ELECTROENCEPHALOGRAPHIC STUDIES OF CLASSICAL CONDITIONING IN MAN[1,2]

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Despite the rapid growth in our knowledge of the brain and nervous system in the past century, information in this field has still fallen far behind the needs of the rapidly growing science of psychology. Even today, the role of the brain and nervous system in the simplest sensory experiences or motor reactions is not completely understood. Our knowledge of what an organism can perceive, learn, remember, and do, is much greater than our understanding of how such proecesses occur. In recent years, however, psychological and physiological resarches have brought us some new discoveries and new concepts of the functioning of the brain and nervous system. Among these discoveries, the EEG (electroencephalograph) which has been utlized to study the relation between brain function and behavior is of particular importance.

In 1929, a German neuropsychiatrist, Hans Berger, demonstrated that the nervous system is not a mere standby system, active only when incoming sensory massages arouse it to activity, but that it is continuously active electrically (Hill and Parr, 1963). This pioneer work was largely ignored until similar investigations were carried out in Adrian's laboratory at Cambrige. Then, in 1934, Adrian and Metthews published their classic paper entitled "The Berger Rhythm; Potential Changes from the Occipital Lobes in Man" confirming to a large extent of Berger's observations.

Adrian and Matthews described regular potential oscillations at approximately 10 cycles per second detected by electrodes applied to the scalp. They agreed with Berger's conclusion that these waves were due to electrical activity of the cortex; they demonstrated, however, that these waves arose from the occipital lobes and not from the whole cortex as Berger had contended. Investigating the response of this activity (which became known as alpha activity) to certain types of stimulation they concluded that the essential activity necessary for the disappearance of the rhythm is pattern vision, although certain other types of stimulation or activity such as unexpected touch stimuli, pressure on eyeballs, probem solving may cause a diminution.

After Adrian and Matthews's confirmation, investigators in Europe and America began to utilize their techniques in an attempt to solve the tangled problem of brain function. The electroencephalographic experiments carried out so far have been concerned chiefly with the effect of light upon alpha activity. Investigators

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have studied the effect of variation in stimulus intensity and duration upon the alpha activity (Cruikshank, 1937; Jasper and Cruikshank, 1956), the effect of attention and external stimulation upon the alpha wave response to light (Jasper and Cruikshank, 1935; Thomas, 1962), the perseveration of the alpha blocking response to light (Jasper and Cruikshank, 1937; Travis and Knott, 1936, 1937), and have made electroencephalographic studies of conditioned learning (Jasper and Shagass, 1941; Knott and Henry, 1941; Travis and Egan, 1936). A review of these researches shows that few investigators have considered the phenomenon of orientation reflex (also entitled habituation) of the alpha wave response to a strong visual stimulation.

In this country, though it has been utilized recently for clinical purpose in several hospitals, electroencephalographic techniques has not yet been employed in psychological laboratory. The present series of experimental studies was undertaken to investigate the basic phenomena of various aspects of electroencephalogram in groups of normal human subjects in a rather simply equipped laboratory. Three related experiments were included in these stduies: (1) the effect of light stimulation upon occipital alpha rhythmic activity; (2) conditioned response formation of occipital alpha rhythm; and (3) orientation reflex of alpha rhythm to light stimulation.

EXPERIMENT I
THE EFFECT OF LIGHT STIMULATION UPON ALPHA RHYTHMIC ACTIVITY

In this experiment, the following two aspects of alpha rhythm were examined: (1) blocking time and recovery time of alpha rhythm; and (2) frequency changes after light stimulation. The term "blocking time", first used by Jasper and Cruikshank (1937), means the time between the incidence of light to the eyes and the last alpha wave. They reported that the proceeding rhythm does seem to be clearly changed only a few milliseconds after the light stimulation. The average blocking time, they found, was 280 msec. (millisecond). By "recovery time", also named by Jasper and Cruikshank (1937), is meant the time from the cessation of the stimulation to the first reappearance of the alpha rhythm. The average recovery time, Jasper and Cruikshank reported, was 1200 msec.

The oscillations of the alpha rhythm in a normal subject are reported as apporximately 10 cycles per second. Berger's data varied from 8 to 12 cycles per second. Adrian and Matthews found frequencies of 9.5 to 10.5 cycles per second. Jasper and Cruikshank (1937) reported a frequency of 8 to 12 cycles per second.

METHOD AND PROCEDURE

Subjects

Ten male college students, screened from sixteen, enrolled in an introductory psychology course at Taiwan Normal University participated as subjects. Their age renged from 18 to 24 years. They were selected based upon two criteria: (1) they were free from pathological conditions of the brain and auditory and visual difficulties; and (2) according to their EEG records obtained from the preliminary experiment, they had the most regular and continuous alpha rhythms.

Apparatus

The apparatus used for recording the electroencephalogram consisted of a Offner Type T amplifier and a eight-pen ink-writing oscillograph. Visual stimulation used in this experiment was light provided by bulbs ranged from 4.5 to 100 watts placed approximately four feet in front of the subject.

The room was semidarkened, but lack of sound-proof and electrically shielded equipment. A black curtain used as a partition to separate the subject from the experimenter, the recording equipment, and the devices for producing stimulations.

