Visual Evoked Potentials and Selective Attention Allocated to Double Stimuli

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This paper describes an experiment which was designed to analyze the effect of selective attention on the amplitude of the average visual evoked potential (VEP). The experiment was especially concerned with the question as to whether the temporal allocation of selective attention can contribute to amplitude changes of the occipital waves toward negative direction.

The classic study of the effect of human selective attention on the VEP was conducted in Lindsley's laboratory (Haider et al., 1964 ; Spong et al., 1965). They have demonstrated that diffuse flash stimuli can produce larger amplitudes of negative and positive occipital components with latencies between 100 and 200 msec when these stimuli are attended than when other stimuli are attended. Eason et al. (1969) have reported that flash stimuli evoke large amplitude of the occipital negative components with latencies of 100–200 msec when presented to an attended locus. Regular alternation and slow rate of presentation of attended and unattended stimuli used in these studies were criticized because evoked potential (EP) enhancement to the attended stimuli may be produced by general alertness changes between task relevant and task irrelevant stimuli (Karlin, 1970 ; Naatanen, 1975 ; Hillyard et al., 1978 ; Hillyard and Picton, 1979 ; Naatanen, 1982).

Some of adequately controlled studies of the VEP correlates of selective attention have failed to show an attention effect on the occipital negative wave with latency of about 170 (N170, called N1 in some studies). This is in marked contrast to the central negative wave (latency about 100 msec, N100) of the auditory EP (AEP) which has been reported as a reliable physiological indicator of selective attention (Hillyard et al., 1973 ; Picton and Hillyard, 1974 ; McCarthy and Donchin, 1976 ; Schwent et al., 1976a ; Schwent et al., 1976b ; Hink et al., 1977 ; Robinson and Sabat, 1977 ; Hink, et al., 1978 ; Hansen and Hillyard, 1980).

Harter's group (Harter and Salmon, 1972 ; Harter and Previc, 1978 ; Harter and Guido, 1980), using a short interstimulus interval (ISI) (about 0.5–1 sec), have demonstrated that a surface-negative peak (latencies 150–300 msec, peak latency 235, N235) increases in amplitude in the occipital area in response to the task relevant stimulus (in their data N235 was not always obvious in the raw VEP waveforms ; the N235 became visible when VEPs to attended and ignored stimuli were subtracted each other). Van Voorhis and Hillyard (1977), using rapid (0.3–0.6 sec ISI) and slow (1–4 sec ISI) delivery rate, required the subject to press a key to small disks flashed at the attended-side of the visual field. They have shown that the central N160, P400 and the occipital P220 components are enhanced to the stimuli at the attended-side of the visual field, in relation to at the unattended-side. The occipital N170 is least sensitive to the spatial direction of attention even in the rapid delivery rate.

However, more recent studies have demonstrated the spatial allocation effect of attention on the occipital N170. Eason (1981) asked the subject to count infrequent (20%) double flashes among frequent (80%) single flashes, presented at random with mean ISI of 2 sec, at the attended-side of the visual field. He has demonstrated that occipital P120, P120–N170, and other later components increase in amplitude when the stimuli are flashed at the attended-side of the visual field. Harter et al. (1982), using an infrequent white ring or green circle target, have found the occipital N172 enhancement in the attended side VEP. Hillyard and Münte (1984) asked the subject detecting infrequent target bars from frequent standard bars flashed at attended right or left visual field with an ISI of 300–500 msec. They have demonstrated that all bars flashed to the attended location elicit enlarged occipital P122, N168 and N264 waves, in relation to bars at the unattended location. Failure of the early studies to demonstrate the effect of spatial attention allocation on the occipital N170 seems due to easy detection of spatially located stimuli (Van Voohris and Hillyard, 1977). Paying attention to visual cues other than spatial location is reflected in broad negative waves (studies of Hater's group, 1972 ; 1978 ; 1980 ; 1982, and Hillyard and Münte, 1984).

There is few studies which have demonstrated the effect of attention on the occipital N170 when attention is temporarily allocated to one of two successive stimuli. To demonstrate the effect of temporal attention allocation on the occipital VEP two pattern stimuli, S1 and S2, were flashed with an ISI of 100 msec in this experiment. The hypothesis to be tested is that the early waves (including N170) of the occipital VEP to the S1–S2 pair are more negative when S1 is attended, in relation to when S2 is attended. Another hypothesis is that the later waves of the S1–S2 VEP are more negative when S2 is attended than when S1 is attended.

Under the masking condition used in this experiment, S1 percept is terminated and replaced by S2 percept. The former is shorter, while the latter longer, in perceptual duration. Long persistence of S2 may attract the subject's attention in the attend S1. This interference effect, if any, may decrease across stimulus positions through short-term habituation process. If this is the case, there may be some development of negative waves in the later components of the attend-S1 VEP which attenuates across stimulus repetition. In order to test this interference effect, the same S1–S2 pair was repeated three times in a trial.

Methods

Subject and procedure

Ten male subjects, ages from 19 to 23 years, from the Hokkaido University were paid to participate in this experiment. They had normal or corrected-to-normal vision. They were tested on two days. On one experimental day a half of them were tested in the attend S1 condition and another half in the attend S2 condition. On the other day the former were tested in the attend S2 condition and the latter the attend S1 condition.

Two stimuli, S1 and S2, were presented successively with an interstimulus interval (ISI) of 100 msec. In the attend S1 condition, S1 was a task relevant target stimulus (TS) and S2 was a task irrelevant masking stimulus (MS). In the attend S2 condition, S1 was the task irrelevant MS and S2 the task relevant TS. Double MS's with 100 msec ISI were used as a warning stimulus (WS) in both conditions.

MS was a light and dark random pattern. TS was either a number (0 and from 2 to 9), composed of light cells of 12X12 checkerboard cell units, or a checkerboard, composed of light cells of 6X6 checkerboard cell units (only one cell of each column was light and that position was chosen at random). These stimuli were matched in total luminance which was about 0.05mL. The stimuli were projected on a translucent screen by two Kodak projectors mounted outside the experiment room. A visual angle was about 3°. The light source of each projector was a xenon tube. An activation of the tube was triggered by electric pulses.

A trial in the attend S1 condition was composed of five successive stimulus pairs : the WS (MS–MS), a triplet consisting of three identical pairs of the TS–MS (intratrial stimulus positions 1–3) and a single pair of the TS–MS (position 4). A trial in the attend S2 condition was the same as the trial in the attend S1 except that the MS–TS pairs were used instead of the TS–MS. An onset-onset interval between the WS and the stimulus pair in position 1 and between the stimulus pairs in positions 3 and 4 was 1500 msec. Three stimulus pairs in the triplet were separated with 1000 msec ISI.

The intertrial interval was varied from 10 to 15 sec with a mean of 13. Four blocks of 40 trials were presented with an interblock interval of about 5min. Twenty number trials and another 20 checkerboard trials were arranged in a random order in the block.

The subject was seated comfortably in a reclining dentist's chair and faced the screen in a darkened, sound-proof and electrically shielded room. The distance between the screen and the subject's eyes was 90cm. After becoming fully adapted to the darkness he was instructed to look binocularly at a faint red fixation point during the stimulus presentation. The fixation point coincided with the center of the stimulus.

The subject was required to name numbers in the triplet and in position 4 when the stimuli were the number. He was required to make a pattern-matching between checkerboards in the triplet and in position 4 when the stimuli were the checkerboard and answer that the patterns were the same or different. To avoid myogenic effects on electroencephalographic (EEG) responses he was asked to answer about 1 sec after the termination of the trial.

After practice trials, 160 trials were presented in four blocks. About 5 sec before the block presentation the subject was signalled to fixate his eyes on the fixation point by a brief tone of 500Hz. After the block presentation he was signalled to relax by another tone.

EEG recording and data analysis

The scalp locations of chlorided silver disk electrodes were frontal, parietal, central and occipital (F3, F4, P3, P4, Cz, O1 and O2 in the international 10–20 system). Elecrodes were placed on the lateral canthus and the supercilium to monitor eye movements. EEG recorded monopolarly with reference to linked ears and electro-oculographic (EOG) responses were amplified by a San-ei electroencephalograph (bandwidth : 0.001–3kHz, time constant : 1.5 sec) and recorded by a Teac FM magnetic tape recorder (bandwidth : DC-1.25kHz).

Eighty EEG responses to the number trials were averaged using a minicomputer HP21MX at analysis time of six sec (giving a resolution of 7.8 msec/point). Ongoing EEG and EOG responses were monitored on an EEG recording chart. EEG responses contaminated by large electromyographic (EMG) and large EOG responses were discarded from computer summation. Averaged EOGs and VEPs were plotted with an HP plotter. Another eighty EEG responses to the checkerboard trials were averaged in the same way as in the case of the number trials.

The peak amplitude was measured from a base line chosen as the mean voltage over the last 50 msec of the prestimulus and the first 50 msec of the post-stimulus EEG responses.

For each of the VEP components an analysis of variance (ANOVA) with repeated measures for attention by electrode effects and ANOVA for attention by stimulus position effects were computed. ANOVA for these effects on the centro-frontal and parietal VEPs and ANOVA on the occipital VEPs were performed separately. Student's *t*-test was used for analyses of the peak latencies and amplitudes at each stimulus position. The significant level for all of these statistical tests was set at 0.05.

Results

No subjects failed to solve the tasks. Error rates were very small : average errors across subjects were four among 160 trials.

The VEP data obtained from nine subjects were analyzed. The VEPs from one subject were discarded because no remarkable occipital peaks were observed except positive components with latencies of about 120 and 220 msec.

VEP waveforms obtained at the central (Cz) and occipital (O1 and O2) electrode loci were shown in Fig. 1 for the number trial and in Fig. 2 for the checkerboard. The waveforms were the grand means across nine subjects. The VEP waveforms at the parietal and frontal loci were similar to those at the central except some variations in amplitude and latency.

