocular. Seven stimulus conditions followed 10 minutes of dark adaptation.

(1) Noise control averages (basic EEG) were taken on all subjects in which stimuli were presented but viewing was blocked with black masking tape placed over the artificial pupils in the tachistoscope eye piece. A 40 watt overhead lamp remained on in the booth. Subjects were instructed to remain physically motionless and to silently count backwards by sevens from 500 to -3.

(2) A single flash of 10 msec duration presented at a luminance of 4.3 mL as measured with a MacBeth Illuminometer through the artificial pupils and focusing prisms occurred at intervals of 1600 msec.

(3) A series of paired flashes was presented; the first (TS) at a luminance of 4.3 mL and a duration of 10 msec, the second (MS), after an ISI of 50 msec at a luminance of 38 mL and with a duration of 20 msec. The intertrial interval in all conditions was 1600 msec.

(4) Condition (3) was repeated with the ISI increased to 200 msec.

(5) The letters TYU were presented as TS and PM3 as MS after an ISI

of 50 msec. Durations and luminances of flashes remained the same as in conditions (2) and (3).

(6) Condition (5) was repeated with the ISI increased to 200 msec.

(7) Conditions (5) and (6) were repeated on the same subjects after an interval of at least two days and up to four weeks.

Results

All individual traces are shown in Figures A through K. An excellent signal to noise ratio was obtained in condition (1) showing that the evoked potentials recorded in conditions (2) through (7) were a result of stimulus presentation with a minimum of contamination from spontaneous brain activity.

The left column of Figure A shows evoked responses to single flashes appearing once every 1600 msec at a luminance of 4.3 mL contained a single positive going component at a latency of approximately 135 msec. At a luminance of 9 mL, Wicke, Donchin and Lindsley (1964) presented single flashes monocularly in a circular stimulus subtending a visual angle of 2 degrees. The flashes were of 10 msec duration produced irregularly by the subject approximately every 2000 msec. The first prominent positive going component appeared at a latency of 110 to 120 msec. As luminance was increased, the latency of this component was found to decrease. Vaughn, Costa, and Gilden (1966) reported visual evoked responses to binocularly presented flashes at several levels of intensity from .5 to 5.5 log mL. Latencies of the first positive peak

ranged from about 75 msec at 5.5 log mL to 140 msec at .5 log mL. The lowest intensity was approximately equivalent to the one used in this study.

The addition of a second flash of greater energy at an interval of 50 msec in condition (3) shortened the latency of the first component by about 35 msec. A second positive going peak appeared at about 215 msec. When the ISI (Figure B) was increased to 200 msec, the first component appeared at a latency midway between that of the single flash and the first component of the double flash with an interval of 50 msec. Donchin, Wicke and Lindsley (1963) studied the masking capabilities of paired blank flashes using a 10 msec test flash with a luminance of .25 mL and a blanking flash with a luminance of 260 mL. Resulting evoked potentials to paired flashes were classified into three groups:

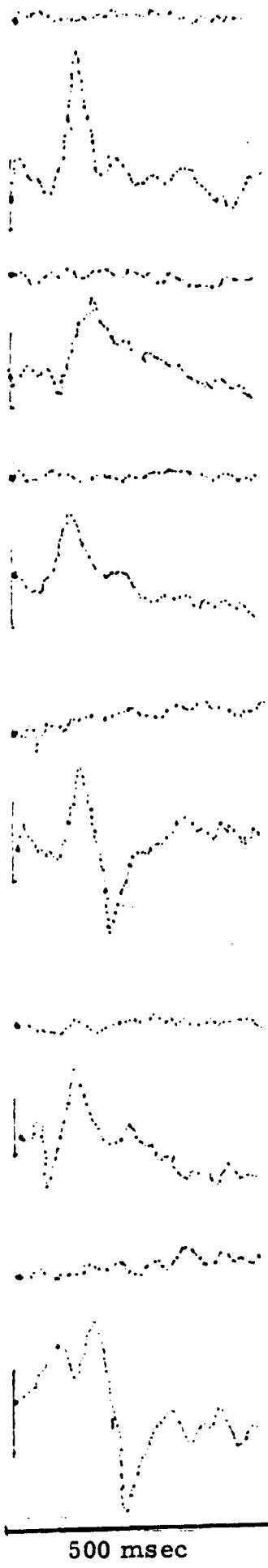
- (1) Those having no perceptual interaction: at ISIs of 200 msec or more, each stimulus was perceived separately and the potentials did not overlap.
- (2) Those showing perceptual interaction: at ISIs of 40 to 100 msec, apparent brightness of the test flash was enhanced by the presentation of the second flash, accompanied by overlapping evoked potentials.
- (3) Perceptual blanking: perception of the first flash was eliminated by the appearance of the second. The waveform suggested displacement of the response to the first flash by that of the second.

The results of condition (4) (Figure B) of the present study, in which the ISI was 200 msec concur with classification (1) above. In condition (3) (Figure A, right), with an ISI of 50 msec, separation also occurred. The differences between these waveforms and the ones described in

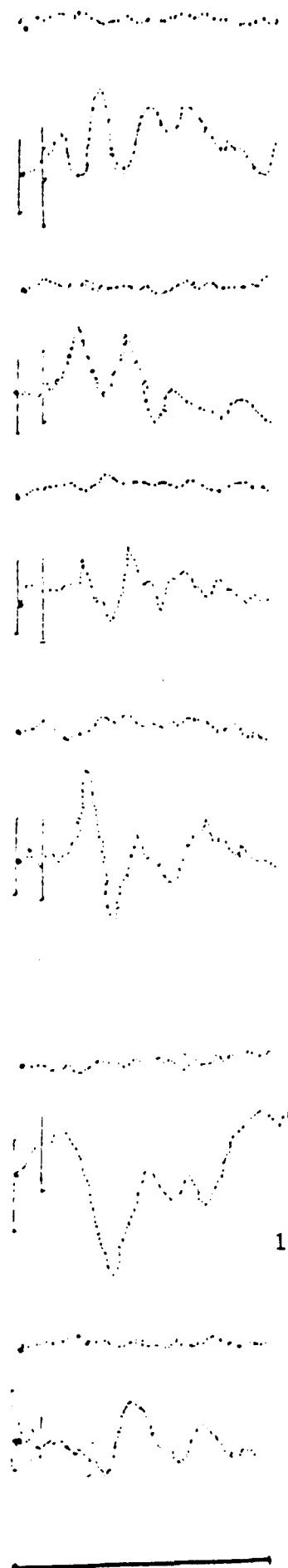
classification (2) above are probably a result of the large differences in luminances used in the two studies. The mask used by Donchin et al. (1963) was more than 100 times as bright as the target flash.

The addition of letters and pattern mask to the blank flashes (conditions (5) and (6), (Figures J and K) altered the evoked potentials in a way which also concurs with reports from Reitveld, Toiridoir, Lubbers, and Spoor (1967) and with Spehlman (1965) in that amplitudes were greater and latencies longer when the flashes contained pattern.

Figure A. The left column shows averaged evoked responses from six subjects to binocular viewing of 10 msec flashes occurring every 1600 msec at a luminance of 4.3 mL. The right column shows averaged responses from six subjects to binocular viewing of paired flashes with a target duration of 10 msec, a mask duration of 20 msec, and an ISI of 50 msec. The target luminance was 4.3 mL, the mask luminance was 38 mL. The small trace above each waveform represents the noise control condition (basic EEG) for that subject. Vertical lines indicate stimulus onset. The calibration marker indicates 10 uV unless otherwise specified. Negativity is downward.



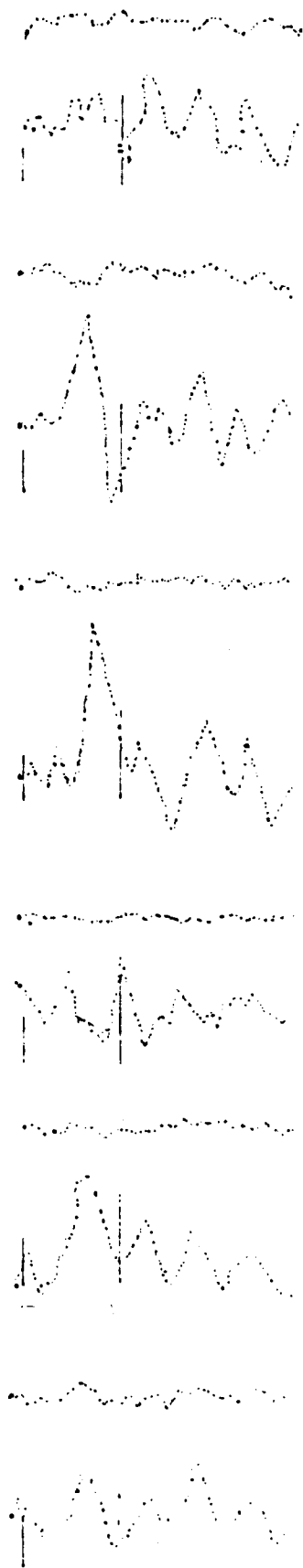
500 msec



500 msec

10 μ V [

Figure B. Averaged evoked responses from six subjects to paired flashes of 10 and 20 msec duration with an ISI of 200 msec. The target luminance was 4.3 mL, the mask luminance was 38 mL. Vertical lines indicate stimulus onset. The calibration marker indicates 10 uV unless otherwise specified. Negativity is downward.



10 μ V $\left[\right.$

500 msec $-103-$

Figure C. Subject D.L. (top left) Left hemisphere responses to conditions (1), (5), and (6). (top right) Right hemisphere responses to conditions (1), (5), and (6). (bottom) Repeat of left hemisphere conditions (top left) seven days later.

