

AN ELECTROENCEPHALOGRAPHIC STUDY ON THE ZEN MEDITATION (ZAZEN)

By

Akira KASAMATSU, M.D. and Tomio HIRAI, M.D.

*Department of Neuropsychiatry, Tokyo University Branch Hospital,
Faculty of Medicine, The University of Tokyo*

INTRODUCTION

It is our common knowledge that EEG undergoes striking changes in the transition from wakefulness to sleep, and has become one of the reliable way to assess the state of wakefulness or sleep. In clinical practice, EEG often becomes a good neurophysiological method to find out the disturbance of consciousness. And many studies, both clinical and experimental, on the consciousness have been published during the past 30 years. In recent years electroencephalographic and neurophysiological studies on the consciousness are focused to understanding of the relationship between the brain mechanisms and consciousness in general¹¹⁾. These studies give rise to attempt to relate the various electrographic findings with the psychological states and their behavioral correlates²⁰⁾.

The authors have carried out the study on EEG changes during anoxia, epileptic seizures, the exogeneous disorders of the brain and other allied states from neurophysiological and psychological points of view¹⁸⁾. In the course of our study, it was revealed that a series of EEG changes was observed in the state of attentive awareness during Zen-sitting (ZAZEN. And what Zazen is like will be explained later.)^{14,18)} These findings deserve further investigation because of understanding EEG pattern to corresponding psychological state and of interpreting the neurophysiological basis of consciousness. The subject of the present paper is to described the results of our experiments in detail and to discuss some of the electrographic characteristics in which the mental state in Zen-sitting will be reflected.

Zazen (Zen meditation) means the sitting meditation which is a kind of religious exercises in Zen-Buddhism. In Japan there are two Zen sects named Soto and Rinzai. Both sects regard Zazen as the most important training method of their disciples to enlighten their minds. Zen sitting is performed in two basic meditation forms: A full cross-legged sitting and a half cross-legged sitting (Fig. 1). During the Zen sitting, the disciples' eyes must be open and look downward about one meter ahead and his hands generally join. In a quiet room the disciple sits on a round cushion and practises the meditation for about 30 minutes. Sometimes the intensive Zen training is performed 8 to 10 times a day for about one week. This is called *Sesshin* in Zen Buddhism. The disciples do not engage in daily activities but live the religious life following a strict schedule¹⁴⁾.

By practising Zen meditation it is said that man can become emancipated from the

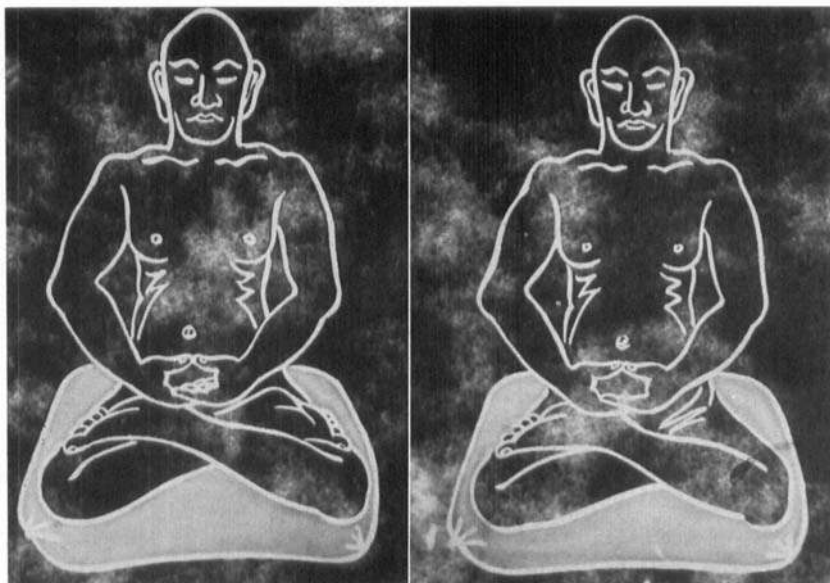


Fig. 1. Two meditation forms of Zen sitting. The left is a full cross-legged sitting and the right a half cross-legged sitting. Zen meditation is performed in holding these two basic sitting forms.

dualistic bondage of subjectivity and objectivity, of mind and body and of birth and death. And he can be free from lust and self-consciousness, and be awakened to his pure, serene and true-self.