Six components were identified in each of the centro-frontal-parietal and the occipital VEPs as shown schematically in Fig. 3. For the centro-frontal and parietal VEPs, A was a negative wave (mean latency of about 140 and 170 msec, N140 and N170, for the centro-frontal and parietal VEPs respectively), B a positive wave (200 and 250 msec, P200 and P250), C a negative wave (250 and 310 msec, N250 and N310), D a positive wave (320 and 370 msec, P320 and P370), E a negative wave (360 and 430 msec, N360 and N430) and F a positive wave (480 and 500 msec, P480 and P500). For the occipital VEPs, A was a positive wave (mean latency of about 130 msec, P130), B a negative wave (180 msec, N180), C a positive wave (250 msec, P250), D a positive wave (310 msec, P310), E a negative wave or negative going wave (360 msec, N360) and F a positive wave (450 msec, P450). Latencies of these waves did not vary significantly across stimulus positions 1–4 except those of the centro-frontal P480 and parrietal P500.

Mean amplitudes across nine subjects of the number VEP are shown in Fig. 4–7 : centro-frontal and parietal waves A–C in Fig. 4, D-F in Fig. 5, occipital waves A-C in Fig. 6, D-F in Fig. 7. Those of the checkerboard VEP are shown in Fig. 8–11. More detailed amplitude values, standard errors of these waves and ANOVA are shown in Table 1–7 for the number VEP and Table 8–14 for the checkerboard VEP. For the sake of simplicity, ANOVA and waveform characteristics of the number VEP are described

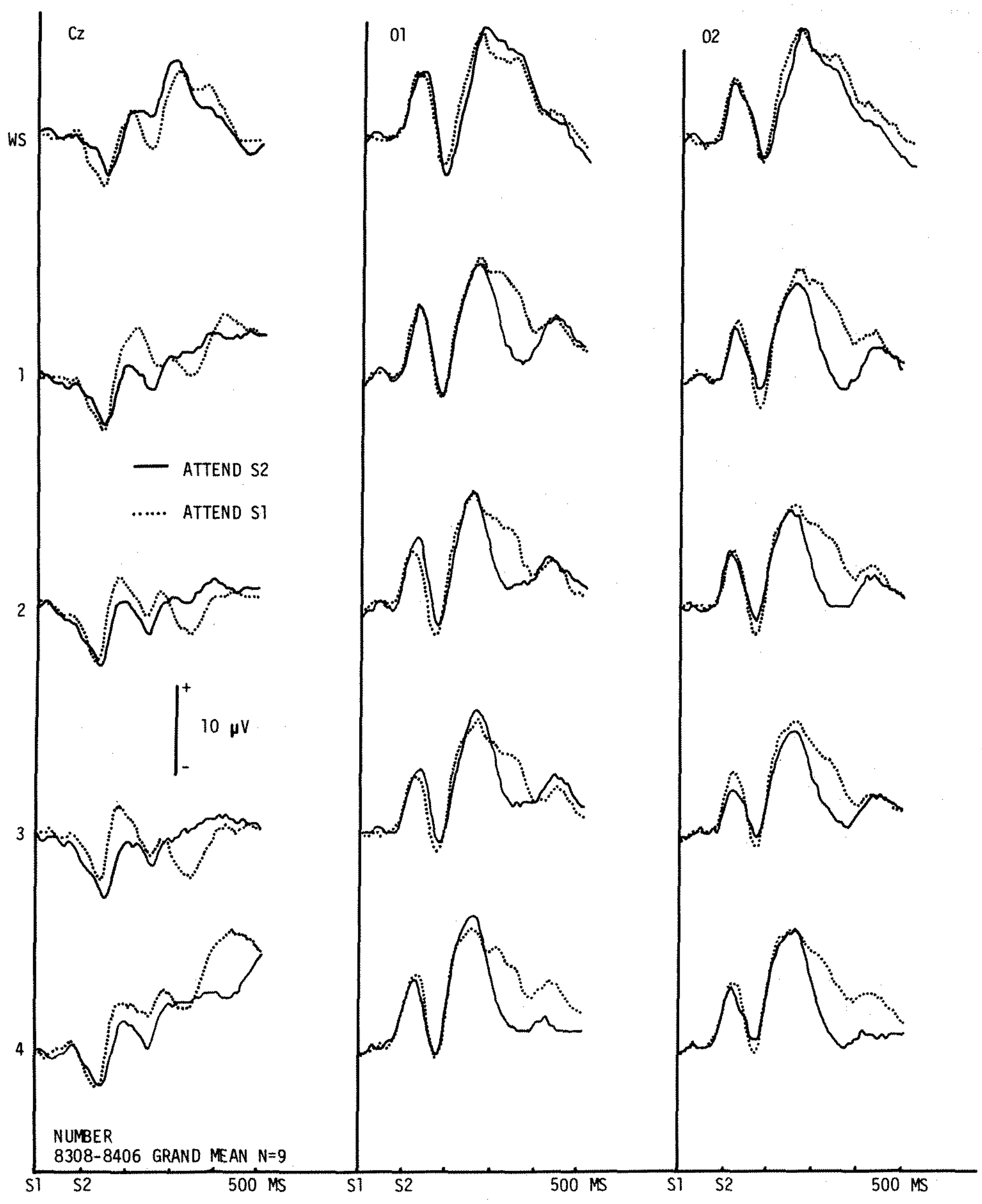

Fig. 1.

Grand mean VEP waveforms to the number trial across nine subjects measured from the central (Cz) and occipital (O1 and O2) electrode loci. The Cz VEPs are shown in the left column and the O1–O2 VEPs in the middle and right columns. The VEPs in the attend S1 condition are traced with dotted lines, and those in the attend S2 with solid lines. Five stimulus positions, WS and positions 1–4 are seen on the ordinate. Latencies in msec are seen on the abscissa. Onsets of two stimuli are shown by the letters S1 and S2 at 0 and 100 msec latency on the abscissa. The VEPs in the attend S1 and attend S2 conditions were similar in waveform at WS. The central P200 and N360 amplitudes were large in the attend S1 condition and small in the attend S2 condition, that is, P200 was more positive in the attend S1 condition and N360 was more positive in the attend S2 condition. The occipital negative wave (N360) increased at positions 1–4 in the attend S2 condition. Positive deflection upward.

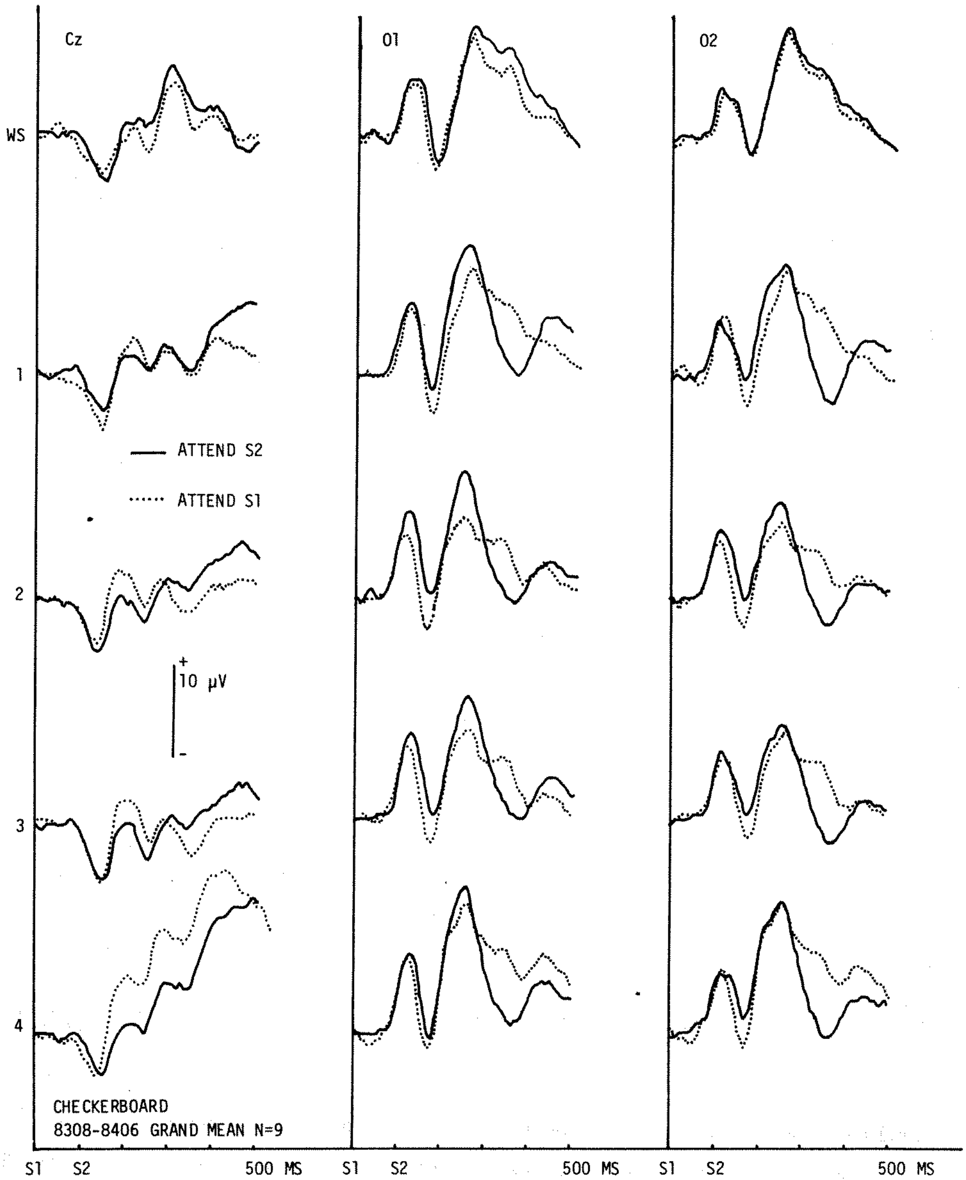

Fig. 2.

Grand mean VEP waveforms to the checkerboard trial. Other details are the same as those in Fig. 1.

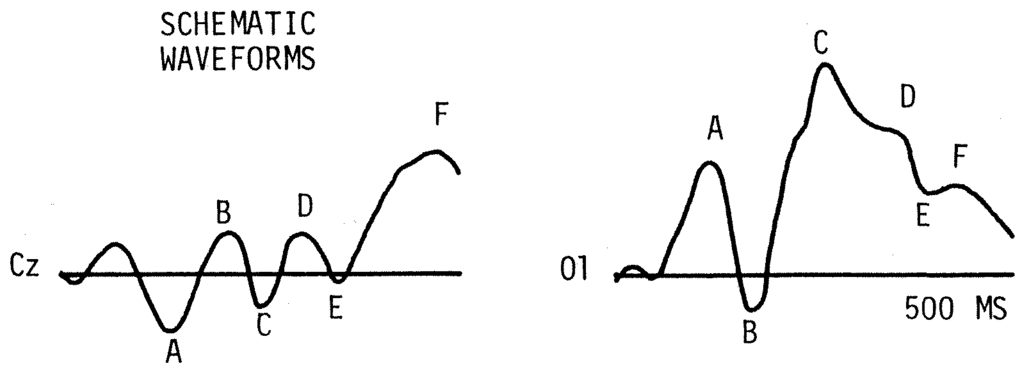

Fig. 3.