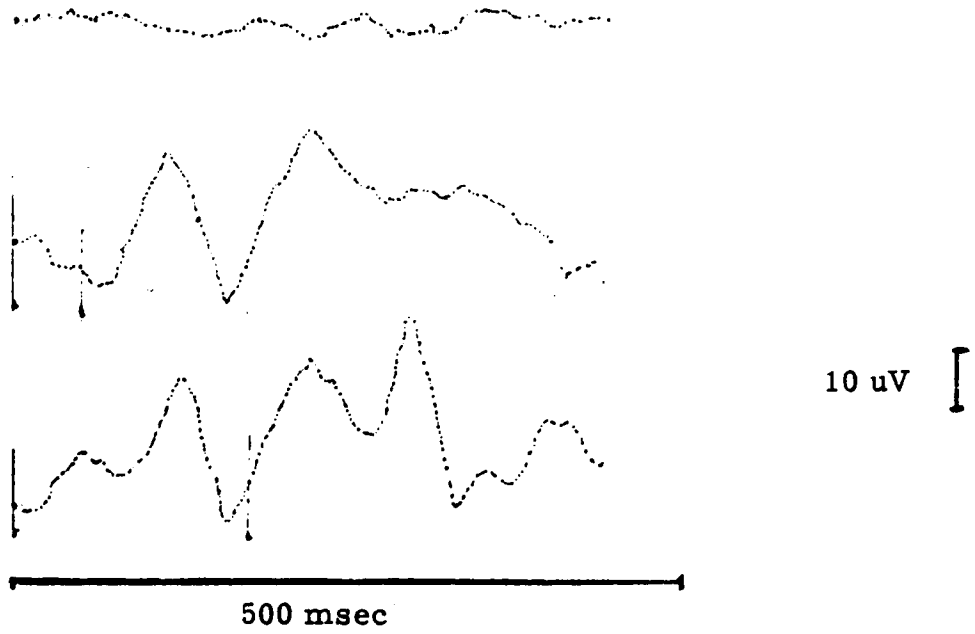
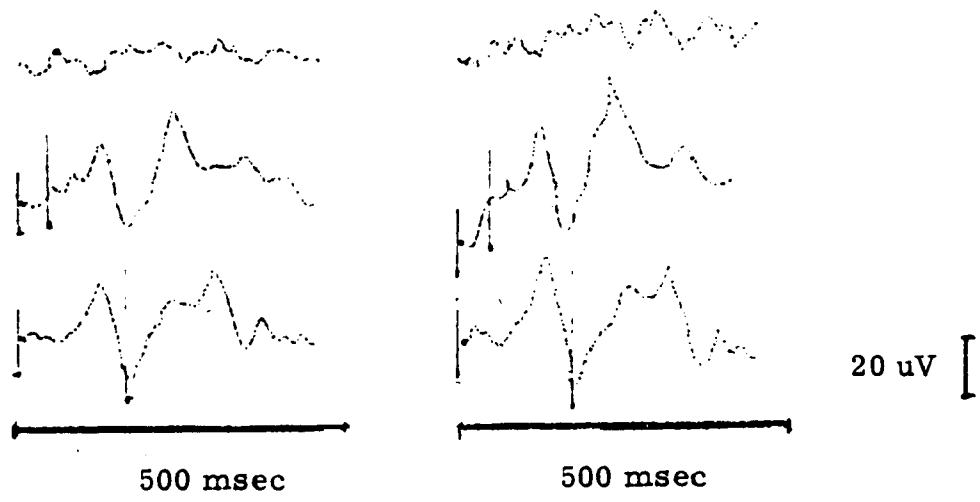


Figure D. Subject J.M. (top left) Left hemisphere responses to conditions (1), (5), and (6). (top right) Right hemisphere responses to conditions (1), (5), and (6). (bottom) Repeat of left hemisphere conditions seven days later.

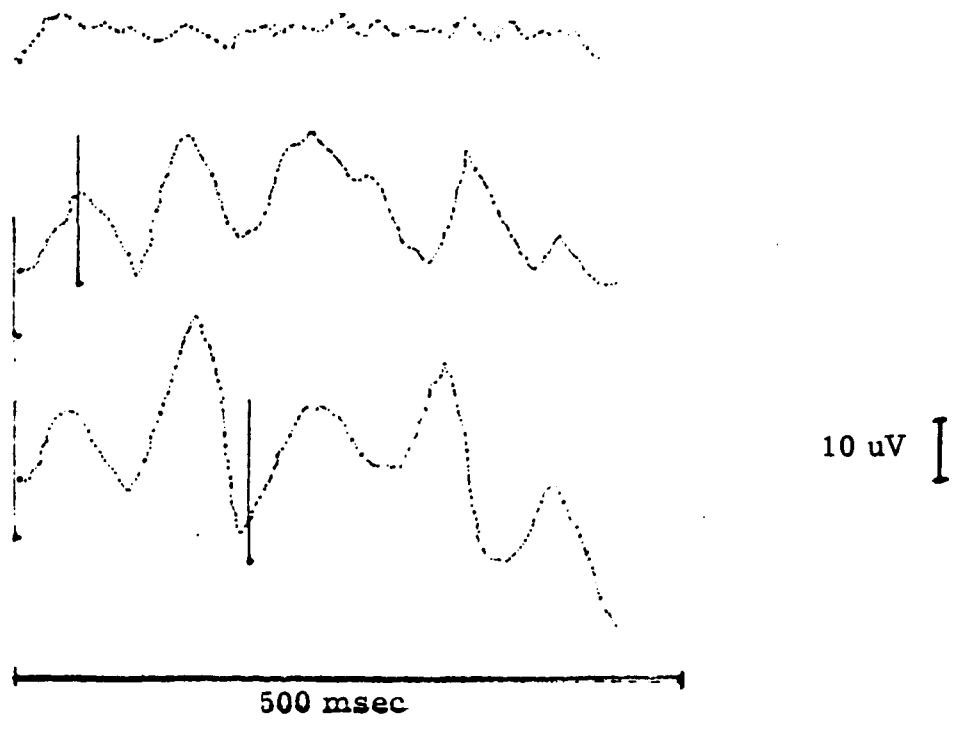
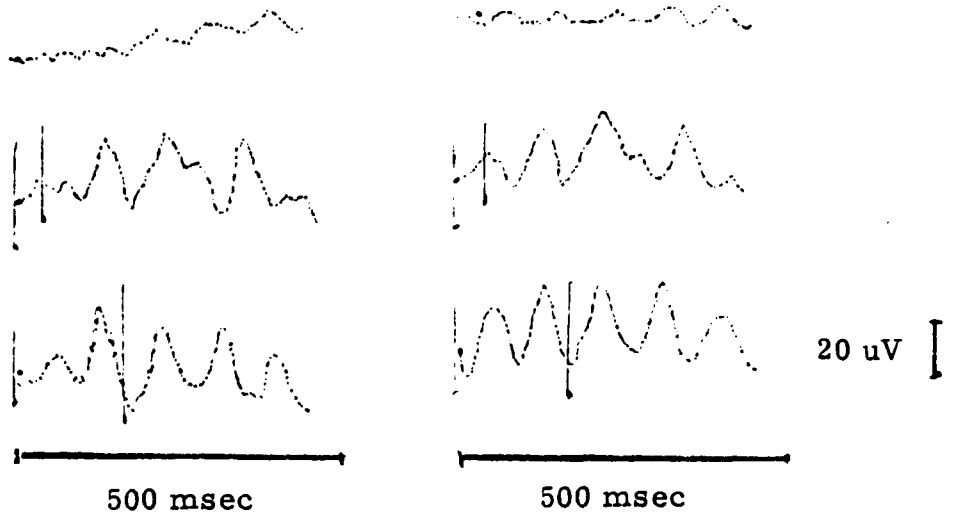


Figure E. Subject M. O'C. (top left) Left hemisphere responses to conditions (1), (5), and (6). (top right) Right hemisphere responses to conditions (1), (5), and (6). (bottom) Repeat of left hemisphere conditions 10 days later.