Procedure

Before recording began, the experimental procedure was explained in general terms to the subject to avoid possible apprehension regarding the study. Scalp electrodes were applied by means of microhm jelly bilaterally to frontal, parietal, occipital, and temporal areas. Bipolar recording technique was used. During the preliminary experiment period, the subject was seated comfortably with eyes closed. While the alpha rhythm appeared, the subject was instructed to open his eyes frequently to test the effect of visual stimulation upon alpha activity. If the alpha rhythm could not be observed after twenty minutes or if it had no effect upon the subject's alpha activity, this subject was then dropt out of the group. If the alpha rhythm of the subject appeared continuously and showed effect, the subject was selected to participate in the subsequent experiment.

RESULTS AND DISCUSSION

Blocking Time and Recovery Time

In the studies reported here, when a light stimulation was presented to the eyes of a subject, the proceeding alpha rhythm changed only a few milliseconds after the stimulation as though a possitive effect were introduced before suppression or blocking effect occurred. This phenomenon is shown in Figure I. In many records, however, no clear positive effect was distinguishable; the alpha rhythm simply dropt out rather abruptly after a delay of time. The periods of delay ranging from approximately 100 to 500 msec. were found in this experiment. 100 measurements of blocking time made on 10 individuals are presented in the left part of Table I. The average time ranged from 176 to 324 msec. for different individuals with a mean of 246 msec., and standard deviation of 41 msec. for the group.

No warning signal was given to these subjects before a light stimulation. The wide difference in blocking is probably due to the difference in mental set assumed by the different individuals to the same instruction. It appeared from some of the records that the latency decreased as the subject became alert and prepared for the appearance of the stimulation.

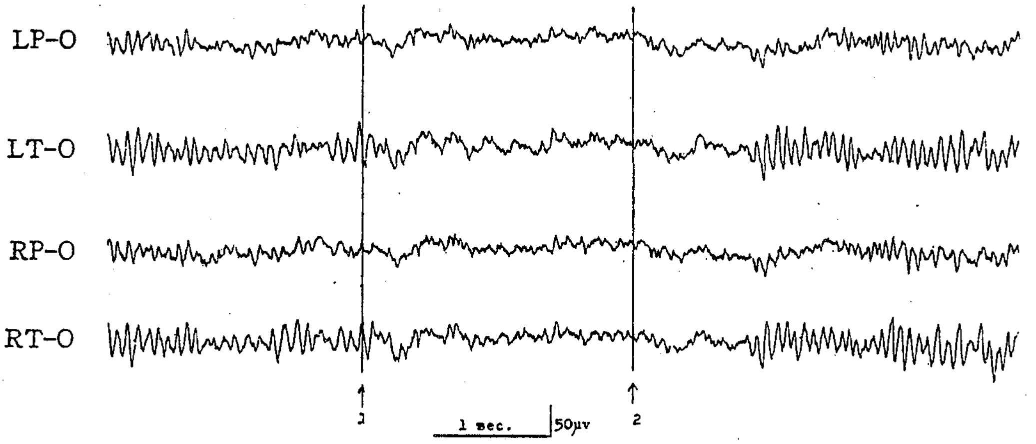

Fig. I. EEG alpha record from the subject Ca. 3-M-21-1/66 indicates the blocking and recovery time after light stimulation. Arrow 1 = appearance of light. Arrow 2 = disappearance of light.
LP-O = Left Parietal-Occipital Lobes.
LT-O = Left Temporal-Occipital Lobes.
RP-O = Right Parietal-Occipital Lobes.
RT-O = Right Temporal-Occipital Lobes.

Table I. Blocking and Recovery Time of EEG Alpha Rhythm

Subject	Number of trials	Average blocking time	Average recovery time
1	10	324	1,150
2	10	277	1,710
3	10	282	860
4	10	247	930
5	10	226	1,110
6	10	265	1,045
7	10	176	900
8	10	193	735
9	10	235	1,090
10	10	238	1,070
Sum...................	100		
Mean..................		246	1,061
SD....................		41	249

In almost every trial in which alpha activity was affected by light stimulation the EEG records of different individuals clearly showed that the recovery time was much longer than the blocking time. This phenomenon may be noted in Figure I. 100 trials of recovery time made on 10 subjects are presented on the right side of Table I. The average time ranged from 735 to 1710 msec. for different individuals with a mean of 1061 msec., and standard deviation of 249 msec. These results, though mutually diverse, were obtained with constant duration (3 seconds each time) and intensity (60-watt bulb) of the light stimulation. The experimenter tested the possibility of recovery time being associated with the duration and intensity of the light stimulation. As a general rule it was shorter for a briefer stimulus period with a higher intensity, but there were some exceptions and some records even showed a reverse trend. Jasper and Carmichael (1935) suggested that the phenomenon of latency in return to normal of the alpha rhythm is possibly associated with the phenomenon of visual after-image.

Frequency Changes

In normal subjects the frequency varying between 8 and 13 cycles per second is considered as normal alpha frequency (Glaser, 1963). Table II shows frequency measurements of the EEG records of 10 normal adult subjects in this experiment. It was found that the frequencies of the occipital alpha rhythm ranged from 9 to 12.5 cycles per second with an average of 10.84 cycles per second. No frequencies were found below 9 cycles per second. This rather skew distribution might be due to the small population. Jasper and Cruikshank (1956) reported that the frequency of the alpha rhythm as it reappears following its blocking by light stimulation is higher than during the pre-stimuation period, and this increase in frequency is greater with higher intensity.