Schematic waveforms of the VEP. The left trace shows the VEP recorded at the central electrode location (Cz) and the right one VEP at the left occipital electrode location (O1) with duration of 500 msec. Letters from A to F were assigned to negative and positive peaks in order of peak latency. For the Cz VEP, A stands for N140, B for P200, C for N250, D for P320, E for N360 and F for P480. For the O1 VEP, A stands for P130, B for N180, C for P250, D for P310, E for N360 and F for P450. Positive deflection upward.

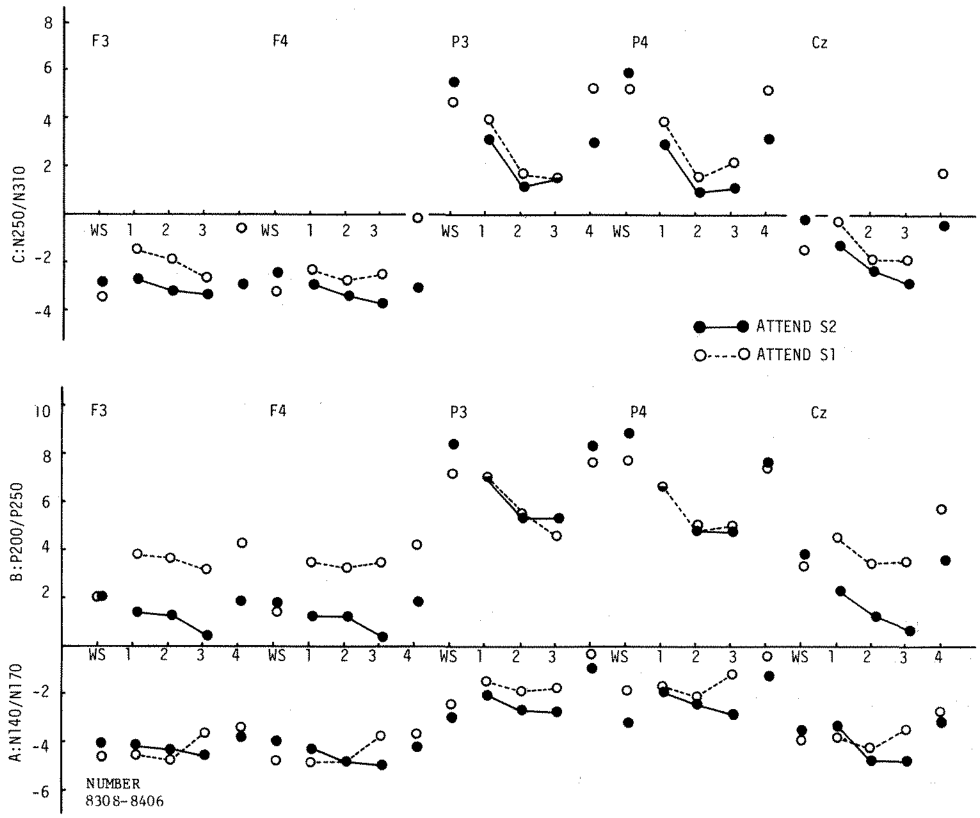

Fig. 4

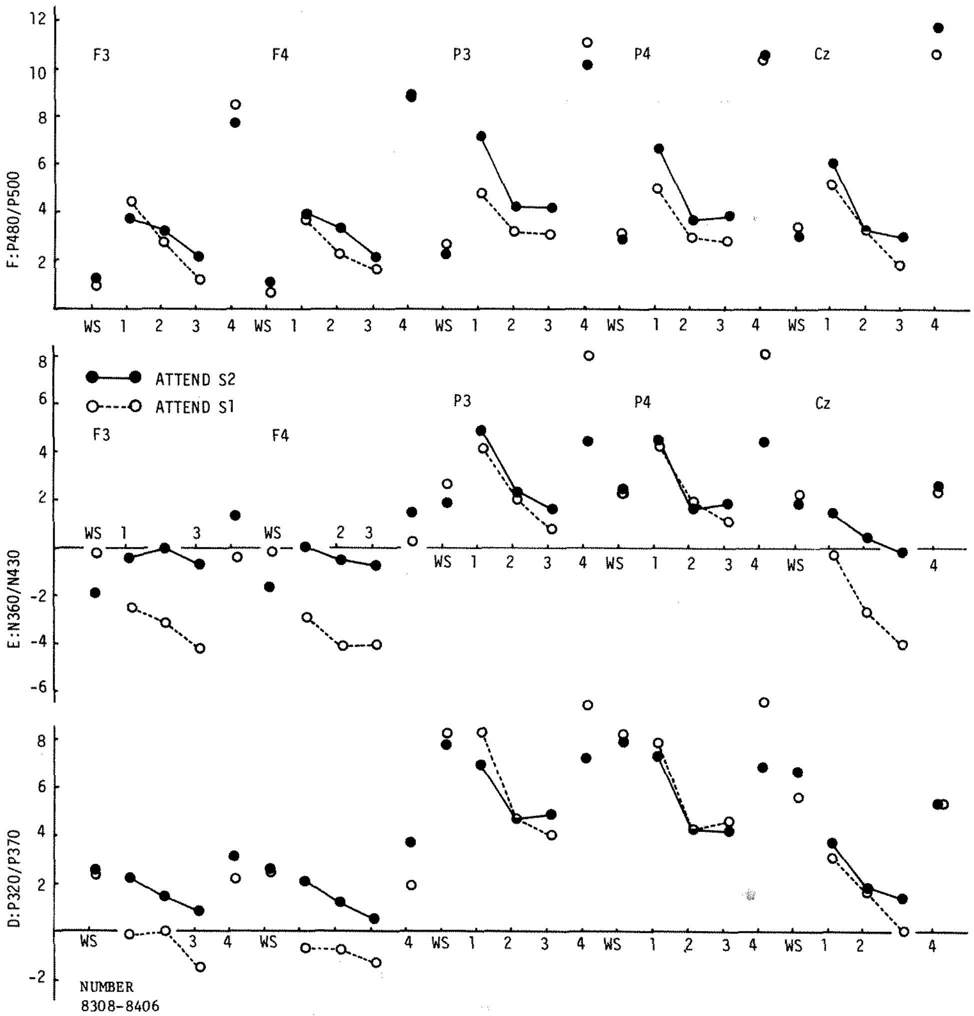

Fig. 5

Fig. 4 and 5.

Amplitude values of the number VEP waves averaged across nine subjects recorded at the centro-frontal and parietal loci. Components A-C are shown in Fig. 4 and D-F in Fig. 5. The amplitude values in the attend S1 are shown with dotted lines and open circles and those in the attend S2 with solid lines and filled circles. Amplitude values in μ V are shown on the ordinate and the stimulus positions on the abscissa. Electrode loci are shown in the upper and middle traces. The amplitude of the parietal VEP components were almost the same in the attend S1 and attend S2 conditions. Significant amplitude differences between two conditions were found at the centro-frontal P200 and N360.

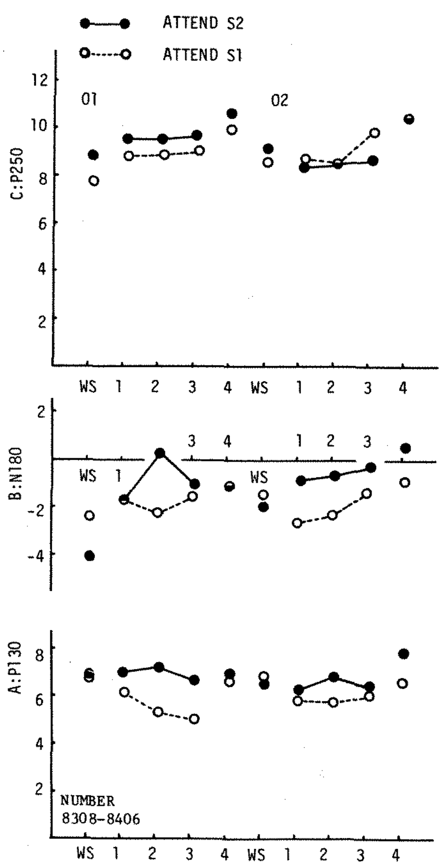

Fig. 6

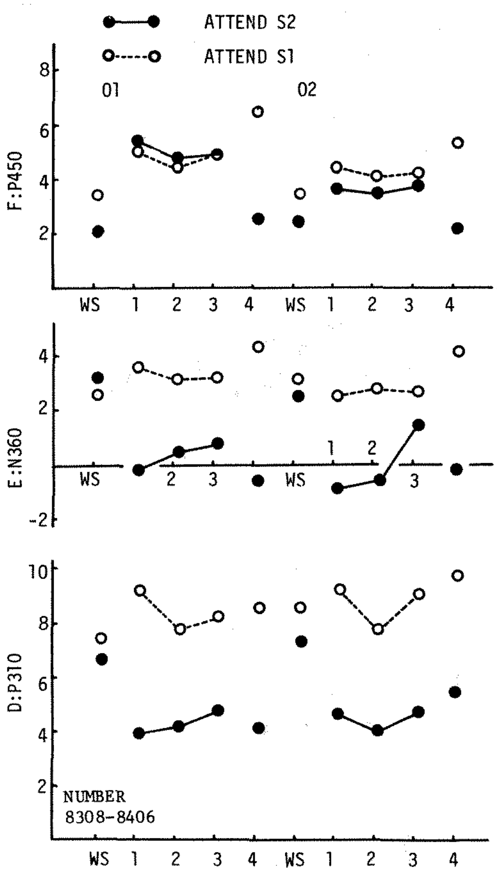

Fig. 7

Fig. 6 and 7.