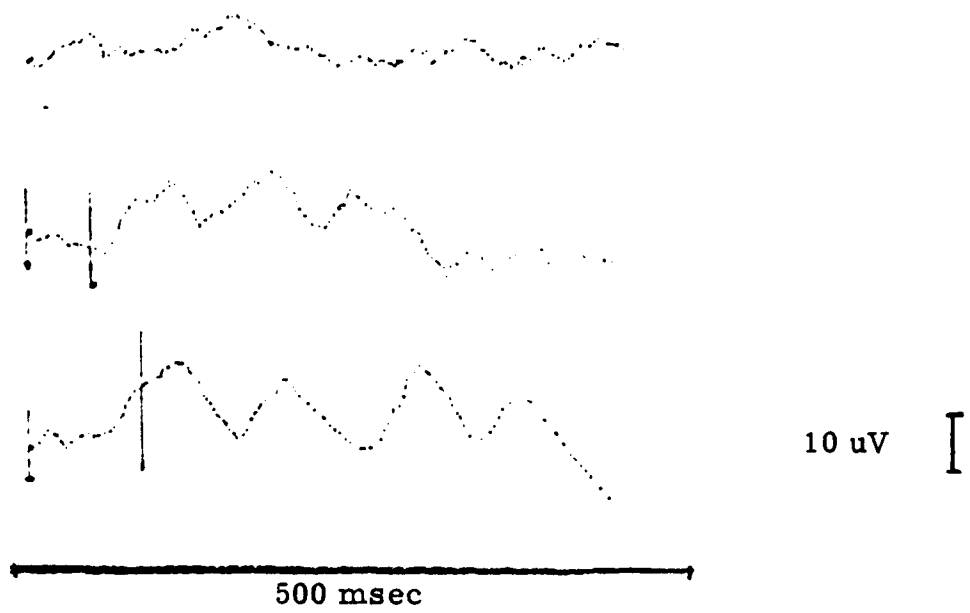
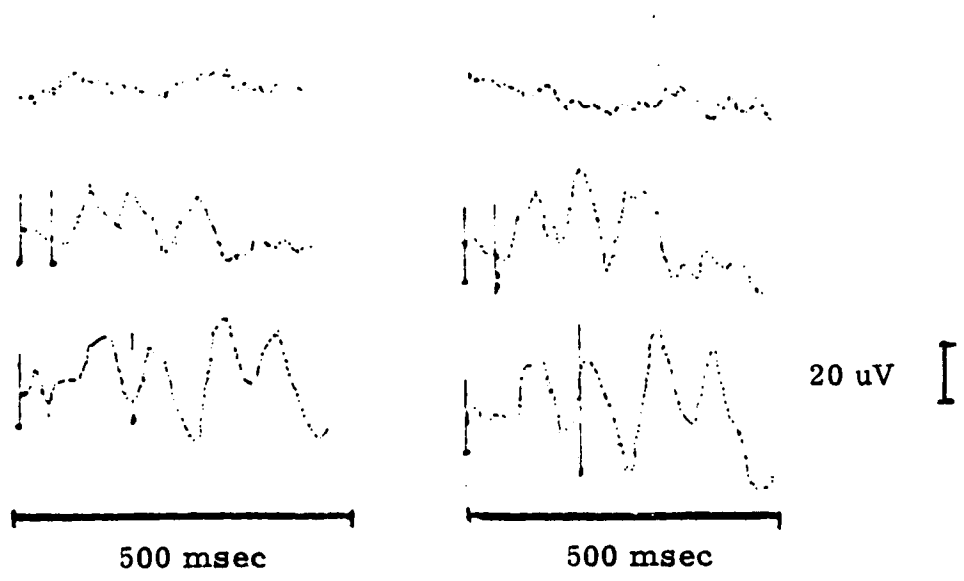


Figure F. Subject P.C.: (top left) Left hemisphere responses to conditions (1), (5), and (6). (top right) Right hemisphere responses to conditions (1), (5), and (6). (bottom) Repeat of left hemisphere conditions seven days later.

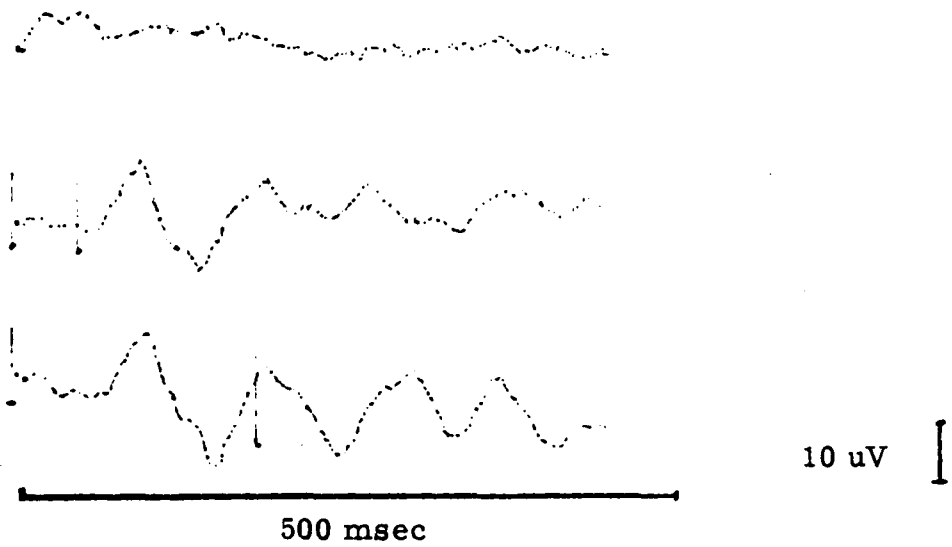
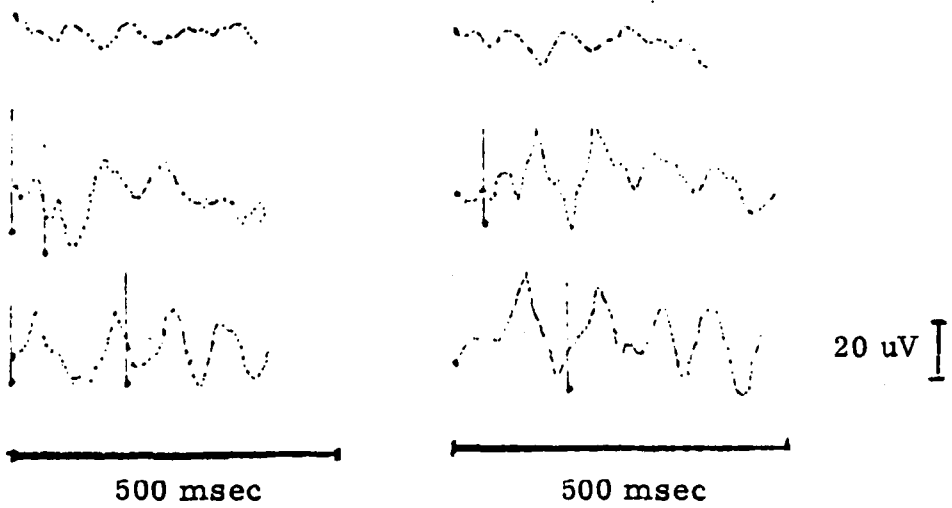
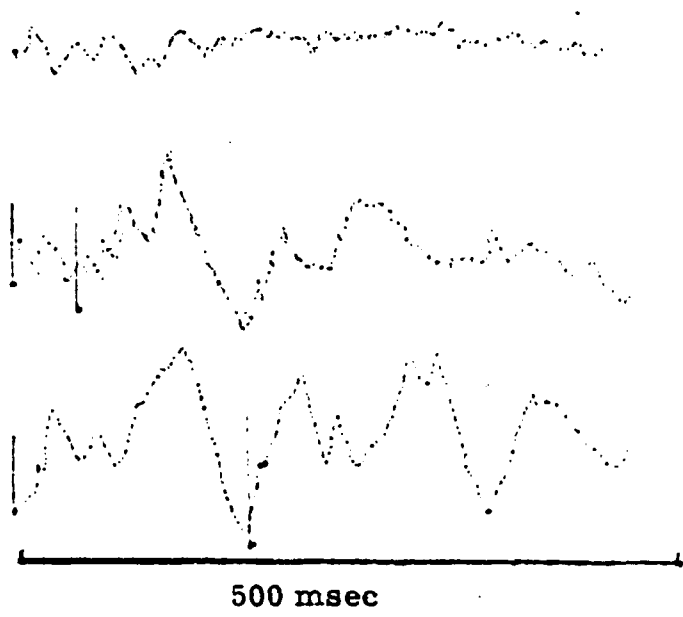
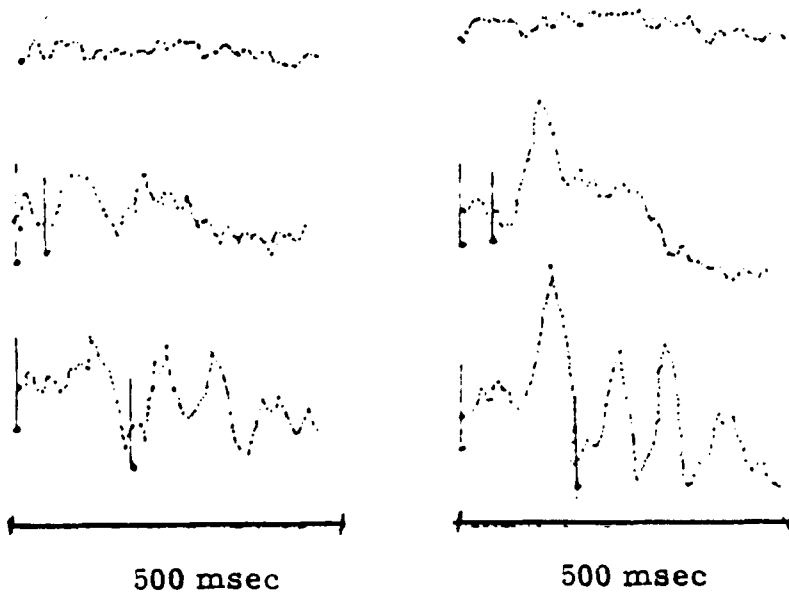


Figure G. Subject G. A. (top left) Left hemisphere responses to conditions (1), (5), and (6). (top right) Right hemisphere responses to conditions (1), (5), and (6). (bottom) Repeat of left hemisphere conditions seven days later.



10 uV [

Figure H. Subject M. B. (top right) Left hemisphere responses to conditions (1), (5), and (6). (top right) Right hemisphere responses to conditions (1), (5), and (6). (bottom) Repeat of left hemisphere conditions five days later.

