

THE LATENCY OF BINOCULAR SUPPRESSION IN THE
EEG OF MAN

by

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ABSTRACT

The latency or binocular suppression (reported by Lansing and Van Balen) has been found to be approximately 220 msec. This is very close to the latency of alpha blocking and suggests that the mechanism may be similar physiologically. Of the forty subjects tested, only four were found to exhibit the suppression to a degree necessary to secure a large number of measures of the phenomenon.

INTRODUCTION

In normal binocular vision, the slightly different visual fields fuse forming a single impression. If, however, there is considerable difference in the two fields, it is found that one of the two fields is suppressed and we are aware of only the material in the non-suppressed field. This phenomenon is not a stable one however. Under certain conditions, the two fields fluctuate with suppression shifting from one field to the other or from parts of one field to the other.

Binocular suppression is an easily produced phenomenon and represents a condition investigated under the heading of the classical perceptual problem in psychology known as "binocular rivalry" or "retinal rivalry." The suppression phenomenon is related to the fusion mechanism of binocular vision and is an important variation on the normal binocular fusion process.

Van Balen (1964) and Lansing (1964) found that EEG patterns were modified by the suppression mechanism. These findings opened the binocular rivalry problem to direct physiological investigation. Working separately, these investigators found that by recording the

photically driven response to stimulation in one eye and presenting a stimulus to the other eye, a clear indication of the suppression phenomenon could be seen in EEG records. The driven potentials were recorded when the eye receiving the flashing light was dominant and the driven waves were suppressed when the eye receiving a constant stimulus was dominant.

The purpose of this study is to investigate the time course of the EEG changes accompanying suppression. In particular, the latency of the binocular suppression phenomenon has been studied in an attempt to determine at what level in the nervous system the phenomenon of suppression is taking place. The latency of the suppression phenomenon would also give us a chance to compare the perceptual phenomenon with the recorded EEG change on the basis of time of occurrence.

HISTORY

Investigators of binocular rivalry fall into two broad categories: those who study the stimuli that bring about rivalry, and those who attempt to explore the physiological basis of the phenomenon.

Early investigators, Helmholtz (1925), and Breese (1909), clearly identified the conditions that produce rivalry. Their findings, in general, were that with identical stimulus manipulation of both monocular fields, the rate of rivalry or alternation between fields was found to increase with increases of light intensity, area of field, distinctness of lines, and with shift of target location from peripheral to foveal vision. The dominance of a field (in terms of percentage of time of visibility) was increased by the presence of movement in the field, by the presence of contours or figures, and by increase of illumination of the field. Breese concluded that rivalry was controlled by some central, involuntary process closely related to attention. This interpretation assumes that peripheral retinal events are not significant variables for an explanation of rivalry.

Further evidence pointing to a central mechanism responsible for the rivalry phenomenon has been gathered by many workers. Peckham (1936), Fry (1936), Bárány and Hallden (1947 and 1948), and Kaufman (1963) have shown that peripheral events such as pupil size, eye blinking, and eye movements were not responsible for the rate of rivalry.

Attempts have been made to get at the nature of the central process responsible for the phenomenon of binocular rivalry. Alexander (1951) found that "strong" figures will alternate more rapidly than "weak" figures. He feels that the data substantiates the hypothesis of Köhler and Wallach (1944) that strong figures produce "cortical satiation" and are related to the spread of broad cortical potentials.

Fox (1963) investigated visual sensitivity during binocular rivalry suppression. He attempted to evaluate models relating binocular suppression to habituation, scanning mechanisms, and afferent inhibition. These models represent different kinds of central processes. He concluded that habituation probably played no role in suppression, that no simple "scanning" model would answer all questions in rivalry, and that the afferent inhibition model is not adequate. He concludes that none of the models clearly indicates the nature of suppression.

Crain (1961) investigating the relationship between rate of rivalry and intelligence (in which he found no significant relationship) postulated a relationship might exist between rivalry and the alpha rhythm. He proceeded to examine EEG records taken during binocular rivalry experiments but could find no clear relationship to exist. This was the first attempt to measure the central process related to rivalry.

One method of obtaining information about the nature of the physiological mechanism is through a study of latency. It would be helpful to examine the background of electrophysiological measures of latency in the visual system from several directions. First, the background of the latency of evoked potentials in the visual system will be examined. Second, the latency of the blocking or flicker or photically driven potentials will be considered. Lastly, the latency of alpha blocking as a comparative measure will be reviewed.