Amplitude values of the number VEP waves averaged across nine subjects recorded at the occipital loci. Electrode loci are shown in the upper trace. Other details are the same as those in Fig. 4 and 5. Significant amplitude differences between the attend S1 and attend S2 conditions were found at P310 and N360 which were more positive in the attend S1 condition and more negative in the attend S2 condition.

in the following sections except the section of occipital waves.

Centro-frontal waves

The VEP waveform appears additive combination of the waves to S1 and S2. Latencies of the negative and positive waves to S2 were almost 100 msec longer than those of the corresponding waves to S1. Remarkable waveform differences between the attend S1 and attend S2 VEPs were found at latencies of 200 and 360 msec (P200 and N360).

ANOVA for attention by electrode effects revealed that the P200 amplitudes were significantly larger in the attend S1 condition than in the attend S2 at each of the stimulus positions 1–4 ($F(1, 80) =$

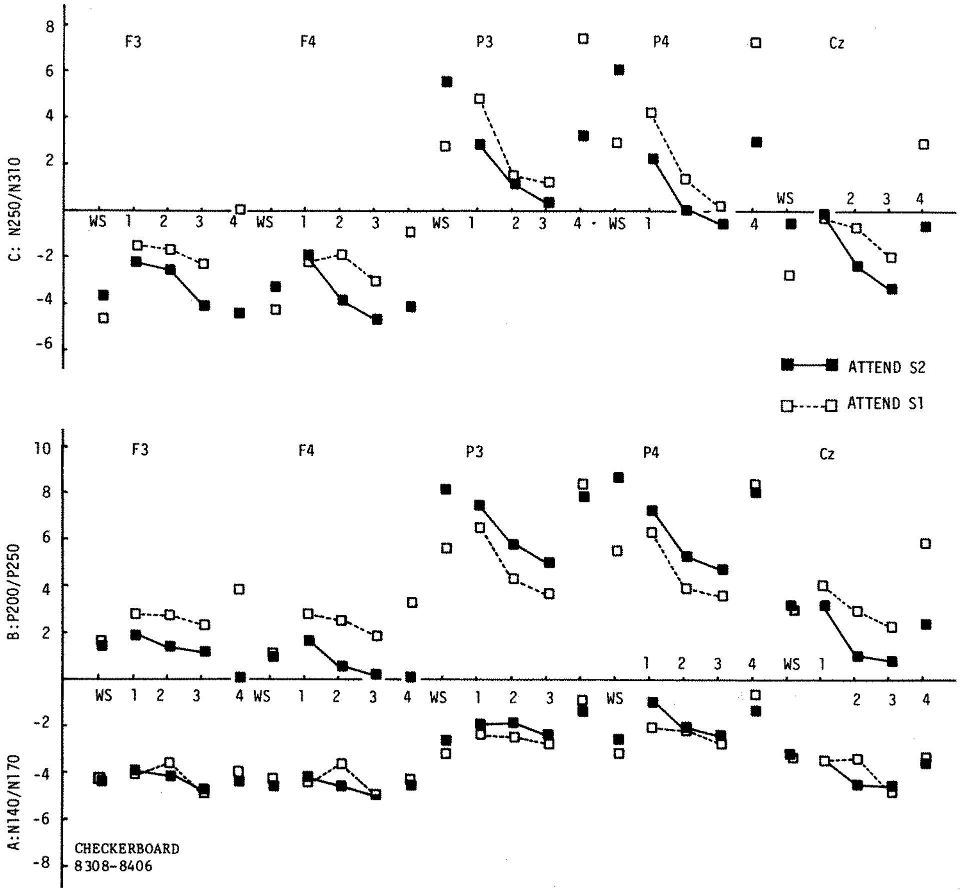

Fig. 8

8.63 or more, $p < .01$ at positions 1–3 ; $F(1, 80) = 4.87$, $p < .05$ at position 4). The N360 amplitudes were significantly larger in the attend S1 condition than in the attend S2 at each of the stimulus positions 1–3 ($F(1, 80) = 6.29$, $p < .05$ at position 1 ; $F(1, 80) = 13.48$ or more, $p < .01$ at positions 2 and 3). The N360 differences between the attend S1 and attend S2 conditions were smaller at position 1, became larger at positions 2–3.

ANOVA for attention by stimulus position effects revealed that the central P320 amplitude significantly decreased across stimulus positions 1–3 ($F(2, 48) = 6.12$, $p < .01$). The P480 amplitudes also decreased significantly across stimulus positions 1–3 ($F(2, 48) = 4.55$, $p < .05$ at F3 ; $F(2, 48) =$

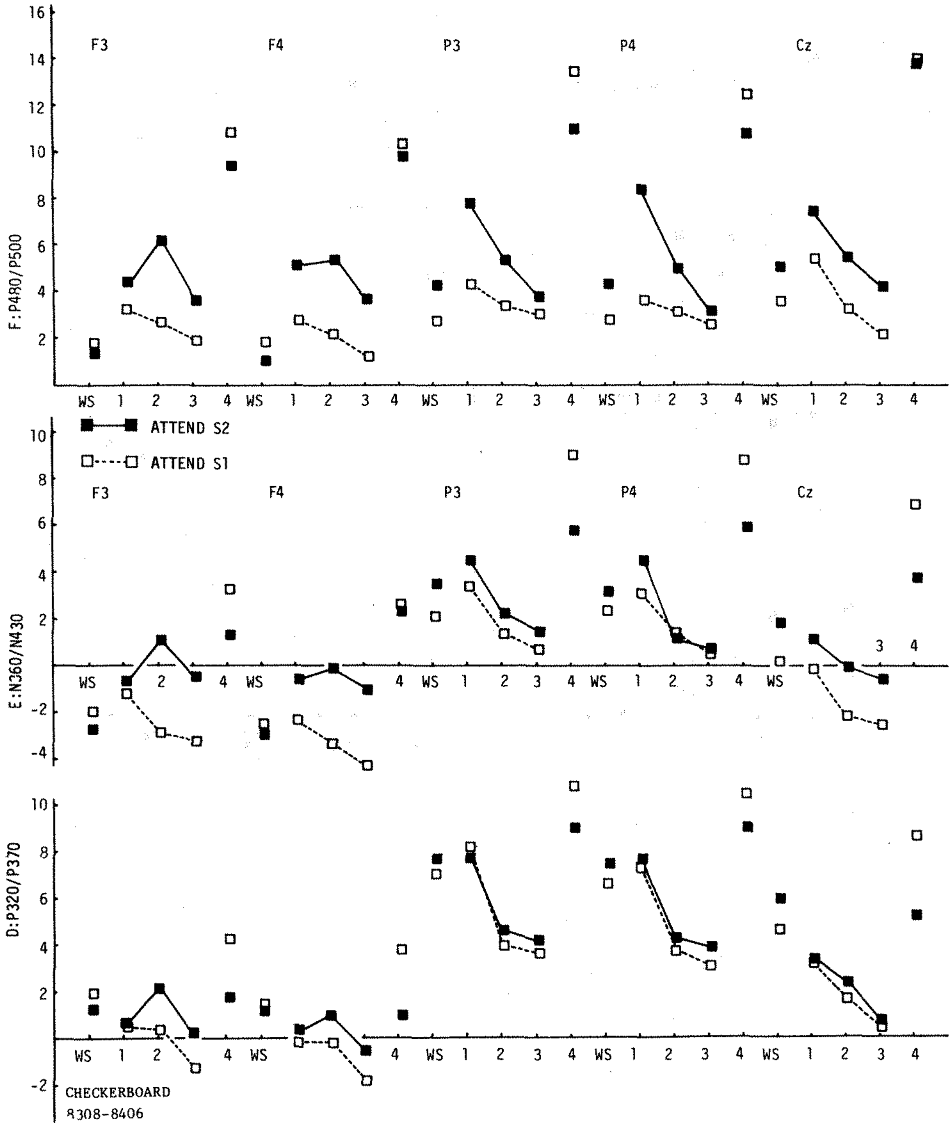

Fig. 9

Fig. 8 and 9.

Amplitude values of the checkerboard VEP waves across nine subjects recorded at the centro-frontal and parietal loci. Other details are the same as those in Fig. 4 and 5.

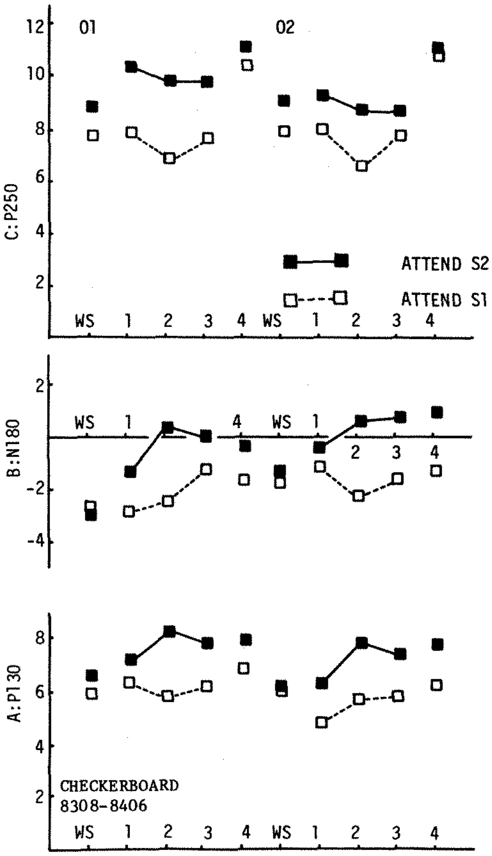

Fig. 10

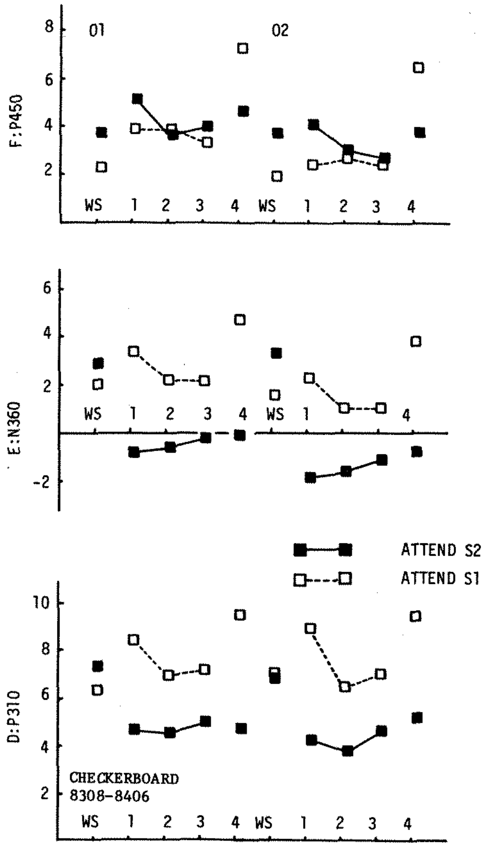

Fig. 11

Fig. 10 and 11.