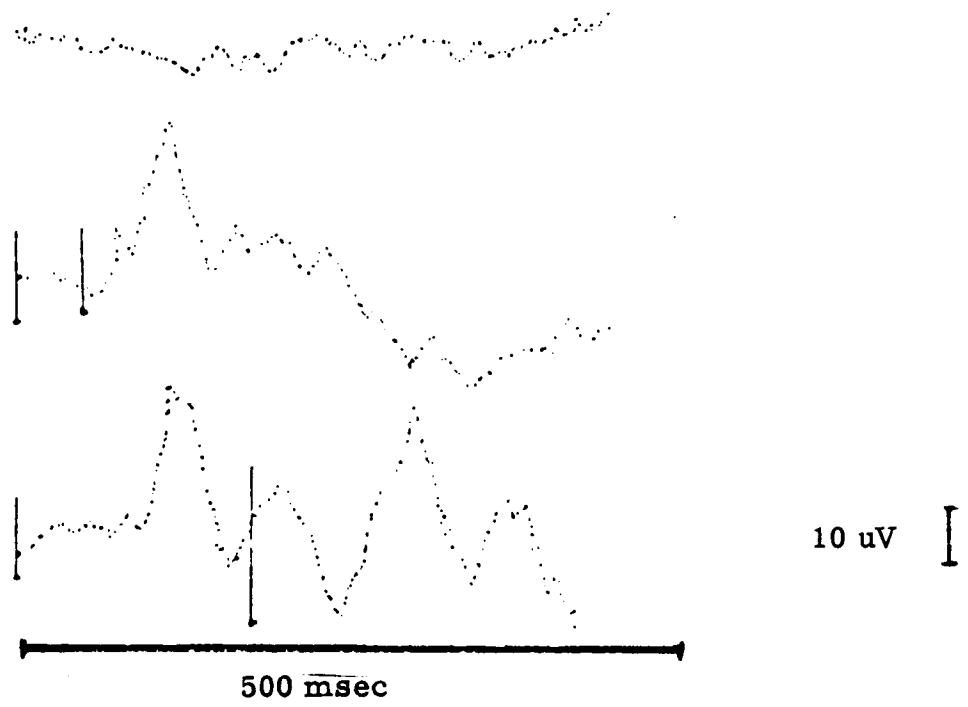
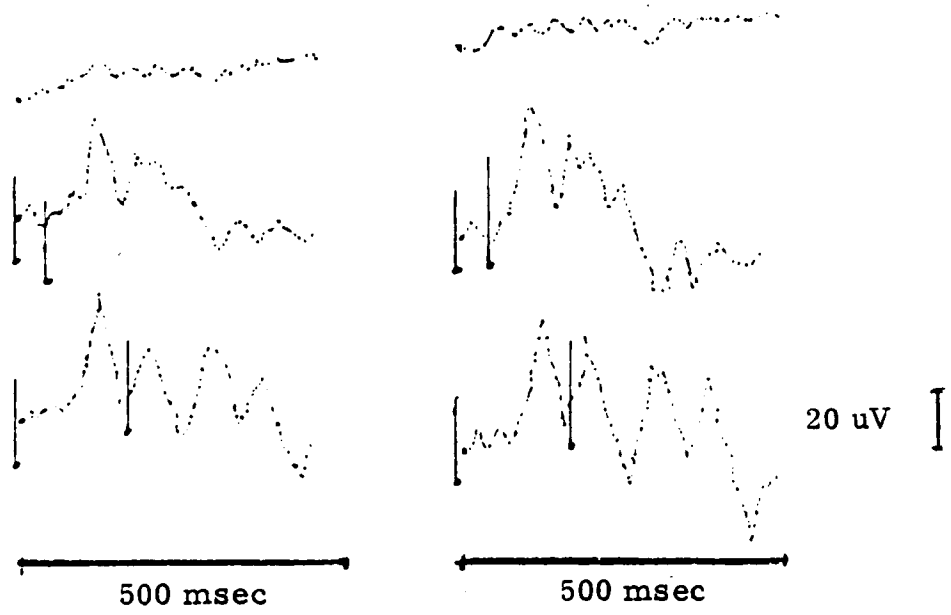
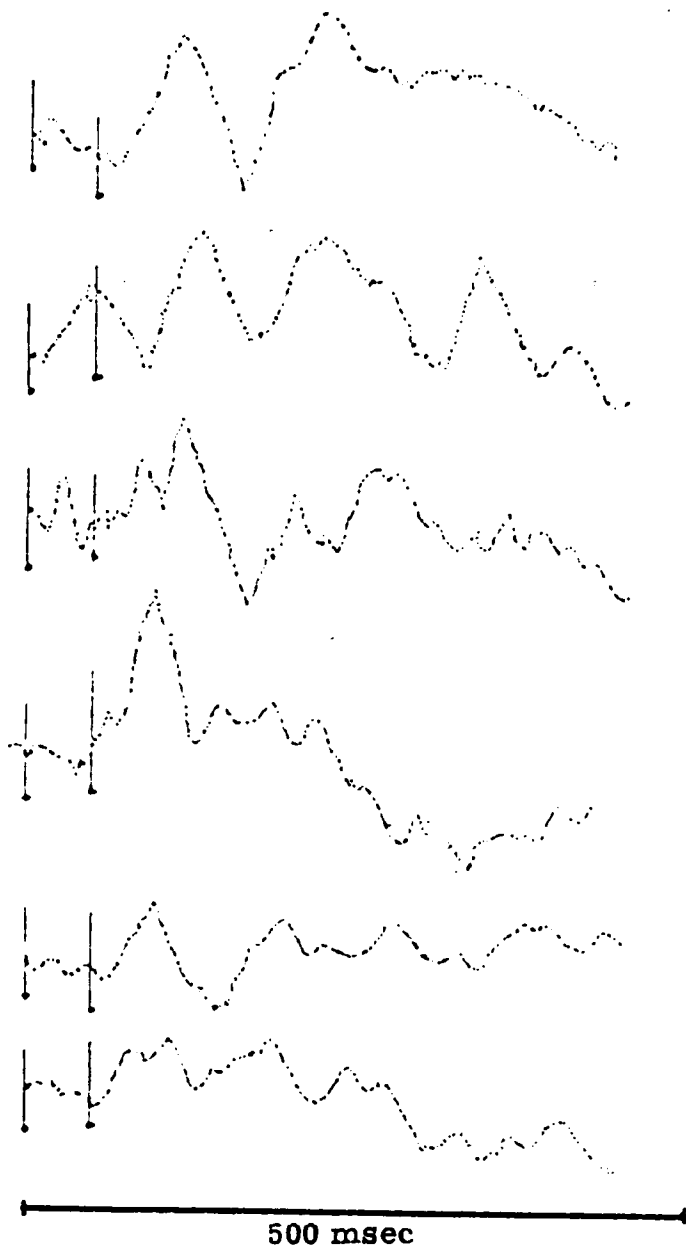
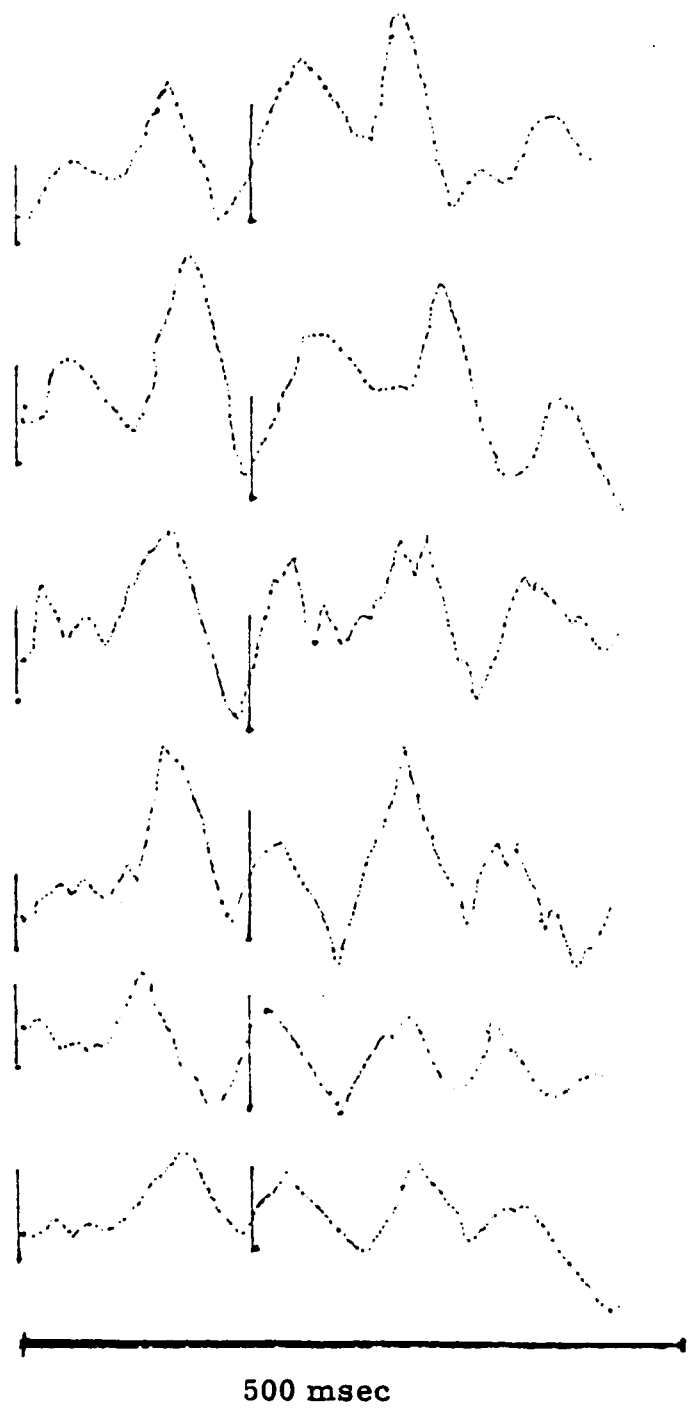


Figure J. The averaged evoked responses from six subjects to binocular viewing of paired informational stimuli with the letters TYU as TS and PM3 as mask. The ISI was 50 msec (condition 5).