Electrophysiological Latencies

in the Visual System

1. Visually evoked cortical potentials. The first recorded cortical event in response to a flash of light occurs as early as 12 msec. after a 35 msec. flash or 47 msec. after the initiation of the stimulus

(Fisher 1934). This appears as a positive deflection of the oscillograph record. A slow negative deflection follows the positive wave and is regarded as the electrical concomitant of discharging cortical neurons.

A secondary response begins about 70 msec. after the flash and is a positive deflection (Forbes 1939).

The third event is a fast after-discharge demonstrated by Bremer (1950) and is interpreted as a transitory intensification of spontaneous cortical activity. There may be as many as ten repetitive postsynaptic waves following a brief stimulus. Some of the above responses are not seen at stimulus rates of over four cps.

Adrian and Matthews (1927) demonstrated in the eel that increase of intensity and area seems to reduce the latency in the optic nerve.

Bartley (1936) found no single element of the cortex to be responding to higher frequency stimulation. In this situation, a syncopated response occurs. A waxing and waning of excitability of various cortical neurons was found when working with successive stimulation.

2. Rhythmically evoked potentials. Specific data on the latency of the photically driven or flicker potentials may be slightly different from evoked potentials as indicated by Van Hof (1960). Using an averaging method, Van Hof found certain constant features in the

records of cortical responses to flicker. First, a large surface negative wave appears with a latency of 75 to 100 msec.; this is followed with a surface positive wave with a latency of 110 to 165 msec. The total duration of the response varies between about 250 msec. and well over 330 msec.

Toman (1941) compared photically driven potentials and alpha rhythm data. He found that the optimal effect of flicker potentials is in the alpha range but that alpha and photically driven potentials do not have an identical distribution over the cortical areas. It was also observed that after-effects of the driving could be noticed after stimuli had been removed.

3. Alpha rhythm blocking. The blocking of the alpha rhythm by visual stimuli will be considered for comparison to blocking of flicker and the latency of evoked potentials. Monnier (1949) investigated the response of the ERG and EEG to brief light stimulation. He found that cortical response could be found before the appearance of the b wave of the ERG. Motor reaction time begins about 110 msec. after the flash. The alpha blocking time occurs 215 ± 45 msec. after the stimuli and is subject to "emotional" conditions. He postulated a cortico-subcortical reverberating mechanism involved in the "reaction d'arret."

Cruikshank (1937) found values of latency of alpha blocking to be between 167 msec. and 589 msec. depending on the strength of the stimulus. Jasper and Cruikshank (1937) found that latency decreased from 280 msec. to 250 msec. under passive and active conditions and to 200 msec. when a vague sound was used as a fore-signal to the stimulus. Stamm (1952) points out that reaction time is often shorter than alpha blocking time indicating that there may not be a significant relationship between the two variables.

It is generally believed that the mechanism for alpha blocking is related to the diffuse reticular actuating system. This accounts for the long delay involved in alpha blocking. The blocking appears to be more closely related to attention rather than to the more direct connections of the visual process (Lindsley 1960).

In the present study, the measurement of suppression of photic driving under conditions of rivalry showed that the response latency is similar to that of alpha blocking.

METHOD

Subjects

The subjects were 40 students enrolled at the University of Arizona. Of the total, 22 were found to exhibit some drifting with the light presented to one eye. Of this group, 4 were found to illustrate clearly the blocking or suppression phenomenon. The 4 subjects were male, with a mean age of 22 years (range 18 to 25 years). One of the subjects had had previous experience in EEG experiments.

The subjects were tested for visual defects that might effect binocular suppression. A Bausch and Lomb orthorater was used to measure lateral and vertical phorea. This measure indicated muscular imbalance that may cause the eyes to drift from their attention to the visual field. Two of the subjects showed considerable lateral phorea but this did not seem to effect their record appreciably.

Apparatus

The apparatus was essentially the same as that used by Lansing (1965) and is shown in "Block Diagram Apparatus," p. 11. Stimuli were presented to the separate fields of a modified stereoscope. The PS-T2 photo lamp of a Grass PS 2

photostimulator was mounted in a tube delivering bright light pulses to the left eye. A frequency of from 6 to 15 cps was used with maximum brightness setting on the PS 2 stimulator. This illuminated the left stereoscope field after passing through a diffusion glass and produced a brightness of 864 millilamberts. A visual angle of 54° horizontally and 35° vertically was subtended by stimuli presented to both eyes. An eye fixation target, a small cross, was placed in the center of the left field.