Table II. Frequency Changes of Alpha Rhythm Pre- and Post-Light Stimulation

Subject	Number of trials	Average frequency pre-S	Average frequency post-S	Difference	Increment, per cent
1	5	12.2	13.2	1.0	8.20
2	5	11.4	13.2	1.8	15.79
3	5	11.8	12.5	0.7	5.93
4	5	11.0	12.4	1.4	12.73
5	5	11.6	12.6	1.0	8.62
6	5	10.6	12.0	1.4	13.20
7	5	9.6	10.2	0.6	6.25
8	5	9.6	10.4	0.8	8.33
9	5	10.4	10.5	0.1	0.96
10	5	10.2	11.6	1.4	13.73
	Sum=50	M_1=10.84 SD=0.86	M_2=11.86 SD=0.94	M_2-M_1=1.02	Av. Incr.=9.34

The frequency changes found after light stimulation are presented in Table II. These data cover 50 trials made on 10 subjects. The average frequencies of alpha rhythm of pre-stimulation ranged from 9.6 to 12.2 cycles per second for different individuals with a mean of 10.84 cycles per second, and standart deviation of 0.86 cycles per second for the group. On the other hand the average of alpha rhytm of post-stimulation ranged from 10.2 to 13.2 cycles per second for different individuals with a mean of 11.86 per second, and standard deviation of 0.94 cycles per second for the group. The increments of alpha frequency after light stimulation ranged from 0.96% to 15.79% comparing with the average frequencies before light stimulation for different individuals. The mean difference between the two situations was 1.02 cycles per second, and the total average increment of the 50 trials reached 9.34%.

The difference between the two means is highly significant ($t=6.50$, $P<0.001$), the statistical probability of this difference occurring by chance being far less than one per cent.

EXPERIMENT II
CONDITIONED RESPONSE FORMATION OF OCCIPITAL ALPHA RHYTHM

Studies of electroencephalographic response to light led accidentally to the discovery that the alpha blocking response could be conditioned. Durup and Fessard (quoted by Glaser, 1963) were studying the response of alpha rhythm to visual stimulation, in 1935, using a camera to photograph changes in alpha activity after the appearance of a bright light. Previous testing had shown that the noise of opening the shutter alone had no effect on the electroencephalogram. When, however, the click was presented in conjunction with the light, they noted that after a few such temporal association the click began to cause disappearance of alpha activity just as had the light. If the click were then presented several times without visual reinforcement, it ceased to affect the alpha activity. Durup and Fessard interpreted this observation to indicate the development of a conditioned response; that is, an auditory stimulus (the conditioned stimulus), previously having no effect upon the alpha activity, had, by its temporal association with the light (the unconditioned stimulus), which routinely caused disappearance of the alpha rhythm, acquired the ability to effect disappearance of the alpha activity. A similar observation was made almost simultaneously by Loomis et al. (1936). They found that if a tone and a light were presented concurrently to the subject lying in a darknese, after a number of combination the tone alone, which previously had no effect, provoked alpha rhythm suppression. However, the effect of the tone alone will not last more than two or three trials without light reinforcement.

Since then study of this form of conditioning has been made in a number of laboratories. Travis and Egan (1938) reported results of more elaborate experiments designed to investigate conditioning of alpha acfivity. The response of the subjects' alpha rhythm to sound or light alone was first tested. The tone alone was followed by disappearance or striking diminution of the amplitude of the alpha activity in 11 per cent of 643 presentations, while light alone was effective in 99 per cent of 344 presentations. The sound and the light were then presented together, the sound preceding the light by 480 to 750 msec. During the paired stimulations, disappearance of the alpha activity followed the sound before appearance of the light in 35 per cent of the records. These observations were interpreted to indicate true conditioning of the alpha activity in man.

Knott and Henry (1941) re-evaluated the data of Travis and Egan, noting that tone was just as effective in producing alpha blocking in the first one-fifth of the paired presentations as in each of the subsequent four-fifths: that is, there was no curve of increasing effectiveness as pairing of sound and light continued. In their opinion, this did not resemble conditioning, but rather sensitization. In similar studies, Knott and Henry confirmed that sound might be followed by disappearance of alpha activity when it was associated temporally with light. They interpreted this phenomenon, however, as a "conditioned anticipatory response" instead of a conditioned response in the Pavlovian sense.

Jasper and Shagass (1941) reported a more elaborate studies on conditioning the occipital alpha rhythm in man. The conditioned stimulus was a 500c/sec. sound, which appeared 700 msec. before the light, the subject having been instructed previously to press a button whenever light appeared. Under these conditions, simple conditioning was fairly easy to achieve, though the conditioned response was unstable, extinction usually occurring after as few as three unreinforced presentations of conditioned stimulus. In addition to simple conditioning, they demonstrated cyclic conditioning, delayed conditioning, differential conditioning, trace conditioning, and backward conditioning. They considered "sensitization" to be ruled out by the demonstration of differential conditioning, that is, the response was frequency-specific and not just any stimulus of equal intensity. More elaborate forms of conditioning were achieved by Jasper and Shagass than by other investigators, probably for two reasons: (1) their experimental design was more complex; and (2) their subjects were instructed to press a button each time that the visual stimulus appeared. It has subsequently been noted that cerebral desychronization to the conditioned stimulus is easier to obtain and more consistent when the unconditioned stimulus represents a signal for a motor act by the subject (Wells, 1963).