10 μ V $\left| \right.$

Figure K. The averaged evoked responses from six subjects to binocular viewing of paired informational stimuli with the letters TYU as TS and PM3 as mask. The ISI was 200 msec (condition 6).



10 uV I

Appendix II

Table A

Personal Data on Older Subjects in the WORD Group					
Subject	Sex	Age	Years of School	Occupation	Mean ISI _c for 3 TDs
F. D'O.	Female	65	15	Waitress	11 msec
F. L.	"	65	12	Retired Secretary	88.6 "
L. Z.	"	78	16	Employment Manager	220.0 "
P. B.	"	70	16	Retired Librarian	38.3 "
I. M.	Male	68	16	Retired Whole- sale Grocer	139.0 "
G. B.	Female	71	14	Retired Editor	48.3 "
M. P.	"	69	16	Retired Secretary	129.0 "
R. W.	"	62	14	Secretary	33.3 "
H. S.	"	69	18	Retired Health Educator	10.0 "
J. A.	Male	66	17	Retired Music Teacher	175.0 "

Table B

Personal Data on Older Subjects in the LETTER Group

Subject	Sex	Age	Years of School	Occupation	Mean ISI _c for 3 TDs
G. G.	Female	64	16	Nurse	33.6 msec
D. Y.	Male	70	16	Retired Window Designer	183.3 "
F. L.	Female	69	16	Retired Bookkeeper	203.0 "
D. L.	"	65	16	Administrative Secretary	11.0 "
S. H.	"	69	18	Retired Language Teacher	62.6 "
S. M.	"	62	12	Retired Switchboard Operator	166.0 "
K. C.	"	74	15	Retired Fur Sales	160.0 "
E. K.	"	63	12	Housewife	171.0 "
H. S.	"	60	16	Photographer	19.0 "
A. P. H.	"	73	20 +	Psychoanalyst	21.3 "

Table C

Personal Data on Older Subjects in th TRIGRAM Group

Subject	Sex	Age	Years of School	Occupation	Mean ISI _c for 3 TDs
A. C.	Male	61	15	Retired Clerk	165.0 "
F. B.	Female	78	16	Retired Nurse	190.0 "
M. C.	"	67	13	Administrative Asst., CUNY	218.0 "
E. R.	"	63	20	Retired Teacher	170.0 "
H. W.	"	72	20 +	Retired Chemist	220.0 "
A. N.	"	67	18	Retired Secretary	210.0 "
E. S.	"	69	18	Retired Teacher	105.0 "
S. H.	"	67	15	Teacher	29.0 "
J. S.	"	70	15	Retired Dental Hygeinist	220.0 "
L. K.	"	69	12	Retired Civil Servant	110.0 "

Appendix III

Evoked Potentials from all Subjects in Experiment II

The left column of Figures L and M show the averaged responses from the left hemisphere of ten young subjects to 60 stimulus presentations in masked condition (2) with both target and mask presented at a duration of 10 msec with an ISI of zero msec, and at a luminance of 4.3 mL. The center trace of each triplet represents the waveform; the upper and lower traces show the 95% confidence limits of each data point on the waveform. The single trace above each triplet represents the response of that subject to the basic EEG (noise control) condition.

The right column shows responses from the right hemispheres of the same subjects in the same conditions. They are almost identical to the traces obtained from the left hemisphere.

Figures N and O show responses of ten older subjects to the same conditions represented in Figures L and M by the young subjects. Waveforms from the left hemisphere are shown in the left column and those from the right hemisphere in the right column.

Figures P through S show the averaged responses from the ten young and ten older subjects to the unmasked condition (3) in which ISI = 150 msec for the young and 250 msec for the older subjects. Both target and mask were presented for 10 msec at a luminance of 4.3 mL. Again, responses from the left hemisphere are shown in the left column and those from the right hemisphere are shown at the right.

Vertical lines indicate stimulus onset. Negativity is downward.

Figure L. The left column shows the averaged responses from the left hemisphere of young subjects 1 through 5 to 60 stimulus presentations in the masked condition (2) (TS = 10, MS = 10, ISI = 0 msec). The luminance of both TS and MS was 4.3 mL. The center trace of each triplet represents the waveform; the upper and lower traces represent the 95% confidence limits for each data point in the waveform. The single trace above each triplet represents the response to the noise control condition from that subject. The right column shows the responses from the right hemisphere of each subject in the same condition averaged at the same time as the trace from the left hemisphere. Vertical lines indicate stimulus onset. Negativity is downward. Stimulus viewing was dichoptic.

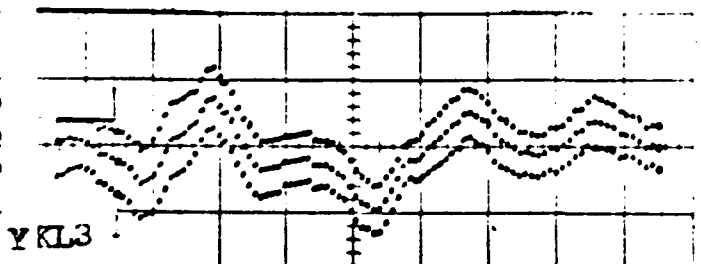
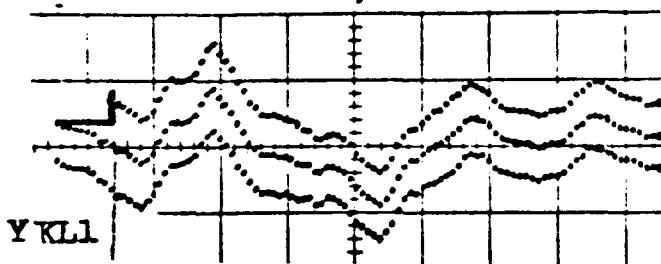
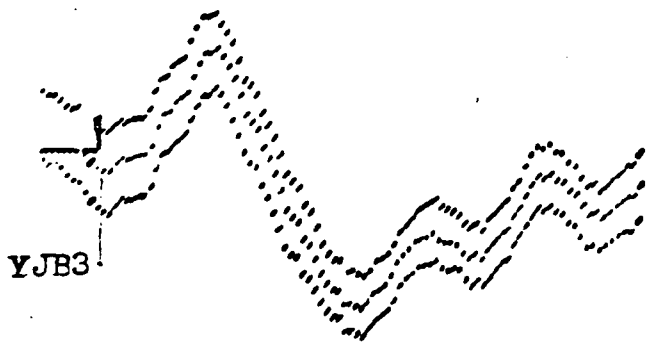
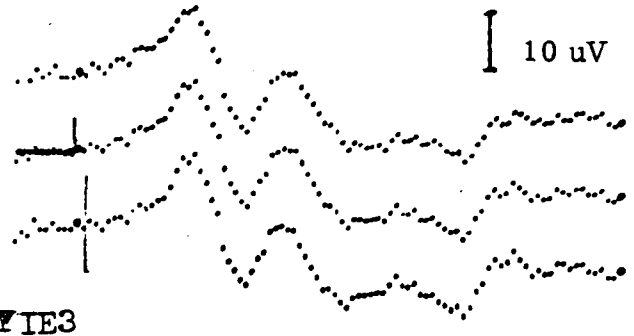
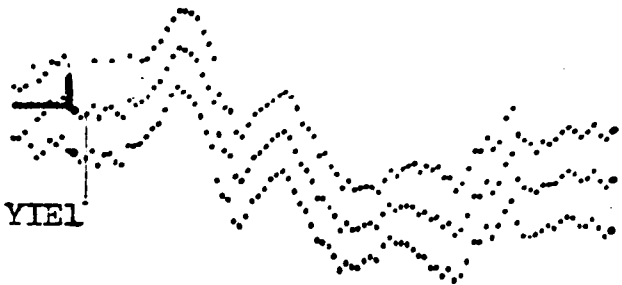
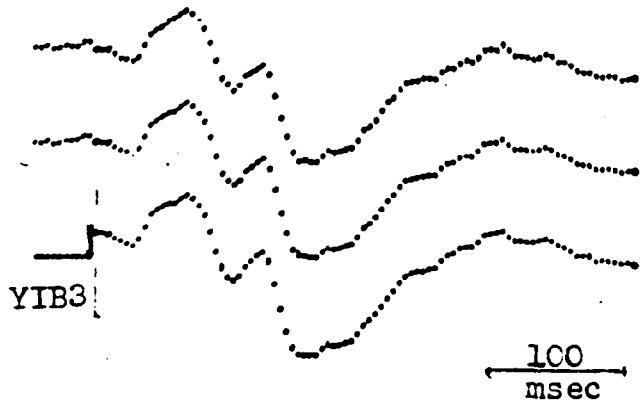
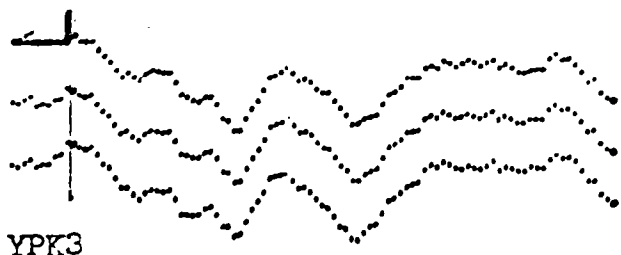
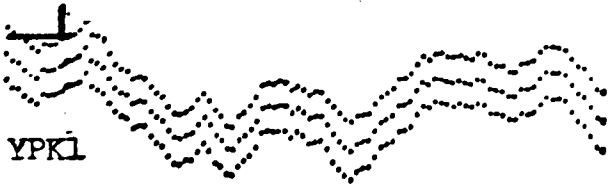
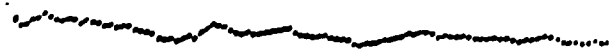
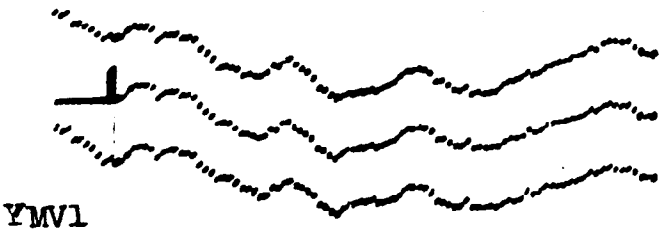


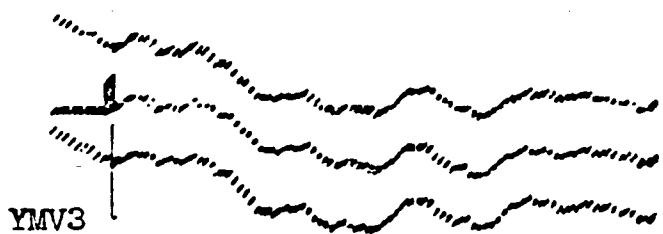
Figure M. A continuation of Figure L showing the responses of young subjects 6 through 10 to the same conditions as described in Figure L.