In the right eye, a red stimulus light of .51 millilamberts was presented on a field of black diagonal stripes. The stimulus light was a Sylvania R 1131C glow modulator tube powered by a Heath regulated power supply at 150 volts and 70 milliamperes. The pulse was triggered by a Grass S4 stimulator through a relay for a duration of 50 msec.

A Grass Model 5 polygraph was used to record cortical activity and used also to record the presentation of stimuli. The recording paper was run at a speed of 120 mm per second. A narrowly-tuned filter (Becker et al. 1958) with a Q value of approximately 28 was set at the flash frequency. The filter writeout was recorded on a separate channel of the polygraph. (See "Block Diagram of Apparatus," p. 11.)

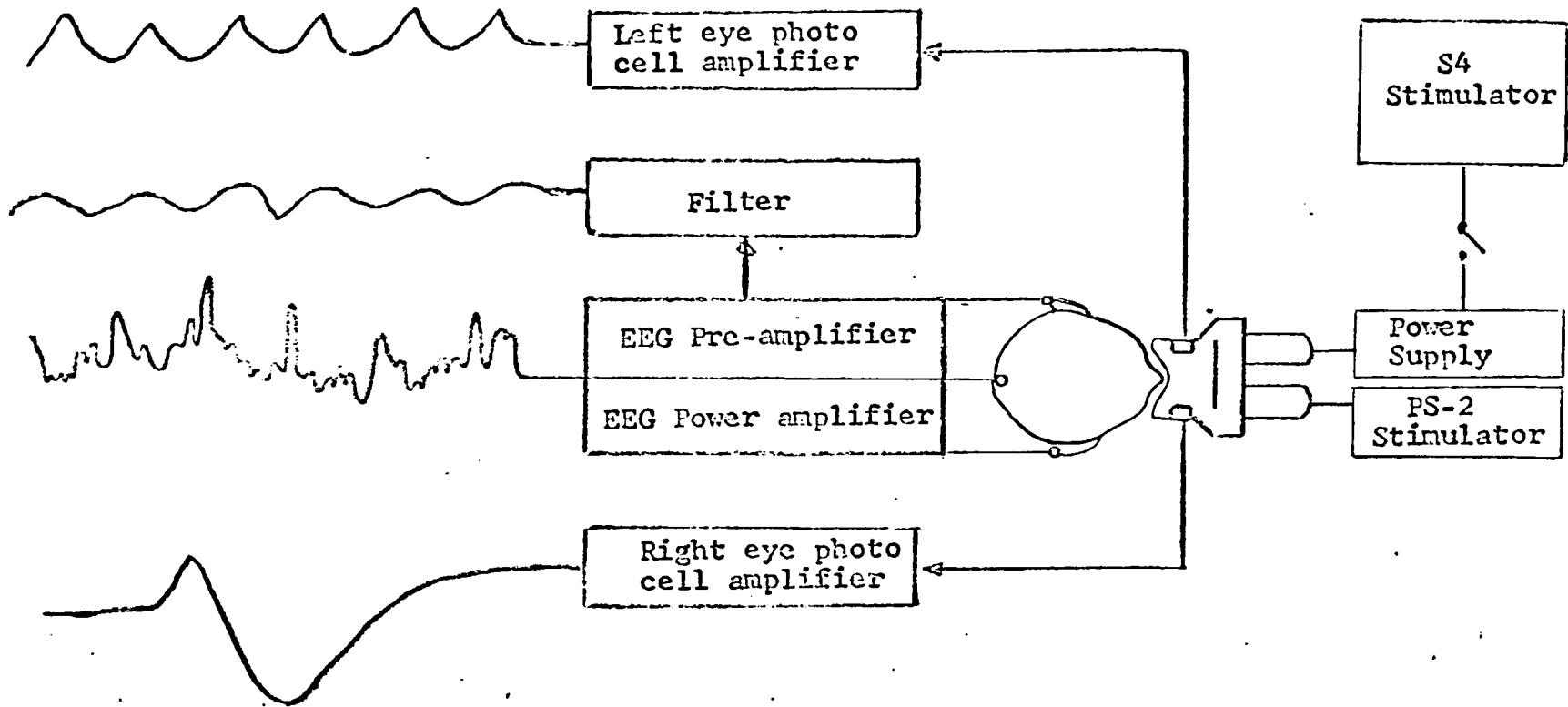


Fig. 1 BLOCK DIAGRAM OF APPARATUS

During the last part of the experiment, it was possible to deliver stimuli to the right eye only when the filter record was indicating photic driving was taking place. A small sensitive microswitch was placed next to the pen writeout of the filter. As the deflection of the pen reached a predetermined magnitude, the microswitch was triggered and the pulses could be delivered manually from the S4 to the light source for the right eye.