Amplitude values of the checkerboard VEP waves across nine subjects recorded at the occipital loci. Other details are the same as those in Fig. 4 and 5.

7.75, $p < .01$ at Cz) and increased at position 4. For other components there were no significant attention nor position effect.

Parietal waves

The VEP waveforms in the attend S1 condition were quite similar to those in the attend S2 condition except P500. ANOVA for attention by stimulus position effects revealed that the P500 amplitudes were significantly larger in the attend S2 condition than in the attend S1 at P3 ($F(1, 48) = 4.39$, $p < .05$) but not at P4. The P370, N430 and P500 amplitudes were larger at stimulus position 1, decreased

Table 1. Mean amplitude and standard error in μV of major VEP waves (A–F) at five stimulus positions (WS and 1–4) obtained in the TM and MT conditions, mean latency of the A–F waves in msec across four positions (1–4), and ANOVA (n=9). Target stimulus: Number Electrode location: F 3 TM stands for the attend S1, MT for the attend S2.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1–3)	NOTES
A	TM	−4.8±0.6	−4.7±0.6	−4.9±0.7	−3.8±0.6	−3.5±0.5	136	F( )=	
	MT	−4.2±0.6	−4.3±0.7	−4.5±0.7	−4.7±0.7	−3.9±0.7	141	p<	
B	TM	1.9±1.2	3.7±0.4	3.5±0.6	3.0±0.7	4.1±0.6	193	F(1,48)=30.20	Condition
	MT	1.9±1.2	1.2±0.6	1.1±0.5	0.2±0.6	1.7±0.7	196	p<.01	
C	TM	−3.6±1.3	−1.6±1.4	−2.0±1.0	−2.7±0.9	−0.7±0.9	252	F( )=	
	MT	−3.0±1.2	−2.9±1.0	−3.3±0.9	−3.5±0.9	−3.0±1.5	252	p<	
D	TM	2.3±1.7	−0.3±0.9	−0.1±0.9	−1.6±0.7	2.0±1.0	293	F(1,48)=12.25	Condition
	MT	2.3±1.3	2.0±0.5	1.2±0.6	0.7±0.4	2.9±0.8	319	p<.01	
E	TM	−0.3±1.5	−2.6±0.9	−3.3±1.2	−4.3±0.6	−0.5±1.1	347	F(1,48)=18.36	Condition
	MT	−2.1±1.4	−0.6±0.7	−0.3±0.7	−0.9±0.7	1.2±1.0	370	p<.01	
F	TM	0.8±0.9	4.3±0.8	2.6±0.9	1.1±0.5	8.4±1.3	421 ④ 476	F(2,48)=4.55	Position
	MT	1.1±1.1	3.6±1.0	3.1±0.7	2.0±0.8	7.6±1.5	498 ④ 548	p<.05	

Table 2. Target stimulus: Number Elecrode location: F4 Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1–3)	NOTES
A	TM	−4.9±0.8	−5.0±0.5	−4.9±0.7	−3.9±0.6	−3.8±0.5	135	F( )=	
	MT	−4.1±0.7	−4.4±0.8	−5.0±0.7	−5.1±0.8	−4.4±1.0	139	p<	
B	TM	1.2±1.0	3.3±0.4	3.1±0.4	3.3±0.6	4.0±0.7	193	F(1,48)=37.81	Condition
	MT	1.6±1.1	1.1±0.5	1.0±0.4	0.2±0.6	1.7±0.8	198	p<.01	
C	TM	−3.3±1.4	−2.4±1.4	−2.8±1.0	−2.6±1.1	−0.2±0.9	250	F( )=	
	MT	−2.6±1.3	−3.1±1.0	−3.5±0.9	−3.9±1.2	−3.2±1.8	250	p<	
D	TM	2.3±1.5	−0.8±0.9	−0.9±0.9	−1.4±0.8	1.8±1.1	298	F(1,48)=13.38	Condition
	MT	2.4±1.4	1.9±0.5	1.0±0.6	0.3±0.3	3.5±0.6	317	p<.01	
E	TM	−0.3±1.7	−3.0±0.7	−4.2±1.1	−4.2±0.9	0.1±1.8	351	F(1,48)=27.10	Condition
	MT	−1.8±1.7	−0.1±0.7	−0.7±0.5	−0.9±0.4	1.3±1.0	371	p<.01	
F	TM	0.5±1.1	3.6±0.8	2.1±0.8	1.5±0.5	8.7±1.4	493 ④ 485	F( )=	
	MT	0.9±1.4	3.8±1.2	3.2±0.9	1.9±0.9	8.8±1.5	496 ④ 520	p<	

Table 3. Target stimulus: Number Elecrode location: P3 Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	−2.5±0.5	−1.6±0.8	−2.0±0.5	−1.8±0.8	−0.5±0.7	170	F( )=	
	MT	−3.1±0.9	−2.2±0.8	−2.8±0.8	−2.8±1.0	−1.1±0.7	173	p<	
B	TM	7.0±1.7	6.9±0.9	5.4±0.9	4.5±0.9	7.5±0.9	253	F( )=	
	MT	8.3±1.2	6.8±1.0	5.2±0.8	5.2±1.2	8.2±1.1	251	p<	
C	TM	4.6±2.1	3.9±1.4	1.6±1.2	1.4±1.0	5.2±1.2	313	F( )=	
	MT	5.4±1.5	3.0±0.9	1.0±0.7	1.3±0.9	2.9±0.8	317	p<	
D	TM	8.2±2.0	8.2±1.3	4.6±1.1	3.9±1.0	9.3±1.3	363	$F(2,48)=6.68$	Position
	MT	7.6±1.3	6.7±0.8	4.5±0.5	4.7±0.9	7.0±0.4	372	$p<.01$	
E	TM	2.5±1.1	4.0±1.2	1.9±0.5	0.7±1.0	7.9±1.9	422	$F(2,48)=7.13$	Position
	MT	1.7±1.2	4.7±1.0	2.1±0.6	1.4±1.0	4.3±0.6	434	$p<.01$	
F	TM	2.5±0.7	4.6±0.9	3.1±0.6	3.0±0.5	11.0±1.5	499 ④ 458	$F(1,48)=4.39$	Condition
	MT	2.1±1.1	7.0±1.3	4.1±0.8	4.0±0.9	10.1±1.2	528 ④ 570	$p<.05$	Position: $F(2,48)=4.54$ $p<.05$

Table 4. Target stimulus: Number Elecrode location: P4 Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	−2.0±0.6	−1.8±0.7	−2.2±0.5	−1.3±0.7	−0.5±0.7	166	F( )=	
	MT	−3.3±0.7	−0.7±0.8	−2.6±0.7	−3.0±1.0	−1.4±0.8	167	p<	
B	TM	7.6±1.6	6.5±1.0	4.7±0.9	4.9±1.0	7.3±1.1	252	F( )=	
	MT	8.7±1.3	6.5±1.1	4.8±0.8	4.7±1.1	7.4±1.0	246	p<	
C	TM	5.2±1.9	3.8±1.4	1.5±1.2	2.1±1.0	5.1±1.1	312	F( )=	
	MT	5.8±1.4	2.8±0.8	0.8±0.7	1.0±1.0	3.0±0.8	311	p<	
D	TM	8.1±1.9	7.7±1.3	4.2±1.1	4.5±0.9	9.5±1.0	367	$F(2,48)=6.80$	Position
	MT	7.7±1.6	7.1±1.2	4.0±0.8	4.0±0.9	6.7±0.6	366	$p<.01$	
E	TM	2.4±0.9	4.1±1.0	1.8±0.6	1.0±1.1	8.0±2.0	423	$F(2,48)=6.24$	Position
	MT	2.2±1.3	4.3±1.1	1.5±0.7	1.7±0.7	4.2±0.6	430	$p<.01$	
F	TM	3.0±0.7	4.9±0.8	2.8±0.4	2.7±0.5	10.3±1.4	506 ④ 464	$F(2,48)=5.09$	Position
	MT	2.7±1.3	6.5±1.5	3.6±0.9	3.7±0.9	10.4±1.3	532 ④ 560	$p<.01$	

Table 5. Target stimulus: Number Elecrode location: Cz Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	−4.0±0.6	−3.9±0.7	−4.3±0.8	−3.5±0.8	−2.8±0.7	134	F( )=	
	MT	−3.6±0.8	−3.5±0.9	−4.9±0.8	−4.9±1.0	−3.2±0.9	138	p<	
B	TM	3.2±1.4	4.4±0.7	3.3±0.5	3.4±0.7	5.6±0.8	192	F(1,48)=18.68	Condition
	MT	3.7±1.7	2.2±0.8	1.1±0.6	0.5±0.8	3.4±0.9	196	p<.01	
C	TM	−1.6±1.4	−0.3±1.1	−1.9±1.0	−1.9±0.8	1.7±0.8	251	F( )=	
	MT	−0.4±1.3	−1.4±0.8	−2.5±1.0	−3.0±1.3	−0.6±1.6	242	p<	
D	TM	5.5±2.1	3.0±1.1	1.5±0.9	−0.1±0.8	5.3±1.1	299	F(2,48)=6.12	Position
	MT	6.5±1.4	3.5±0.6	1.6±0.6	1.2±0.5	5.1±0.9	307	p<.01	
E	TM	2.1±2.1	−0.4±1.2	−2.7±1.0	−4.1±0.8	2.3±1.7	351	F(1,48)=16.23	Condition
	MT	1.6±1.3	1.2±0.5	0.2±0.8	−0.4±0.4	2.4±1.1	362	p<.01	
F	TM	3.3±0.9	5.1±0.9	3.2±0.4	1.7±0.4	10.5±1.7	486 ④ 462	F(2,48)=7.75	Position
	MT	2.9±1.4	5.9±1.3	3.0±0.9	2.9±0.9	11.6±1.9	506 ④ 587	p<.01	