Recently, Stern et al. (1961) have advanced further objections to entitling these phenomena "conditioned cerebral responses". This objection to employ Pavlovian terms for electrical events has led their being called "temporary cerebral connections", "electrical correlates of conditioning responses", "contingent alpha blocking", and so on.

The present experimental study was undertaken to discover whether or not the basic phenomena of conditioned response of alpha rhythm in man could be established in this simply equipped laboratory. Due to lack of sound-proof and electrically shielded equipment, the study was limited to two types of conditioning: (1) the simultaneous conditioning; and (2) the delayed conditioning.

METHOD AND PROCEDURE

Subjects

Twelve male college students, screened from twenty, participated in this experiment. The selected criteria and procedure were the same as in experiment I.

Apparatus

In addition to the apparatus used for recording electroencephalogram in experiment I, a sound stimulus, produced by a beltone audiometer and was delivered through earphone to one ear, was employed as a conditioned stimulus; and a 60 watt bulb placed approximately four feet in front of the subject was employed as an unconditioned stimulus. The intensity of sound was adjusted until it was judegd by the subject to near threshold. This was due to minimize the effect of the tone itself upon the alpha rhythm.

Procedure

At the beginning of conditioning experiment, several times of sound stimulus was presented in order to avoid the startle effect of sound on the alpha rhythm. Then 5 to 6 control trials with sound alone were made. In the process of conditioning experiment, the light stimulus was presented after the sound. The intervals between sound and light and the durations of the stimuli varied in different conditioning trials.

RESULTS AND DISCUSSION

(A) Simultaneous Conditioning

According to Pavlov, the simultaneous condtioning is meant one in which the interval between the CS (condtioned stimulus) and UCS (unconditioned stimulus) was not more than five seconds. Pavlov apparently found no important difference in case of conditioning with the CS-UCS intervals between 0 and 5 seconds. More recent experimental evidence, however, indicates that the optimal interval is much shorter than 5 seconds, probably being something more like a tenth of that value (Hilgard and Marquis, 1961).

The interstimuli intervals in this experiment were ranged from 0.5 to 1.0 second. Before conditioning the sound stimulus was presented alone, 2 seconds in duration, for testing the effect of sensitization of alpha activity. The sound stimulus was repeated until the alpha activity became habituated to the sound. In most cases the alpha rhythm became completely habituated to the sound within five trials. This phenomenon is illustrated in Figure II. Following this paired sound and light stimuli were then presented to the subjcet. The sound appearing 0.5 to 1.0 second and then both sound and light continued for 2 to 3 seconds. Conditioning was considered established when at least 5 consecutive responses to the conditioned stimulus occurred in which there was sufficiently depression of the alpha rhythm to be clearly a response to the stimulus rather than a spontaneous variation. At first the alpha activity responded to the light but not to the sound (Fig. III). Upon the average of seven presentations of paired sound-light combinations the conditioned responses of alpha rhythm could be observed. Figure IV demonstrates the typical conditioned responses of alpha rhythm. It could be noted that the alpha rhythm responds to sound stimulus just as it did to light.

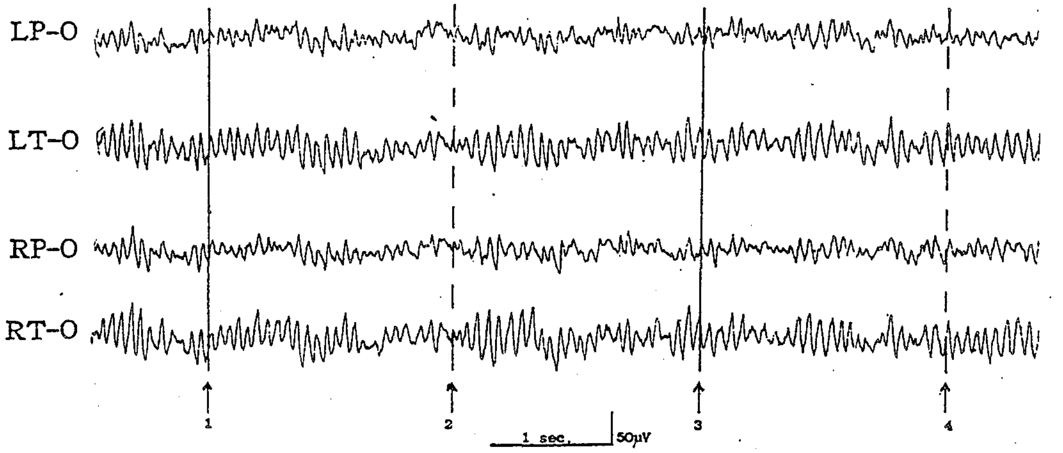

Fig. II. EEG alpha record from the subject Ca. 5-M-20-1/66 indicates the electroencephalogram has become habituated to the effect of sound stimulus after three trials. Arrow 1 and 3 = appearance of sound. Arrow 2 and 4 = disappearance of sound.