A silver disc electrode with bentonite sodium chloride paste was placed 3 cm. above the inion and was used with an indifferent electrode on the ear lobe.

EEG Recording Procedure

The subjects were first tested to ascertain normal and resting EEG records. One minute of record was taken with eyes open and one minute with eyes closed. A photic driving survey was then made with eyes open and attending to the flashing light in the left eye. Fifteen seconds' exposure to each frequency was recorded and a fifteen-second interval spaced between each frequency. Frequencies used were: 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 cps. Subject's response to various frequencies was visually analyzed with the help of the filter record and the frequency at which maximal driving was observed

was used in the main part of the experiment. Paper speed was 120 mm/sec., allowing an accuracy of reading of less than 5 msec. on the EEG paper. The accuracy of the reading was checked by using a "Visicorder" oscillograph to observe a number of reactions.

RESULTS

In order to measure latency of the suppression phenomenon, it was necessary to use only those records that clearly indicated suppression of the driven waves. Records were used that showed driving activity completely obliterated or distinctly changed following presentation of the stimulus to the right eye. Latent time was the interval between the initiation of the stimulus and the beginning of the blocking period.

Each subject was presented with the suppression stimulus 100 times during the course of the experiment. From the four subjects used, a total of 203 reactions was obtained that clearly indicated the binocular suppression reaction on the EEG records. The results are shown in Tables I and II.

The range of suppression times ran from less than 100 msec. to over 400 msec. Some of these reactions may be attributed to factors other than suppression. Photic driving was found to stop spontaneously on some occasions which may account for the very short latencies. This fact may account also for long latencies that were among those that caused no real suppression but simply stopped spontaneously.

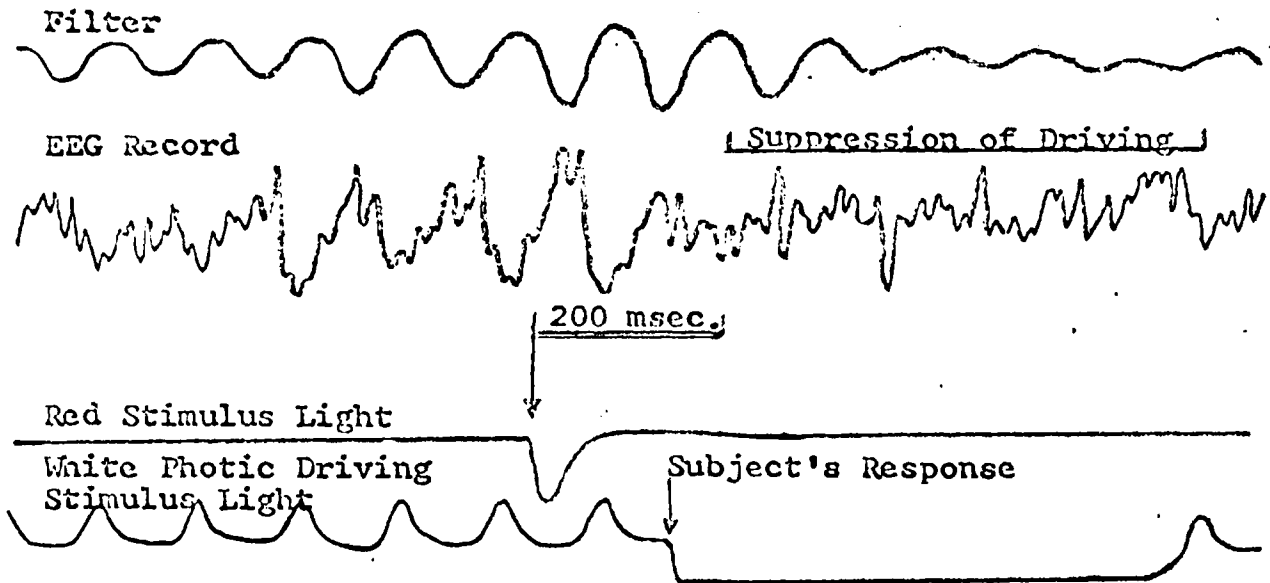


Fig. 2 REPRODUCTION OF SUPPRESSION RECORD SHOWING FILTER, EEG AND STIMULI CHANNELS

TABLE I

NUMBER OF EXPERIMENTAL TRIALS FOR EACH SUBJECT
SHOWING SUPPRESSION, PHOTIC DRIVING AND LACK OF SUPPRESSION

Subject	Trials Showing Suppression	Trials Presented with No Photic Driving	Trials with Photic Driving but No Suppression
B N	38	55	7
R S	65	26	9
R M	67	27	6
V P	33	53	14