Table 6. Target stimulus: Number Elecrode location: O1 Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	6.5±0.8	5.9±0.8	5.1±0.5	4.8±0.8	6.4±0.5	121	F(1,48)=5.52	Condition
	MT	6.7±0.8	6.8±0.5	7.0±0.9	6.4±0.9	6.7±0.8	126	p<.05	
B	TM	−2.5±0.8	−1.8±0.9	−2.3±0.5	−1.7±0.6	−1.2±0.8	176	F( )=	
	MT	−4.2±1.3	−1.9±1.1	0.1±1.3	−1.2±1.2	−1.3±1.3	180	p<	
C	TM	7.6±1.8	8.6±1.4	8.7±1.3	8.9±1.4	9.7±1.4	243	F( )=	
	MT	8.6±1.4	9.3±1.2	9.4±1.1	9.5±1.4	10.5±1.2	244	p<	
D	TM	7.1±1.3	9.0±1.4	7.6±0.8	8.0±0.9	8.6±1.2	314	F(1,48)=19.23	Condition
	MT	6.4±1.0	3.7±1.3	4.0±1.2	4.6±1.1	3.9±1.3	309	p<.01	
E	TM	2.4±1.2	3.4±1.2	3.0±0.6	3.1±1.0	4.2±1.1	377	F(1,48)=15.49	Condition
	MT	3.1±1.4	−0.3±1.0	0.3±0.7	0.7±0.9	−0.7±1.1	357	p<.01	
F	TM	3.2±0.9	4.8±1.3	4.2±0.7	4.7±0.8	6.3±1.3	436	F( )=	
	MT	1.9±1.2	5.3±1.0	4.6±0.6	4.7±0.8	2.4±1.3	430	p<	

Table 7. Target stimulus: Number Elecrode location: O2 Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	6.7±0.9	5.6±0.9	5.6±0.8	5.8±1.0	6.3±0.7	119	F(　)=	
	MT	6.3±1.1	6.1±1.3	6.6±1.2	6.1±1.2	7.5±1.3	125	p<	
B	TM	−1.6±1.1	−2.7±1.2	−2.4±0.9	−1.4±0.8	−1.0±1.1	172	F(　)=	
	MT	−2.1±1.3	−1.0±1.1	−0.8±1.2	−0.4±1.3	0.4±1.4	179	p<	
C	TM	8.4±1.8	8.5±1.2	8.4±1.2	9.7±1.4	10.3±1.4	243	F(　)=	
	MT	9.0±2.2	8.1±1.5	8.4±1.1	8.5±1.3	10.2±1.5	243	p<	
D	TM	8.3±1.3	9.1±1.5	7.5±0.9	8.9±1.1	9.5±1.5	309	F(1,48)=18.14	Condition
	MT	7.1±1.7	4.4±1.5	3.8±0.9	4.5±1.2	5.3±1.5	305	p<.01	
E	TM	3.0±1.3	2.4±1.3	2.7±0.9	2.5±1.0	4.0±0.9	378	F(1,48)=8.89	Condition
	MT	2.4±1.5	−1.0±1.3	−0.7±0.7	1.3±1.3	−0.3±1.0	358	p<.01	
F	TM	3.2±1.2	4.2±1.4	3.9±0.9	4.0±1.0	5.1±1.2	434	F(　)=	
	MT	2.3±1.3	3.5±1.3	3.3±0.9	3.5±0.8	2.0±1.4	433	p<	

Table 8. Target stimulus: Checker Elecrode location: F3 Other details are the same as those in Table 1.

POSITIONS / WAVES		WS	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	−4.5±0.5	−4.2±0.6	−3.8±0.5	−5.0±0.5	−4.1±0.7	138	F(　)=	
	MT	−4.6±0.7	−4.1±0.5	−4.4±0.8	−4.9±0.5	−4.6±0.7	144	p<	
B	TM	1.4±1.1	2.6±0.6	2.5±0.7	2.1±0.8	3.6±0.6	194	F(1,48)=4.06	Condition
	MT	1.2±1.1	1.6±0.5	1.2±0.6	0.9±0.9	−0.1±0.7	199	p<.05	
C	TM	−4.8±1.1	−1.8±0.7	−1.9±1.0	−2.5±0.8	−0.2±1.0	248	F(　)=	
	MT	−3.9±1.3	−2.4±0.8	−2.7±1.1	−4.3±1.1	−4.6±1.4	254	p<	
D	TM	1.8±1.4	0.3±0.8	0.2±1.0	−1.4±0.8	4.2±1.6	306	F(　)=	
	MT	1.1±1.3	0.5±0.5	2.0±1.2	0.1±1.0	1.6±0.9	310	p<	
E	TM	−2.1±1.3	−1.4±0.8	−3.1±1.1	−3.4±0.9	3.1±1.6	360	F(1,48)=12.07	Condition
	MT	−2.9±1.5	−0.8±0.6	0.9±0.9	−0.6±0.7	1.2±0.9	358	p<.01	
F	TM	1.6±1.0	3.1±0.9	2.4±0.7	1.7±0.7	10.6±1.9	484 ④ 454	F(1,48)=8.69	Condition
	MT	1.2±0.9	4.2±1.0	6.0±1.0	3.4±1.0	9.3±2.1	497 ④ 535	p<.01	

Table 9. Target stimulus: Checker Elecrode location: F4 Other details are the same as those in Table 1.

POSITIONS / WAVES		W S	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	−4.5±0.7	−4.6±0.5	−3.8±0.6	−5.2±0.5	−4.5±0.7	135	F( )=	
	MT	−4.8±0.6	−4.4±0.5	−4.8±0.8	−5.2±0.7	−4.7±0.7	144	p<	
B	TM	0.9±0.8	2.6±0.5	2.3±0.7	1.6±0.8	3.1±0.5	192	F(1,48)=8.75	Condition
	MT	0.8±1.0	1.4±0.3	0.3±0.7	0±0.8	−0.1±0.6	199	p<.01	
C	TM	−4.4±1.4	−2.3±0.7	−2.1±0.9	−3.2±0.9	−1.1±1.1	250	F( )=	
	MT	−3.5±1.4	−2.1±0.5	−4.0±1.3	−4.8±1.3	−4.3±1.4	256	p<	
D	TM	1.3±1.3	−0.3±0.7	−0.3±1.1	−1.9±1.0	3.7±1.5	308	F( )=	
	MT	1.1±1.2	0.2±0.5	0.8±1.3	−0.6±1.0	0.9±1.0	314	p<	
E	TM	−2.7±1.6	−2.5±1.1	−3.5±1.0	−4.5±0.8	2.4±1.8	357	F(1,48)=14.44	Condition
	MT	−3.1±1.5	−0.7±0.7	−0.3±0.9	−1.2±0.8	2.2±1.6	364	p<.01	
F	TM	1.6±1.2	2.6±1.1	1.9±0.5	1.0±0.7	10.1±2.0	476 ④447	F(1,48)=12.40	Condition
	MT	0.8±1.1	4.9±1.1	5.2±1.2	3.5±0.9	9.6±2.2	501 ④551	p<.01	

Table 10. Target stimulus: Checker Elecrode location: P3 Other details are the same as those in Table 1.

POSITIONS / WAVES		W S	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	−3.3±1.0	−2.6±0.5	−2.7±0.8	−3.0±0.8	−1.1±0.5	175	F( )=	
	MT	−2.8±1.0	−2.1±0.8	−2.1±0.7	−2.6±0.8	−1.6±0.6	175	p<	
B	TM	5.4±1.6	6.3±1.1	4.1±1.1	3.5±1.1	8.2±1.1	252	F( )=	
	MT	7.9±1.3	7.3±1.2	5.6±1.0	4.7±1.2	7.6±1.3	255	p<	
C	TM	2.6±2.0	4.6±1.2	1.4±1.4	1.1±1.2	7.2±1.4	304	F(2,48)=3.29	Position
	MT	5.4±1.8	2.6±1.4	1.0±1.3	0.2±1.1	3.1±1.1	321	p<.05	
D	TM	6.9±1.8	8.1±1.3	3.8±1.4	3.5±1.0	10.7±1.6	355	F(2,48)=7.97	Position
	MT	7.6±1.4	7.6±1.2	4.5±0.8	4.1±0.8	8.9±1.2	381	p<.01	
E	TM	1.9±1.3	3.2±1.4	1.2±1.2	0.5±1.0	8.8±2.2	417	F(2,48)=3.50	Position
	MT	3.3±0.9	4.3±1.2	2.0±1.0	1.3±1.0	5.7±1.3	455	p<.05	
F	TM	2.5±0.9	4.1±0.8	3.2±1.1	2.8±0.9	13.3±2.0	493 ④456	F(1,48)=7.14	Condition
	MT	4.0±1.1	7.6±1.1	5.1±0.9	3.6±0.9	10.8±1.6	531 ④560	p<.05	Position: F(2,48)=4.04 p<.05

Table 11. Target stimulus: Checker Elecrode location: P4 Other details are the same as those in Table 1.

POSITIONS / WAVES	W S	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A TM	−3.3±1.0	−2.3±0.8	−2.3±0.7	−2.9±0.8	−0.8±0.7	170	F( )=	
MT	−2.8±0.8	−1.2±0.8	−2.3±0.6	−2.6±0.8	−1.5±0.7	171	p<	
B TM	5.3±1.5	6.1±1.2	3.7±1.0	3.4±1.3	8.2±1.3	251	F( )=	
MT	8.5±1.2	7.1±1.1	5.1±0.9	4.5±1.1	7.8±1.3	253	p<	
C TM	2.8±1.8	4.0±1.6	1.2±1.1	0.1±1.3	7.1±1.5	300	F (2,48) =4.02	Position
MT	5.9±1.6	2.1±1.3	−0.1±1.2	−0.8±0.8	2.8±1.6	318	p <.05	
D TM	6.5±1.7	7.2±1.5	3.6±1.4	3.0±1.2	10.3±1.7	359	F (2,48) =5.99	Position
MT	7.3±1.4	7.5±1.3	4.2±1.1	3.8±0.9	8.9±1.7	379	p <.01	
E TM	2.1±1.2	2.9±1.2	1.2±1.2	0.3±1.3	8.6±2.2	412	F (2,48) =3.50	Position
MT	3.0±1.1	4.4±1.6	1.1±1.1	0.6±1.2	5.8±1.7	448	p <.05	
F TM	2.6±0.8	3.4±0.9	2.9±0.7	2.4±0.9	12.3±1.9	495 ④ 457	F (1,48) =8.36	Condition
MT	4.1±1.0	8.1±1.2	4.8±1.2	2.9±1.0	10.5±1.7	524 ④ 555	p <.01	Position: F(2,48) = 4.96 p<.05

Table 12. Target stimulus: Checker Elecrode location: Cz Other details are the same as those in Table 1.