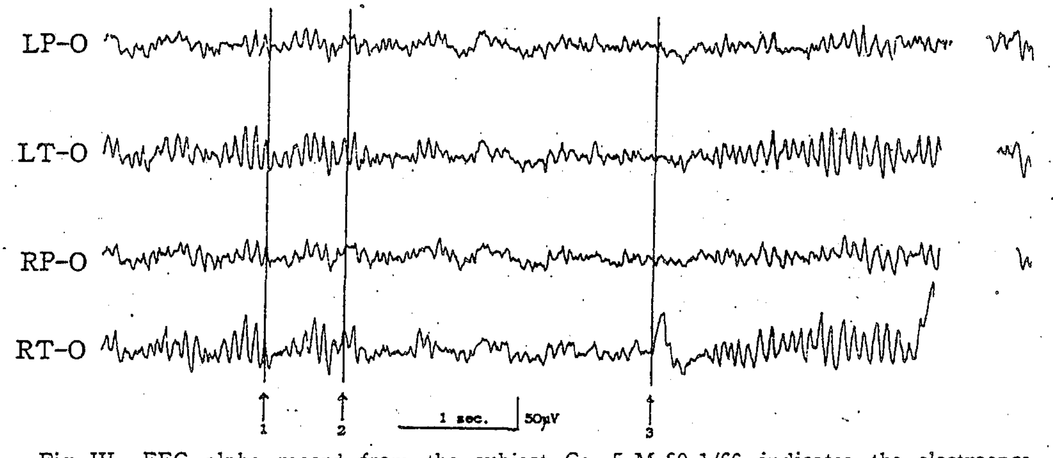

Fig. III. EEG alpha record from the subject Ca. 5-M-20-1/66 indicates the electroencephalogram responses to paired sound-light stimuli. Arrow 1 = appearance of sound. Arrow 2 = appearance of light. Arrow 3 = disappearance of sound and light. Note that sound alone has no effect upon the alpha activity, while light is followed by disappearance of it.

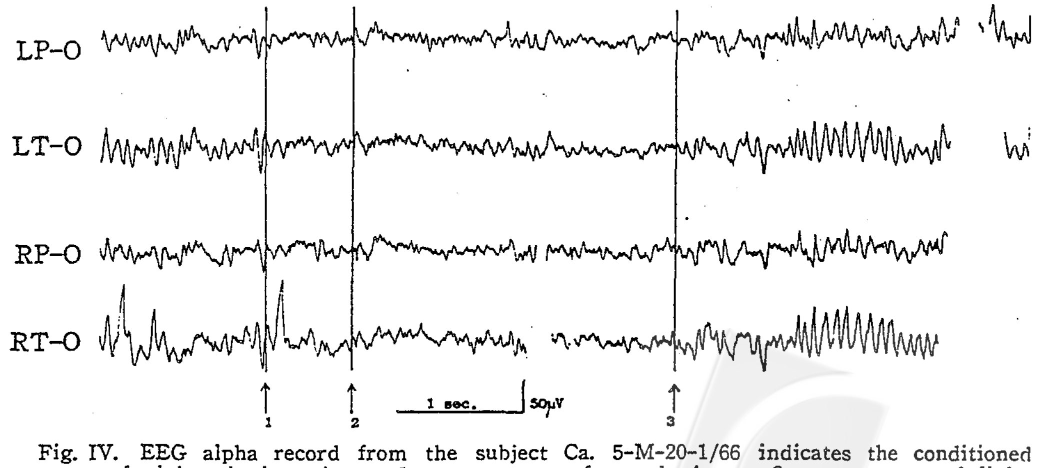

Fig. IV. EEG alpha record from the subject Ca. 5-M-20-1/66 indicates the conditioned responses of alpha rhythm. Arrow 1 = appearance of sound. Arrow 2 = appearance of light. Arrow 3 = disappearance of sound and light. Note that the sound is followed by disappearance of alpha activity before light appears.

When conditioned responses established several test trials were made. The sound stimulus was presented alone and without following the light. The conditioned responses of alpha rhythm did occur and was of comparable duration (Fig. V). These conditioned responses were not stable. In most cases extinction occurred after as few as four or five test trials without light reinforcement.

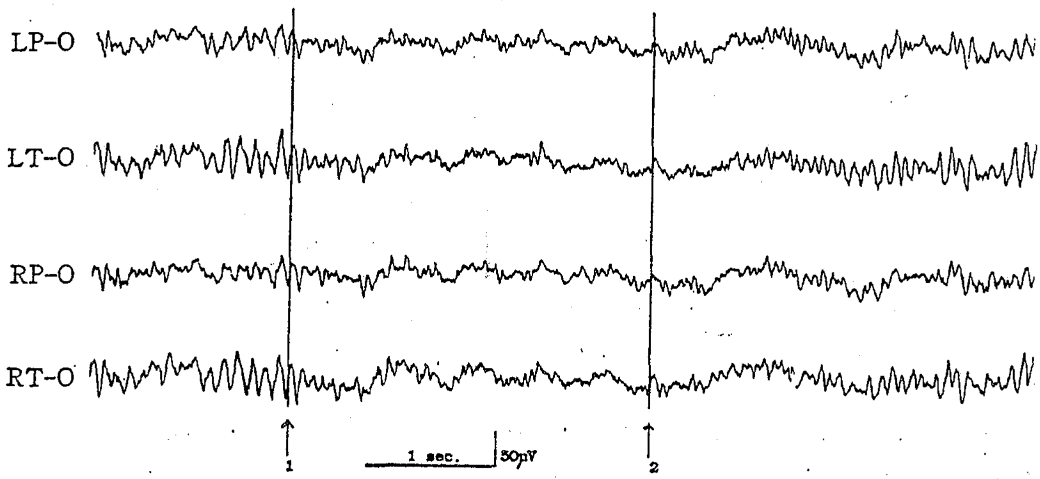

Fig. V. EEG alpha record from the subject Ca. 5-M-20-2/66 indicates the electroencephalogram of the subject is completely conditioned to sound. Arrow 1 = appearance of sound. Arrow 2 = disappearance of sound.