TABLE II

THE MEAN LATENCY AND VARIABILITY OF
SUPPRESSION RESPONSE FOR INDIVIDUAL SUBJECTS

Subject	Number of Responses	Mean Latency (msec.)	Standard Deviation (msec.)	Range (msec.)
B N	38	217	60	75-325
V P	33	208	91	100-400
R S	65	212	65	75-425
R M	67	247	82	100-425
Total Value	203	222	75	75-425

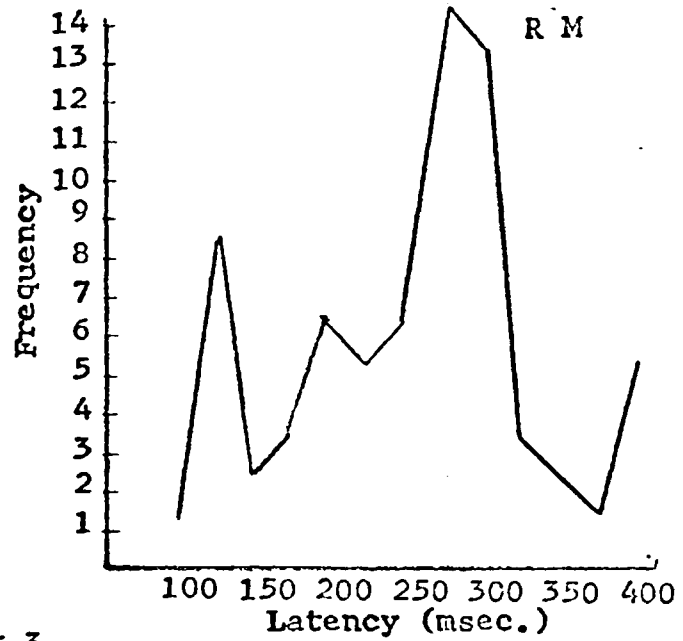
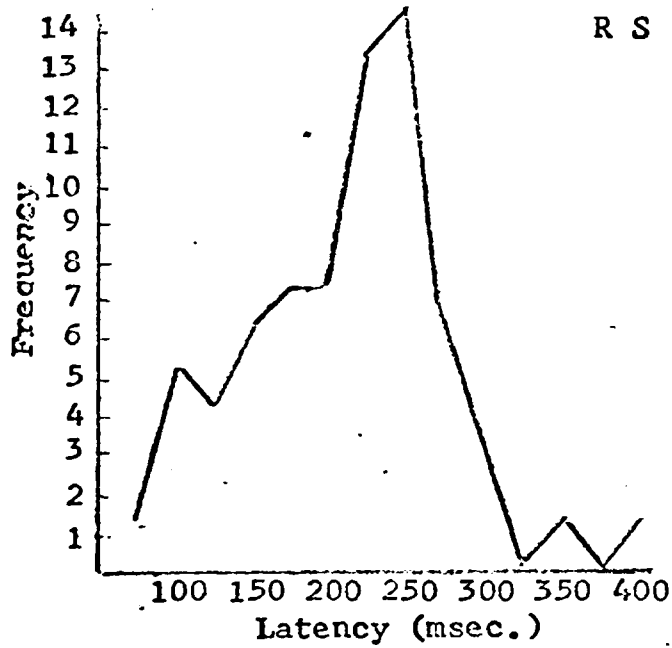
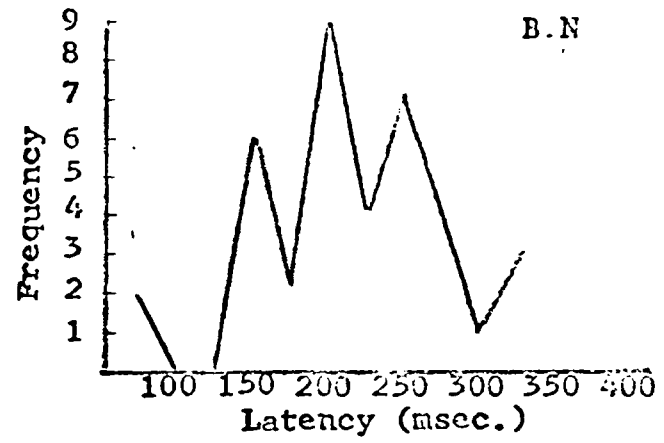
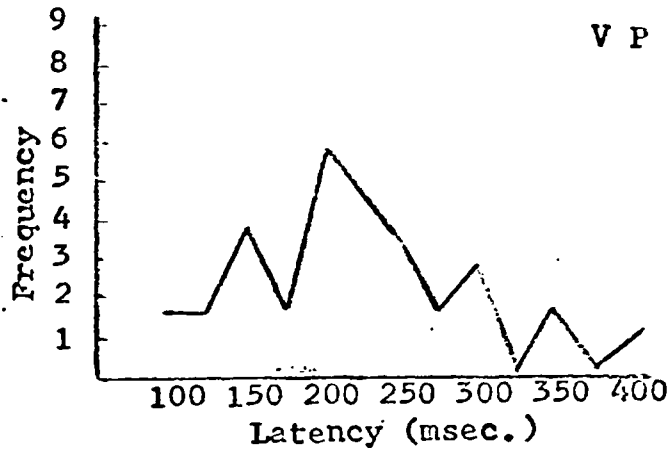