YPK3



YMV1



YMV3

100
msec

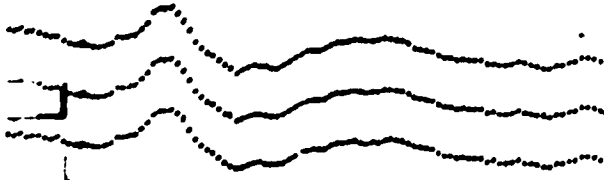
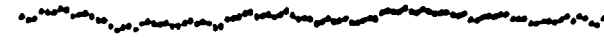


YGS1

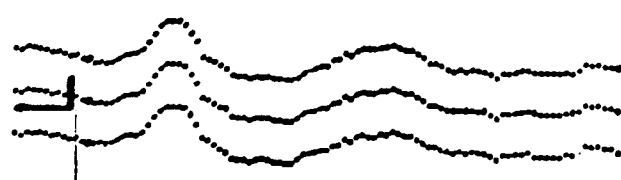


YGS3

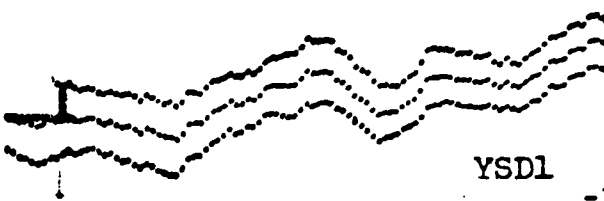
10 uV



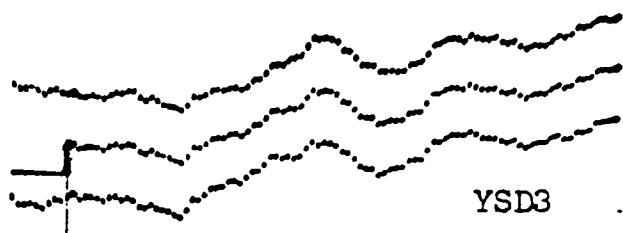
YAF1



YAF3

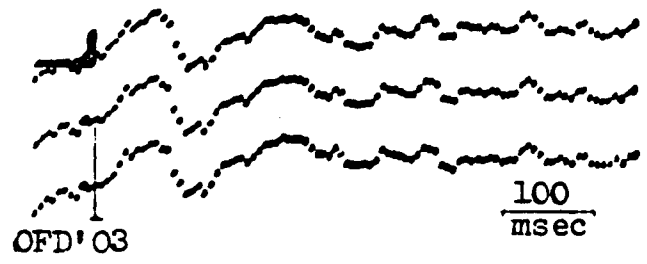
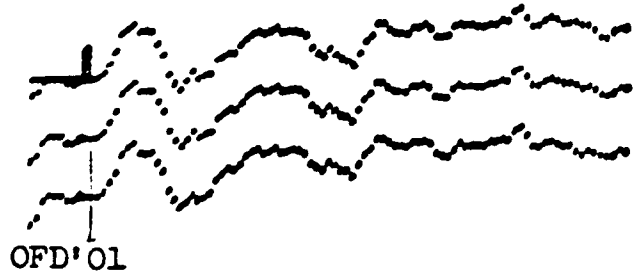
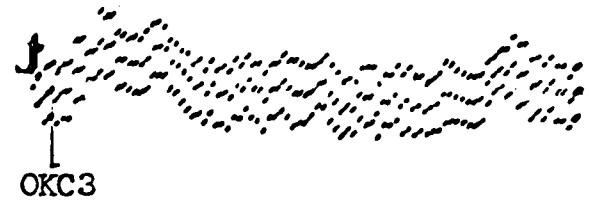
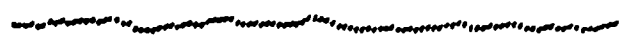
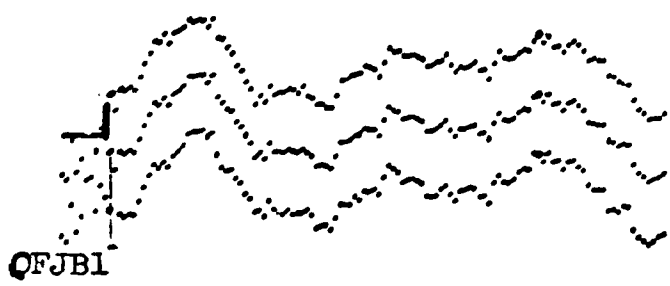
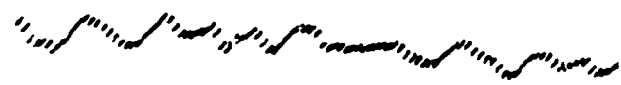
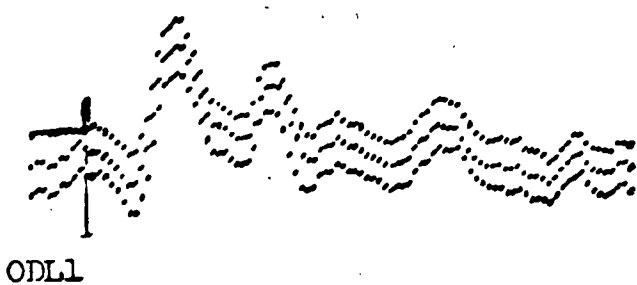


YSD1



YSD3

Figure N. The evoked responses of older subjects 11 through 15 to the stimulus conditions represented in Figures L and M.



100
msec



10 uV
I

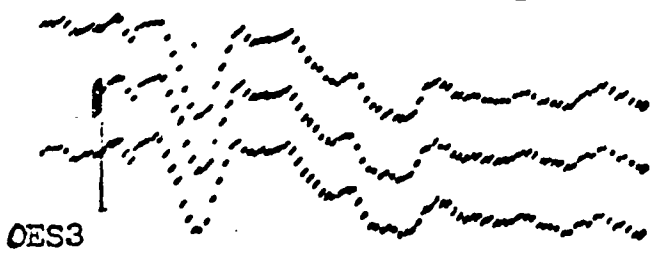
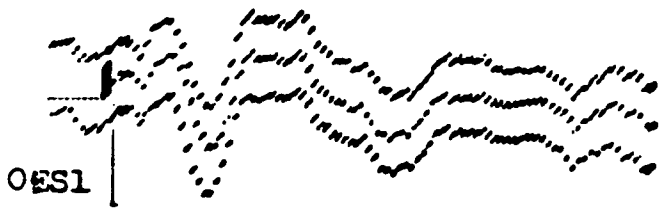
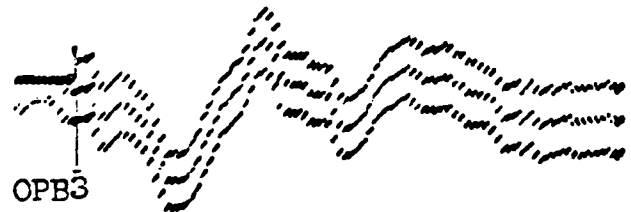
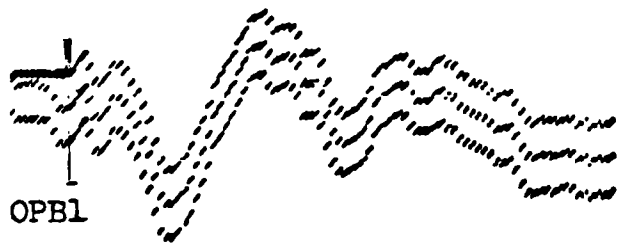
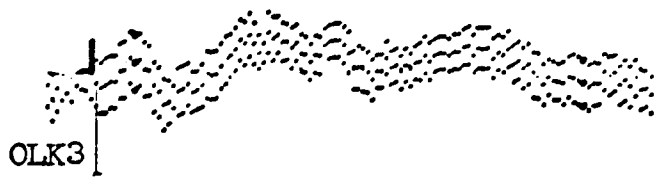
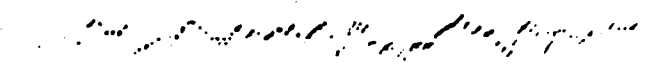
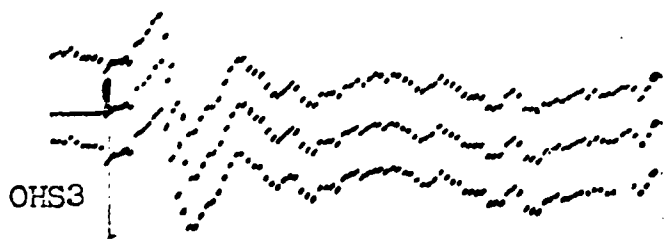
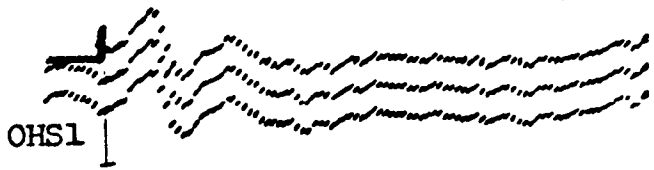
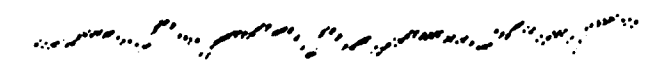


Figure O. The evoked responses of older subjects 16 through 20 to the stimulus conditions represented in Figures L, M, and N.