(B) Delayed Conditioning

By delayed conditioning is meant that the conditioned stimulus begins from 5 seconds to several minutes before the unconditioned stimulus and overlapping it in repeated conditioning trials. Before conditioning the sound was presented alone, 5 to 10 seconds in durations for testing the effect of sensitization of alpha activity just as the procedure in the simultaneous conditioning. Then the paired sound-light stimuli, with 5 to 10 seconds intervals, were presented. After 50 such presentations, however, the experimenter failed to observe the occurrence of any conditioned response (Fig. VI). It was found necessary to use Pavlov's method of conditioning first with short delay (e. g. for 1 second) and then gradually postponed it until to 10 seconds. Under this manner of arrangement the delayed conditioning could be established. With a delay of 5 seconds, for example, a delayed conditioned response was observed in about 40 trials (Fig. VII.). The duration of the sound before the light varied in different trials between 5 to 10 seconds. The rate of establishment of this form of conditioned response varied with the length of delay; the longer the delay, the greater number of trials needed.

It was contrary to simultaneous condtioning, the deleyed conditioned response was always anticiptory, that is, the blocking of alpha rhythm occurred before the time at which the light had begun before. Fore example in the experiment from

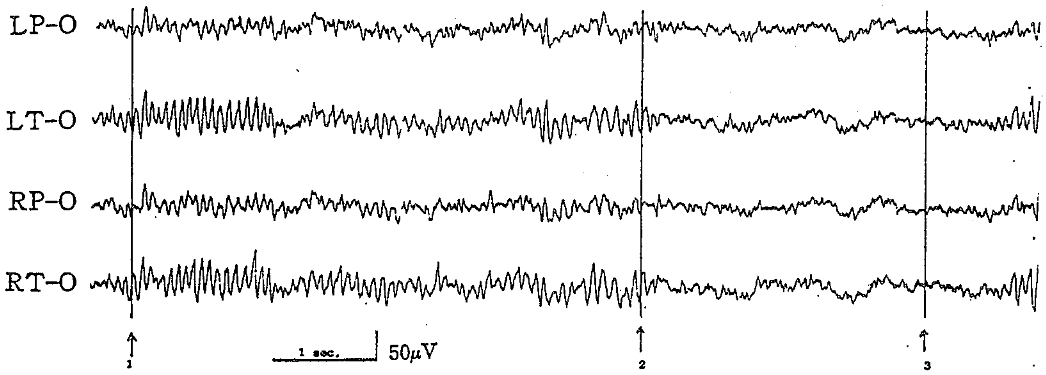

Fig. VI. EEG alpha record from the subject Ca. 8-M-21-3/66 indicates the electroencephalogram responeses to paired sound-light stimuli. Arrow 1 = appearance of sound. Arrow 2 = appearance of light. Arrow 3 = disappearance of sound and light. Note that the sound alone has no effect upon the alpha acctivity, while the light is followed by disappearance of it.

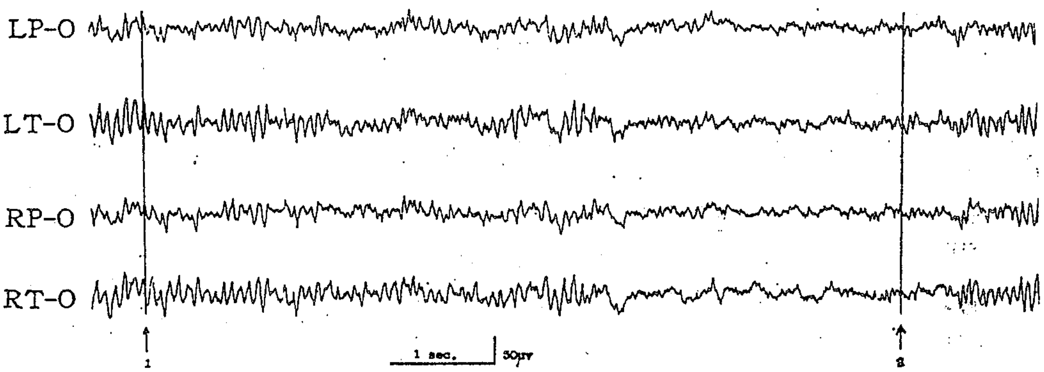

Fig. VII. EEG alpha record from the subject Ca. 8-M-21-3/66 indicates the delayed conditioning of alpha rhythm. Arrow 1 = appearance of sound. Arrow 2 = disappearance of sound. Note that the delayed conditioned response is anticipatory, the blocking of alpha activity occurred before the time at which the light had begun before.

which the sample of Figure VII was taken conditioning trials were given delay of 5 seconds, the conditioned response occurred after a delay of 4.3 seconds and lasted until the sound was turned off.