POSITIONS / WAVES	W S	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A TM	−3.5±0.4	−3.6±0.6	−3.6±0.6	−4.9±0.8	−3.5±0.7	131	F( )=	
MT	−3.4±0.7	−3.7±0.5	−4.7±0.7	−4.8±0.8	−3.8±0.7	141	p<	
B TM	3.1±1.1	3.8±0.8	2.8±1.0	2.1±1.0	5.7±0.8	196	F (1,48) =4.06	Condition
MT	3.0±1.5	3.0±0.7	0.8±0.8	0.6±1.0	2.2±0.8	199	p <.05	
C TM	−2.9±1.6	−0.3±0.8	−0.8±0.9	−2.1±0.8	2.8±1.2	243	F( )=	
MT	−0.7±1.5	−0.3±0.7	−2.5±1.2	−3.5±1.3	−0.8±1.3	246	p<	
D TM	4.5±1.9	3.1±1.1	1.6±1.1	0.3±0.9	8.5±1.9	296	F (2,48) =3.76	Position
MT	5.9±1.6	3.3±0.6	2.3±1.2	0.7±0.9	5.2±1.6	304	p <.05	
E TM	0±2.2	−0.3±1.5	−2.4±1.1	−2.7±1.2	6.7±2.3	349	F (1,48) =4.09	Condition
MT	1.7±1.6	1.0±1.0	−0.2±1.0	−0.7±0.7	3.7±1.4	356	p <.05	
F TM	3.4±1.4	5.2±1.5	3.1±0.7	2.0±0.9	13.8±2.4	485 ④ 448	F (1,48) =5.48	Condition
MT	4.8±1.6	7.2±1.0	5.2±1.2	4.0±0.9	13.6±2.3	493 ④ 541	p <.05	Position: F(2,48) = 4.65 p<.05

Table 13. Taget stimulus: Checker Elecrode location: O1 Other details are the same as those in Table 1.

POSITIONS / WAVES		W S	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	5.8±0.7	6.2±0.6	5.6±0.7	6.0±0.7	6.7±0.7	123	F (1,48)=6.59	Condition
	MT	6.4±0.7	7.1±0.6	8.1±1.0	7.6±1.0	7.8±1.0	127	p <.05	
B	TM	−2.8±1.2	−3.0±0.6	−2.6±0.7	−1.4±1.3	−1.8±0.6	180	F (1,48) =6.35	Condition
	MT	−3.2±1.1	−1.5±1.1	0.2±1.0	−0.1±0.7	−0.5±0.9	178	p <.05	
C	TM	7.5±1.5	7.7±1.3	6.6±1.2	7.4±1.2	10.2±1.2	243	F (1,48) =6.18	Condition
	MT	8.7±1.2	10.2±1.5	9.7±1.2	9.6±1.1	10.9±1.5	244	p <.05	
D	TM	6.0±1.5	8.1±1.1	6.6±0.8	6.8±0.9	9.2±1.1	320	F (1,48) =9.56	Condition
	MT	7.0±1.0	4.4±1.3	4.2±1.3	4.7±1.0	4.4±1.3	311	p <.01	
E	TM	1.9±1.3	3.2±1.0	2.0±1.0	2.0±0.8	4.6±1.0	378	F (1,48)=19.50	Condition
	MT	2.7±1.1	−1.0±0.8	−0.8±1.0	−0.4±0.7	−0.3±1.0	366	p <.01	
F	TM	2.1±0.9	3.7±1.1	3.7±0.8	3.2±0.7	7.1±1.5	444	F ( )=	
	MT	3.4±0.9	4.9±1.2	3.4±0.7	3.8±0.9	4.4±1.4	434	p <	

Table 14. Target stimulus: Checker Elecrode location: O2 Other details are the same as those in Table 1.

POSITIONS / WAVES		W S	1	2	3	4	MEAN LATENCY	ANOVA (POSITIONS 1−3)	NOTES
A	TM	5.8±0.8	4.6±1.3	5.5±0.8	5.6±1.0	6.1±1.0	120	F ( )=	
	MT	6.0±0.8	6.1±0.9	7.7±1.2	7.2±1.1	7.6±1.3	126	p <	
B	TM	−1.9±1.1	−1.3±1.7	−2.4±1.0	−1.8±1.1	−1.5±0.9	179	F ( )=	
	MT	−1.5±1.2	−0.6±1.1	0.4±1.4	0.6±1.0	0.8±1.2	177	p <	
C	TM	7.7±1.7	7.7±1.3	6.4±1.1	7.6±1.5	10.6±1.4	247	F ( )=	
	MT	8.9±1.6	9.1±1.3	8.5±1.1	8.5±1.2	10.9±1.5	245	p <	
D	TM	6.7±2.2	8.6±1.5	6.2±0.8	6.7±1.2	9.2±1.5	314	F (1,48) =9.37	Condition
	MT	6.5±1.3	4.0±1.8	3.5±1.1	4.4±1.1	4.9±2.2	311	p <.01	
E	TM	1.4±1.4	2.1±1.1	0.9±1.2	0.9±0.9	3.7±1.1	377	F (1,48) =10.08	Condition
	MT	3.1±1.3	−2.1±1.2	−1.8±1.3	−1.3±1.3	−0.9±1.4	366	p <.01	
F	TM	1.8±0.9	2.3±0.9	2.5±0.7	2.2±0.7	6.3±1.3	443	F ( )=	
	MT	3.5±1.0	3.9±1.2	2.9±1.2	2.6±1.0	3.6±1.5	441	p <	

significantly at positions 2–3 ($F(2, 48) = 5.09$ or more, $p < .01$ at P3 and P4) and then increased at position 4. Other components showed no attention nor position effect.

Latency of P480/P500

Latencies of the centro-frontal P480 and parietal P500 were longer in the attend S2 condition than in the attend S1 by about 100 msec. This was observed at stimulus position 4, but not at positions 1–3. Mean latencies across 5 electrode loci were 470 msec in the attend S1 condition and 560 msec in the attend S2. Latency differences between the attend S1 and attend S2 conditions were significant for all electrode loci except F4 ($t = 2.3$, $p < .05$ at F3; $t = 3.47$, or more, $p < .01$ at P3, P4 and Cz).

Occipital waves

At WS position, the VEP waveforms in the attend S1 condition were almost the same as in the attend S2 condition. At stimulus positions 1–4, the waveforms were different between the attend S1 and attend S2 conditions.

The waves with latencies shorter than 250 msec were more negative in the attend S1 condition, that is, the P130 was smaller and the N180 was larger in amplitude in the attend S1 condition than in the attend S2. ANOVA for attention by stimulus position effects revealed the significant attention effects upon these waves (in the number trial, for the P130 at O1, $F(1, 48) = 5.52$, $p < .05$; in the checkerboard trial, for the P130 at O1, $F(1, 48) = 6.59$, $p < .05$; for the N180 at O1, $F(1, 48) = 6.35$, $p < .05$).

The waves with latencies longer than 300 msec were more negative in the attend S2 condition, that is, the P310 was smaller and the N360 was larger in amplitude in the attend S2 condition than in the attend S1 (actually the P310 was not obvious in the attend S2 condition, so the P310 amplitude was measured at the point with latency of 310 msec; the N360 amplitudes were positive at all of the stimulus positions 1–4 in the attend S1 condition, but named N360 for convenience). ANOVA revealed that these amplitude differences between the attend S1 and attend S2 conditions were significant (in the number trail, for the P310, $F(1, 48) = 19.23$, $p < .01$ at O1, $F(1, 48) = 18.14$, $p < .01$ at O2; for the N360, $F(1, 48) = 15.49$, $p < .01$ at O1, $F(1, 48) = 8.89$, $p < .01$ at O2; for the checkerboard trial, for the P130, $F(1, 48) = 9.56$, $p < .01$ at O1, $F(1, 48) = 9.39$, $p < .01$ at O2; for the N360, $F(1, 48) = 19.50$, $p < .01$ at O1, $F(1,48) = 10.08$, $p < .01$ at O2). The P310 was smaller in amplitude at position 2 than at position 1 in the attend S1 condition, but not significant.

Residual waveforms of the extraction of the occipital and central VEPs in the attend S2 condition from those in the attend S1 are shown in Fig. 12 (the number VEP) and Fig. 13 (the checkerboard VEP). Positive deflection of the early components of the checkerboard VEP reflect more negative distribution of these components in the attend S1 VEP. Negative deflection of the later components of the number and checkerboard VEPs reflect more negative distribution of these components in the attend S2 VEP.