Fig.3

FREQUENCY DISTRIBUTION OF SUPPRESSION LATENCIES FOR THE FOUR SUBJECTS

A mean latency was computed from the data giving a time of 222 msec. The standard deviation of this measure was found to be 75 msec.

The subjects were required to press a reaction time button each time the stimulus was presented. From the records it was clear that the reaction time to the suppression stimulus was approximately 50 msec: shorter than the latency of the EEG suppression.

DISCUSSION AND CONCLUSION

One problem that stood out in the study was the difficulty of observing the suppression reaction. It was first necessary to find subjects capable of driving for a few hundred milliseconds to a photic stimulus presented to one eye only. The necessity of using monocular driving as well as long periods of driving limited the number of subjects that could be used. Automatic methods for analyzing records using selective filters or averaging techniques could be used in a study of this type; however, it is more difficult (as may be observed in Fig. [2]) to obtain short latencies with electronic filters or similar equipment.

The most important finding of the study is the relatively long latency of the suppression reaction as compared with other visual pathway latencies. It was found that the reaction time of the subjects was consistently shorter than the latency of the suppression recorded on EEG records. This means that the reaction is very fast as it has already occurred and been reacted to some 50 msec. before the suppression of the photically driven potentials occurs. The latency of alpha blocking

found by Monnier (1949) was 215 ± 45 msec. The latency of the suppression studied here is 222 msec. with approximately the same range of variability as alpha blocking.

Two of the 40 subjects (not included in the four subjects used) showed very dominant alpha rhythms even during exposure to the photic driving stimuli. It was found that the presentation of the red stimuli was sufficient to block their alpha activity. The blocking of the alpha activity was of the same latency as the blocking of photic driving in this experiment. To prevent misinterpretation of alpha rhythm and photic driving in this study, subjects were always presented photic driving stimuli at a flash rate higher or lower than their alpha rhythm. In both the observed suppression mechanism and the alpha blocking, transmission time is longer than the time required to reach the visual cortex. This indicates that both systems (they are possibly different cortical systems) are mediated by a number of synaptic pathways. Similarities of the latencies for the blocking of photic driving and the blocking of alpha activity indicate a similar neurological mechanism. Lindsley (1960) attributes the mechanism for alpha blocking to the reticular activating system.

One problem is apparent in the explanation that suppression is mediated by an attentional process. Normally increasing the level of attention to visual stimuli would enhance photic driving. Just the opposite occurs in photic driving suppression observed here. Lansing (1964) discusses this problem and concludes that the attentional process must be "linked to the special conditions of discrepant retinal stimulation."

The finding that reaction time is shorter than EEG suppression latencies leads to the final problem. If the subject has experienced binocular rivalry and has pressed the reaction time switch in response to rivalry, then the EEG suppression could hardly be the causal mechanism. It would, therefore, be a mistake for investigators to attempt to use EEG suppression as a measure of the perceptual phenomenon of rivalry, at least until the mechanisms underlying these processes have been further explored.

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