100 msec



10 uV

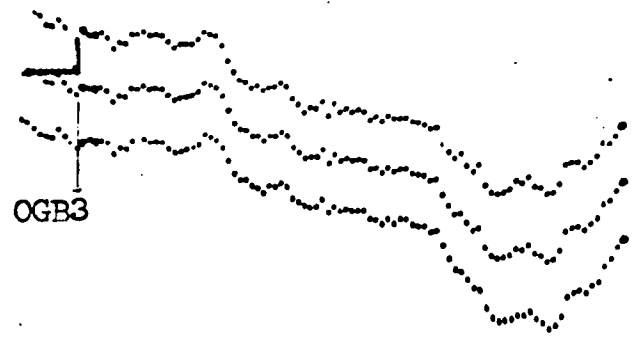
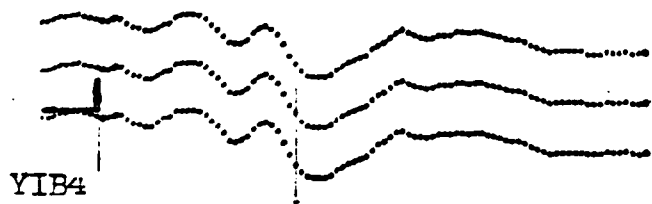
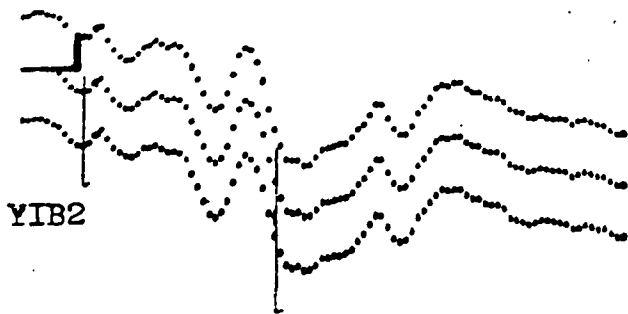
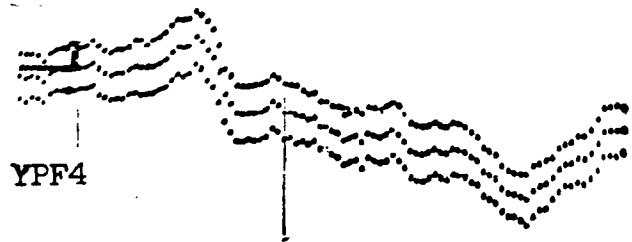
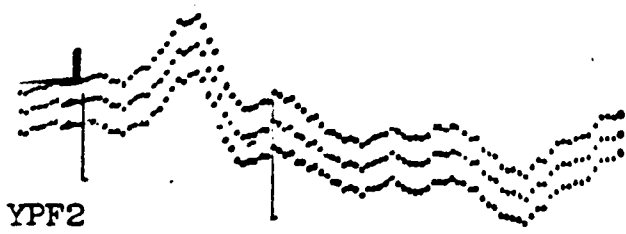
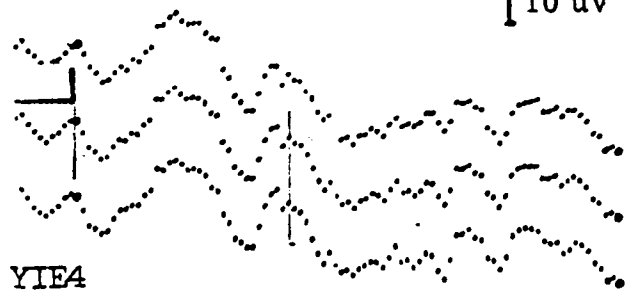
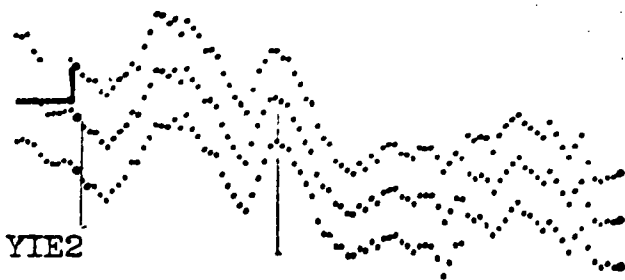


Figure P. The left column shows the averaged responses from the left hemisphere of young subjects 1 through 5 to 60 stimulus presentations in the unmasked condition (3) (TS = 10, MS = 10, ISI = 150.msec). The luminance of both TS and MS was 4.3 mL. The right column represents responses from the right hemisphere to the same condition averaged at the same time as the trace from the left hemisphere. Vertical lines indicate stimulus onset. Negativity is downward. Stimulus viewing was dichoptic.



10 uV



100 msec

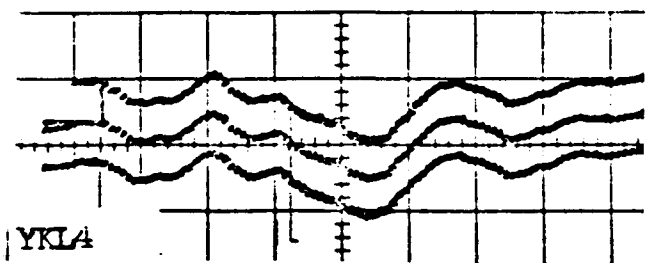
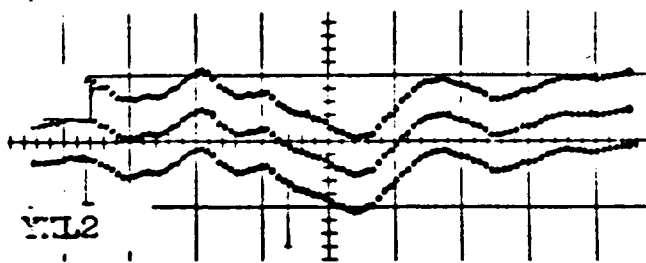
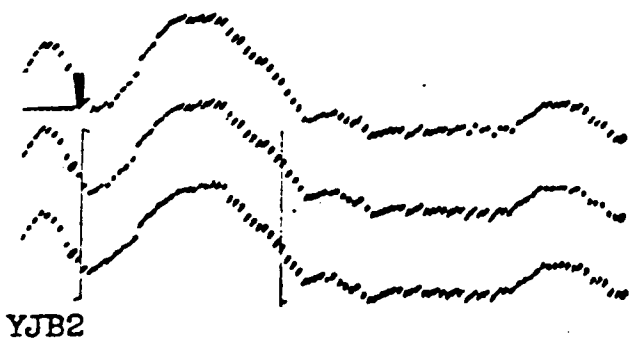


Figure Q. A continuation of Figure P showing the averaged responses of young subjects 6 through 10 to the same conditions represented in Figure P.