Delayed conditioned response was more unstable than that of simultaneous conditioning. Extinction was easily observed after two or three trials without light reinforcement.

EXPERIMENT III
ORIENTATION REFLEX OF ALPHA RHYTHM TO LIGHT

Recent investigators (Roger et al, 1958; Gastaut and Bert, 1961) have reported that alpha blocking response to light stimulation, especially to rhythmically repeated light stimulation, could be become habituated, the light lost its effect upon alpha activity. Roger et al. called this phenomenon "orientation reflex" and this led some investigators convinced that the light stimulation, though it blocking the alpha activity, could not simply be interpreted as an unconditioned stimulus in Pavlovian sense. Gastaut and Bert (1961) have studied orientation reflex of alpha blocking response to rhythmically repeated light stimulation. Using as a light stimulus a 75-watt lamp placed 1.5m from the subject, the stimulus being presented rhythmically for 4 sec. every 20 sec., they found that the orientation reflex appeared usually between the third and eight such presentations. The present experiment was purposed to examine if the orientation reflex phenomenon could be observed under a strong flashed light stimulation.

METHOD AND PROCEDURE

Subjects and Apparatus

Both the subjects and apparatus used in this experiment were the same as in experiment II.

Procedure

The source of the flahed light stimulation used in this experiment was provided by a 100-watt bulb placed four feet in front of subject. A specially designed equipment made the light flashed. The frequencies of the flashes varied from 5 to 11 times per second, and were presented at irregular time intervals. No sound stimulation was provided.

RESULTS AND DISCUSSION

Figure VIII illustrates the phenomenon of orientation reflex of alpha rhythm to flashed light stimulation. The intensity of light was 100-watt with frequencies of 9 times per second. The average of the first appearance of this phenomenon in different individuals and in different trials was about 30 seconds after the beginning of the continued flashed light stimulation. That is, when the flashed light continued for 30 seconds, the alpha rhythmic activity began to become habituated, and the light had lost the effect of blocking upon the alsha rhythm. When the flashed light continued for 50 seconds the rhythmic activity had become almost completely habituated. As the records inditcate (Fig. VIII), when the flashed light was interrupted the alpha rhythm was blocked just as in its usual respnses to light stimulation. The cessation of light stimulation to which the subject had been habituated now became a new effector blocking the rhythm. When the absence of flashed light lasted about 3 seconds the rhythmic activity recovered, it became habituated to dark. As soon as the alpha potential recovered its full strength the flashed light was again presented. The alpha activity was blocked as in its usual responses, but recovered about one and one half seconds. When the alpha rhythm had recovered fully the flashes were stopped and the same responses as in the second period were observed. It was noted that when alpha rhythm became completely habituated to the light, it recovery after blocking tends to be easier when it is in the light than when in the dark.

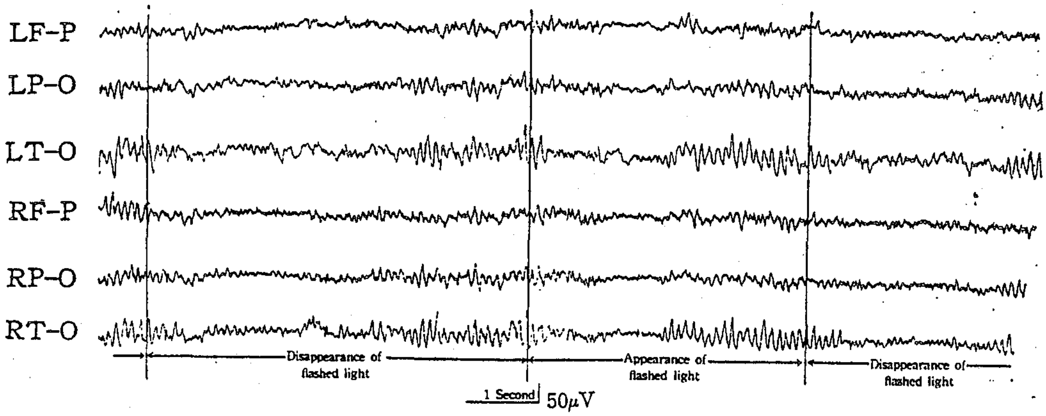

Fig. VIII. EEG record from the subject Ca. 10-M-20-3/66 indicates the phenomenon of orientation reflex to a flashed light stimulation. Note that in the first period, the extreme left side, the alpha rhythm had become habituated to the flashed light stimulation. The disappearance of the flashed light, instead of appearance of it, blocked the rhythmic activity (as shown in the 2nd. period). When alpha rhythm was habituated to the dark, however, the appearance of light blocked its rhythm as usual (as shown in the 3rd period).

LF-P=Left Frontal-Parietal Lobes.

RF-P=Right Frontal-Parietal Lobes.

The experimenter tried to vary the frequencies of flashed light from 5 to 10 times per second. The results indicated that when the frequencies ranged from 8 to 10 times per second, the orientation reflexes were more easily observed. This might be related to the frequencies of alpha rhythm in which 8 to 10 cycles per second have been usually considered as normal alpha frequency.