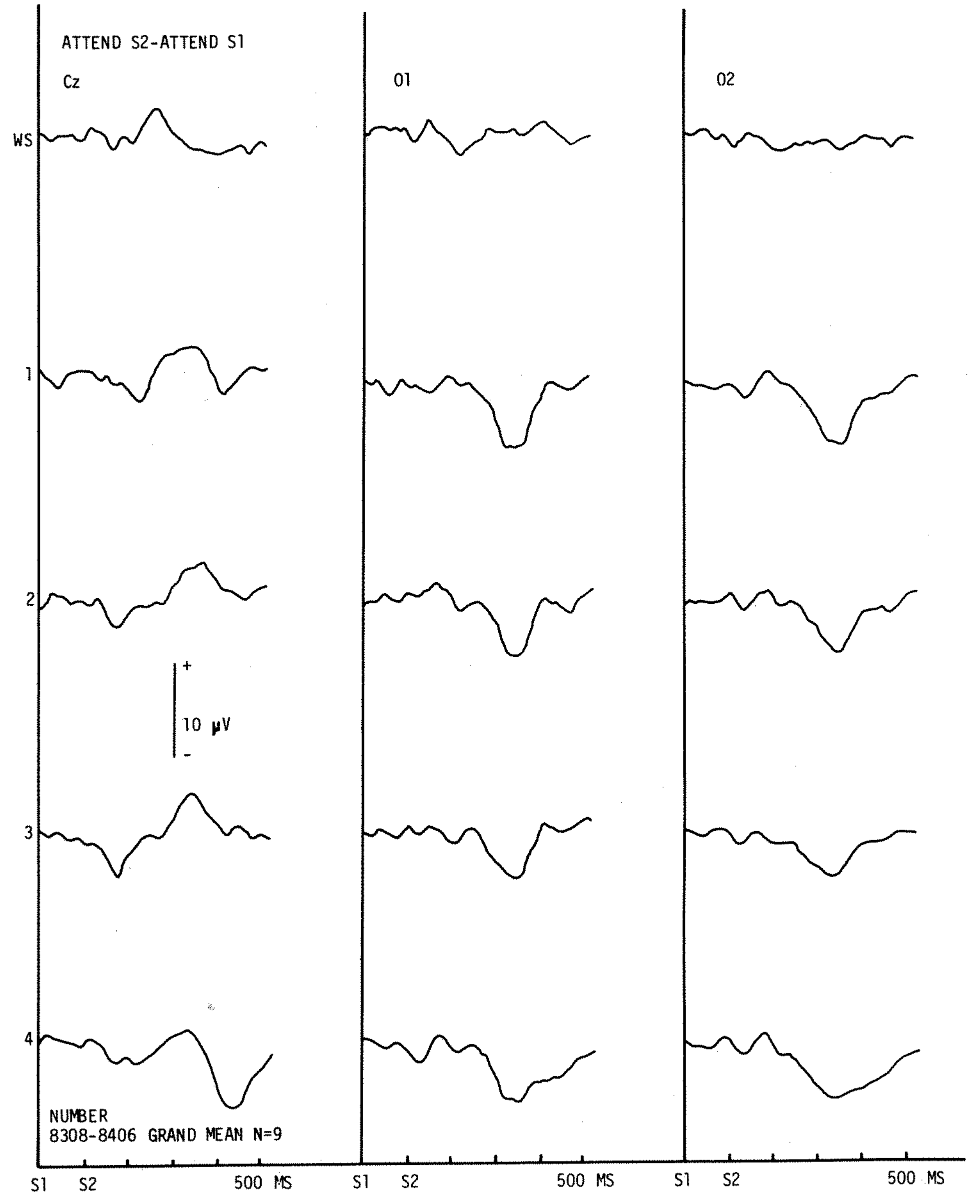

Fig. 12.

The central and occipital residual waveforms of the number VEP between the attend S1 and attend S2 conditions. The attend-S1 VEP was subtracted from the attend-S2 VEP.

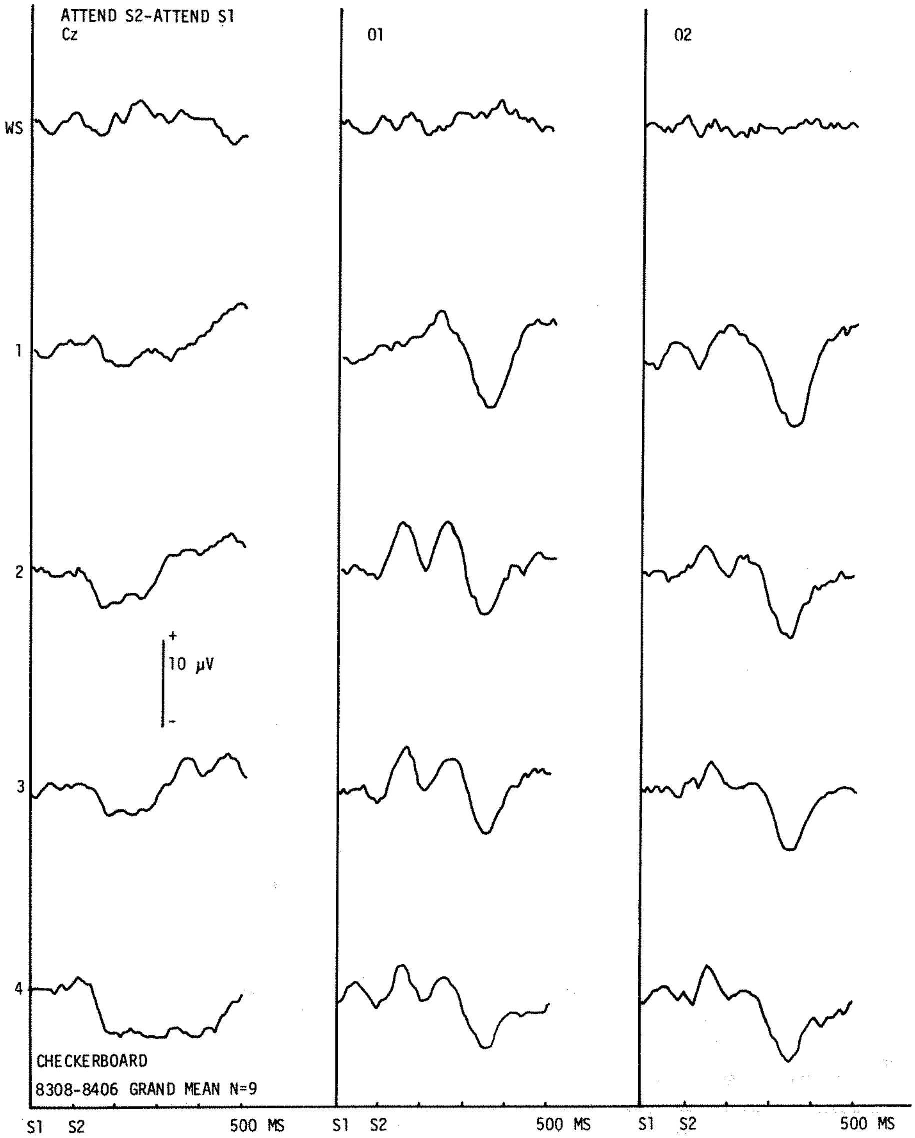

Fig. 13.

The central and occipital residual waveforms of the checkerboard VEP between the attend S1 and attend S2 conditions. The attend-S1 VEP was subtracted from the attend-S2 VEP.

Discussion

The major finding in this experiment was that early occipital waves (P130, N180) of the S1–S2 VEP were more negative when S1 was attended than when S2 was attended. Another was that later occipital waves (P310, N360) were more negative when S2 was attended than when S1 was attended. These facts seem to coincide with enlarged N170 reported in relation to the spatial allocation of attention (Eason, 1981 ; Harter et al., 1982 ; Hillyard and Münte, 1984).

Due to a shortage of the experiment design, the N360 can not be indentified as evoked exclusively by S2. Further difficulty was that, even if the N360 was evoked by S2, the N360 amplitude difference between the attend S1 and attend S2 conditions might be explained in terms of different S2 pattern in these conditions : S2 was the random pattern in the attend S1 condition, whereas it was the number or checkerboard in the attend S2 condition.

The latency of the N360 from S2 is 260 msec. This figure is close to the latency of the Na and N2 in Simson et al. (1977a) and Ritter et al. (1982 ; 1983) and N235 in Harter and Salmon (1972), Harter and Previc (1978) and Harter and Guido (1980). The task relevant stimuli in these studies were presented at random with low probability among the task irrelevant stimuli, whereas in this experiment S2 in the attend S2 condition was always task relevant and presented in all trials. Therefore, it is questionable to regard the N360 as the processing negativity in response to S2. The N360 is probably the attention-related negative wave of the S1–S2 VEP.

The occipital VEP waves with latencies shorter than 250 msec showed differential effects of attention allocation between the number and checkerboard VEPs. The effects were more remarkable in the checkerboard VEP than in the number VEP.

This confirmed the hypothesis that the effect of attention on the negative wave of the occipital VEP can be revealed by the temporal allocation of attention either to S1 or S2, and also confirmed previous findings that attention effect on the occipital negative waves is more remarkable when the subject's task is more difficult.

Another finding was the amplitude increase of the centro-frontal positive waves in relation to the attended stimulus. The centro-frontal deflections with latencies shorter than 250 msec were more positive in the attend S1 condition and these deflections with latencies longer than 300 msec were more positive in the attend S2 condition. In contrast to the results in Van Voorhis and Hillyard (1977) the centrofrontal N140 to S1 and N250 to S2 (corresponding to N140 to S1) did not show amplitude differences between the attend S1 and attend S2 conditions. The attention-related positive enhancement of the centro-frontal VEP waves seems to coincide with the fidings in Courchesne's studies (Courchesne et al., 1975 ; 1977 ; 1978) which have shown that a target letter stimulus can evoke larger amplitude of the central P200 than a background letter stimulus. The centro-frontal N140 may be more sensitive to the diffuse stimulus whereas the P200 may be more sensitive to the pattern stimulus in relation to attention allocation.

There was no remarkable development of later negative waves in the attend-S1 VEP. Hypothesized interaction effect of S2 on the later negative waves of the attend-S1 VEP was not proved.

Summary

Two pattern stimuli, S1 and S2, were presented using xenon flashes with 100 msec ISI. In the attend S1 condition S1 was a task relevant target stimulus (TS) and S2 a task irrelevant masking stimulus (MS), whereas in the attend S2 condition S1 was the MS and S2 the TS. The MS was a random pattern and the TS a number (0 and 2–9) or a checkerboard. A warning stimulus (WS) was composed of two MS's with 100 msec ISI. A trial was composed of WS, a triplet consisting of three identical S1–S2 pairs (intratrial positions 1–3) and a single S1–S2 pair (position 4) presented in sequence. The male college students were paid to participate in the experiment. The subject's task was naming the numbers in positions 1–3 and 4, or the pattern-matching of the checkerboards between positions 1–3 and 4. EEG responses were recorded monopolarly from F3, F4, P3, P4, Cz, O1 and O2 in the international 10–20 system with reference to linked ears. Each of the number and checkerboard VEPs was obtained by averaging eighty EEG responses. The amplitude of the VEP wave was measured from the base line and the latency from S1 onset. Early occipital waves of the S1–S2 VEP (including the N180) were significantly more negative in the attend S1 condition than in the attend S2. Later waves of the VEP (including N360) were more negative in the attend S2 condition than in the attend S1.

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