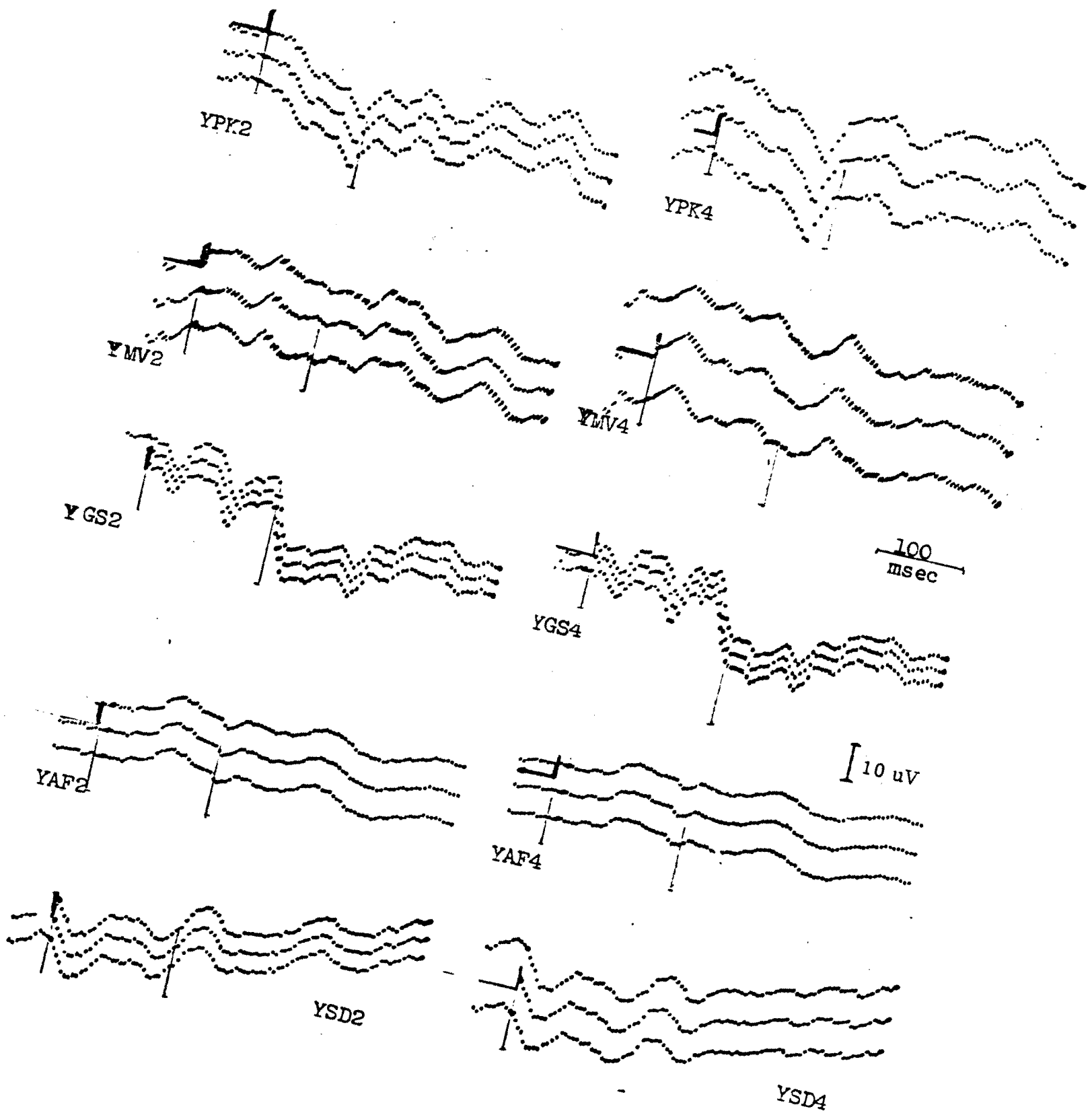


Figure R. The left column shows responses from the left hemisphere of older subjects 11 through 15 in the unmasked condition (3) (TS = 10, MS = 10, ISI = 250 msec). The right column represents responses from the right hemisphere to the same condition averaged at the same time as those from the left. Vertical lines indicate stimulus onset. Negativity is downward. Stimulus viewing was dichoptic.

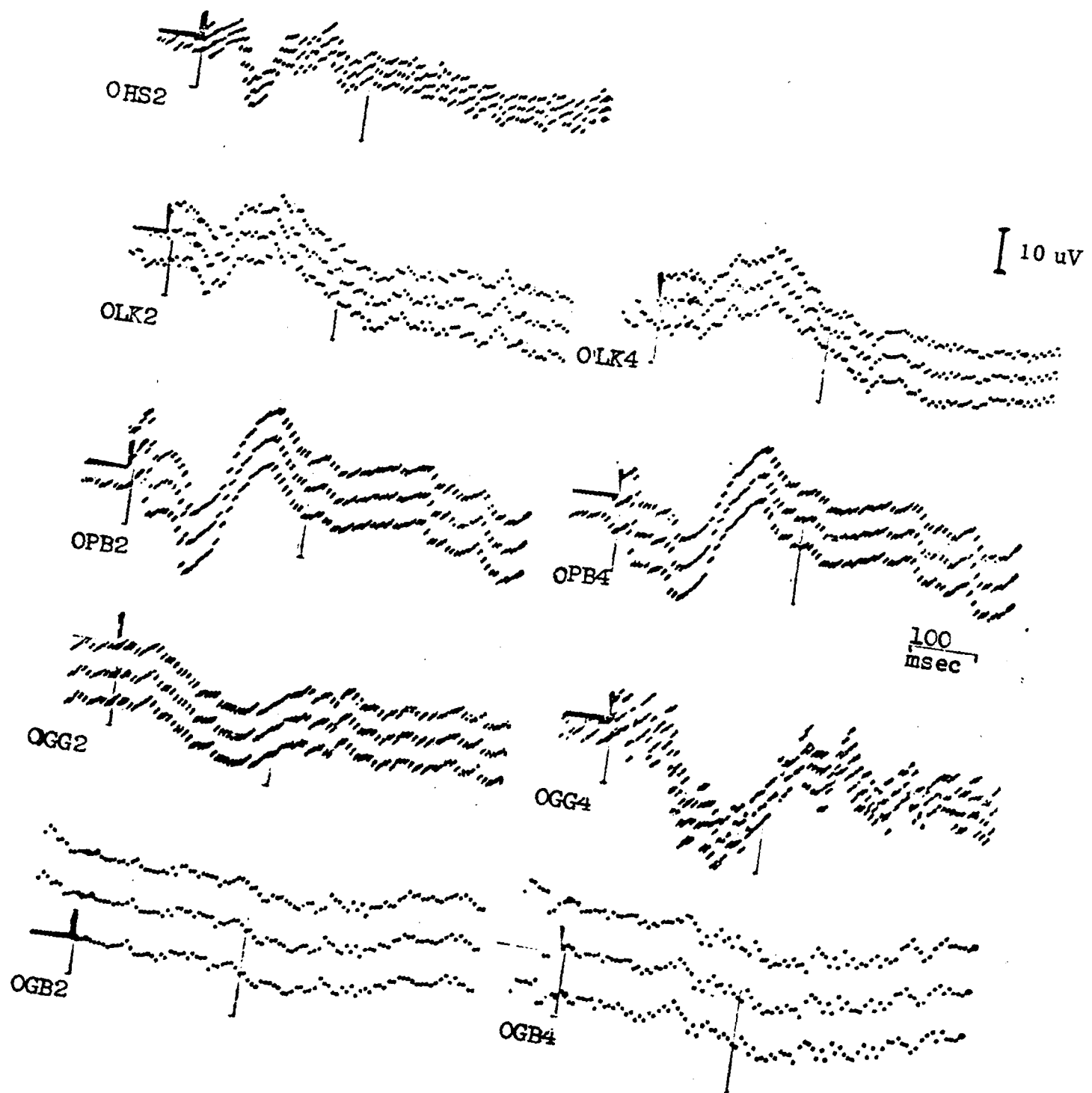
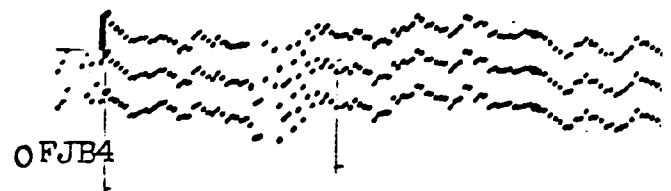
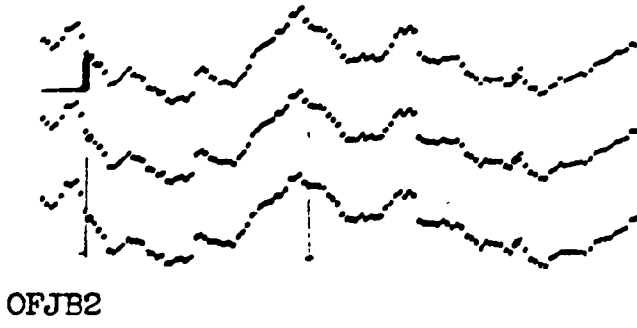
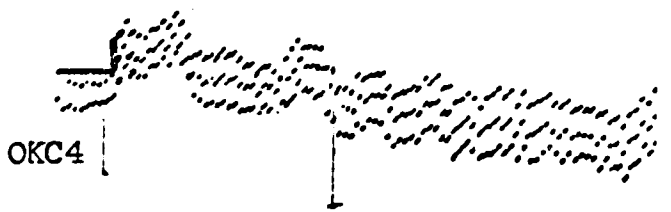
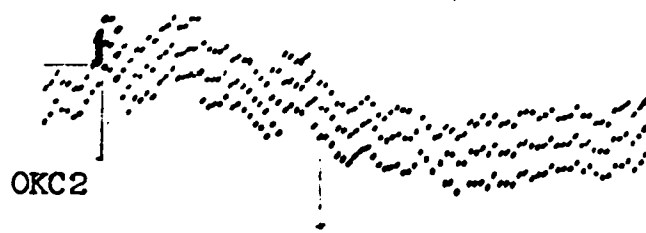


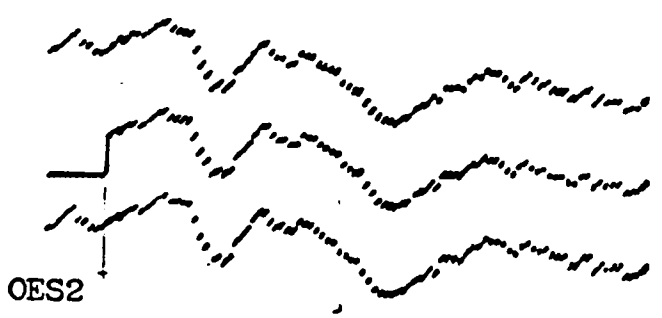
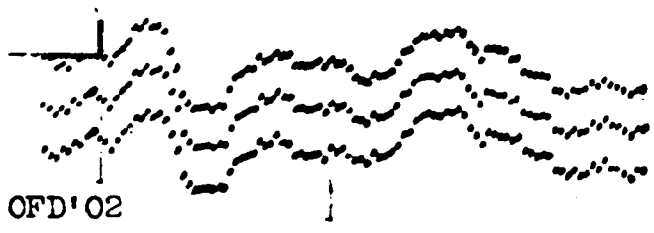
Figure S. A continuation of Figure R showing responses from older subjects 16 through 20 to the same conditions as those represented in Figure R.



100
msec



10 uV



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