SUMMARY

The present experimental studies were purposed to investigate the responsiveness of EEG alpha activity to light stimulation in groups of normal subjects and in particular to examine: (1) the effect of light stimulation upon occipital alpha rhythmic activity; (2) conditioned response formation of occipital alpha rhythm; and (3) orientation reflex of alpha rhythm to light stimulation. The results are summarized as follows:

1. Recovery time was much longer than blocking time. In a total of 100 trials made with 10 subjects, the mean blocking time was 246 msec. with standard deviation of 41 msec. The mean of recovery time of the same trials was 1061 msec. with standard deviation of 249 msec.

2. Frequencies increased after light stimulation. In a total of 50 trials made with 10 subjects, the mean frequencies before light was 10.84c/sec. with standard deviation of 0.86c/sec. The mean frequencies after light was 11.86c/sec. with standard deviation of 0.94c/sec. The mean difference between the two situations was 1.02c/sec. and the total mean increment reached 9.34%.

3. When the intervals between the conditioned and unconditioned stimuli were ranged from 0.5 to 1.0 seconds, the simultanesus conditioning could be easily observed. The conditioned response occured on the average of 7 presentations of the paired sound-light stimulations. Simultaneous conditioned response was unstable, the extinction was obtained after four or five test trials.

4. Delayed conditioning in which the intervals between the conditioned and unconditioned stimulations were ranged from 5 to 10 seconds could be established. With a delay of 5 seconds the conditioned response was observed on the average of 40 presentations of paired sound-light stimulations. Delayed conditioned response was more unstable, and the extinction usually occurred after as few as two or three trials without light reinforcement.

5. Light stimulation, though blocking the alpha activity, could not be viewed as an unconditioned stimulus. In the orientation reflex, light, in many instance, fails to have any effect upon alpha activity, especially under the situation of rhythmic light stimulation. The orientation reflex of alpha rhythm to a strong rhythmic light stimulation about 9 times per second could be demonstrated after 30 to 50 seconds of its continued presentations.

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人類交替學習之腦電波的實驗研究*

張　春　興

摘　要

本實驗研究之目的，在使用腦波儀（Electroencephalograph，簡稱 EEG）以探求人類 Alpha 型腦波，在古典式交替學習（Classical conditioning）的設計下，構成各種交替反應的可能。本研究包括三個相關的實驗：(1) 光刺激變化時對 Alpha 波節律活動的影響；(2) Alpha 波交替反應的建立；(3) 在節律光刺激下定向反射（Orientation reflex）現象的形成。參加本實驗之受試者，均爲師範大學男生，共計36人；其年齡均在18至24歲之間，腦部無疾病，且無視聽覺障碍。本實驗所用之儀器，以美製之 Offner Type T Electroencephalograph (8 channels) 爲主。聲刺激係由一聽力計（Audiometer）發出聲音，經由耳機傳與受試者；其强度以能淸楚聽到爲限。光刺係由置於受試者面前之電燈發出，其强度變化在 4.5 至 100 Watts 之間。電極連接技術以雙極誘導法（Bipolor technique）爲主，單極誘導法（Monopolor technique）副之。誘導區域以腦枕葉（Occipital lobe）與顳顬葉（Temporal lobe）爲主。

由上述三實驗所得記錄，經統計分析後，獲得如下之結果：

一、光刺激消失後，Alpha 波的復原時間（Recovery time）遠較刺激開始後的抑制時間（Blocking time）爲長。在 100 次試驗中，抑制時間的平均值爲 246 msec., 標準差爲 41 msec.; 但復原時間的平均值則爲 1061 msec., 標準差爲 249 msec。

二、光刺激消失後，Alpha 波復原後的頻率，較之光刺激前，有顯著的增加。在 50 次試驗中，光刺激前的平均值 10.84c/sec., 標準差爲 0.86c/sec.; 而刺激後的平均值則爲 11.86c/sec., 標準差爲 0.94c/sec. 平均增加率爲 9.34%。

三、交替刺激(聲)與非交替刺激(光)之間的時距（Interval）爲 500 msec. 至 1 秒時，兩刺激平均相隨出現 7 次後，即可見到同時交替反應（Simultaneous conditioned response）。惟所得之交替反應不甚穩定，多半在 4 至 5 次無增强（Reinforcement）的試驗中，即出現消弱（Extinction）現象。

四、若交替刺激與非交替刺激之間的時距拉長到 5 至10秒時，兩刺激必須相隨出現40次以上，始可見到延宕交替反應（Delayed conditioned response）。此種交替反應極不穩定，停止增强後 2 至 3 次的試驗中，即可出現消弱現象。

五、在節律光刺激下，經過較長的時間（約在30秒以上），Alpha 波對光的反應，會產生定向反射現象。即光刺激此時已失去抑制 Alpha 波活動的作用，而使 Alpha 波對光產生了適應現象。本研究中之實驗三結果顯示：若節律光刺激的頻率接近 Alpha 波的頻率時，定向反射現象就較易出現。由於定向反射現象的產生，可知光刺激對於 Alpha 波的作用，似不能單純被視爲是一種非交替刺激。因此，Alpha 波交替反應的形成後的消弱及增强兩者，似亦不能純以 Pavlov 氏的交替學習原則，獲得完滿的解釋。

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