This mental state (Satori or enlightenment) will often be misunderstood as trance or hypnosis. It is said that Satori is not an abnormal mental state but one's everyday mind in the Zen sense. Dr. Erich Fromm describes "If we would try to express enlightenment in psychological terms, I would say that it is a state in which the person is completely tuned to the reality outside and inside of him, a state in which he is fully aware of it and fully grasps it. *He* is aware of it—that is, not his brain, nor any other part of his organism, but *he*, the whole man. He is aware of *it*; not as of an object over which he grasps with his thought, but *it*, the flower, the dog, the man, in its or his full reality. He who awakes is open and responsive to the world, and he can be open and responsive because he has given up holding on to himself as a thing, and thus has become empty and ready to receive. To be enlightened means 'the full awakening of the total personality to reality.'"³⁶⁾

If one asks what this state of mind is concerned in psychotherapy, it may be said that Zen meditation is the method through which we can communicate with the unconscious. In this context, however, the unconscious does not mean Freud's "unconsciousness". Rather "the unconscious" in Zen is closely related to the unconscious which is stated by Jung, C. G.³⁶⁾ or Fromm, E.³⁶⁾ In regard to this problem Dr. Daisetsu Suzuki states the meaning of it as "the Cosmic unconscious"³⁶⁾.

At any rate the Zen meditation influences not only the mind but also the body as a whole organism. The authors want to investigate Zen meditation as a subject of psychophysiology, especially that of electroencephalography*.

* The significance of Zen to psychiatry will be mentioned elsewhere.

SUBJECTS AND METHODS

EEG was recorded continuously through all stages—before, during and after Zazen with opened eyes. All our EEG data were obtained in the eyes' opened state.

As recording electrodes the silver-coated disc electrodes with thin ($100\ \mu$ to $200\ \mu$) copper wire in vinyl tube were used, and they were applied with collodion on the scalp of the frontal, central, parietal and occipital regions in the middle line of the head. These electrodes did not disturb Zen meditation and the long-lasting recordings were obtained.

Along with EEG, the pulse rate, respiration and GSR were polygraphically recorded on a San-ei 12 channel ink-writing electroencephalograph. The same experiments were performed for one week during Zen meditation's intensive training (Sessin). These results were useful to confirm the EEG changes in the whole course of Zen meditation.

In order to investigate the functional state of the brain, the responses to sensory

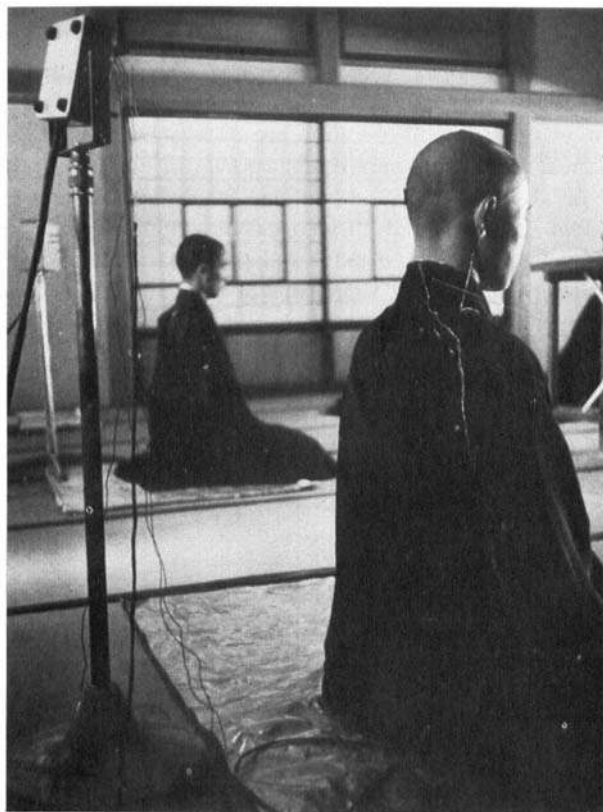


Fig. 2. EEGs were continuously taken before, during and after Zen meditation of the Zen priests and disciples at their Zen-training hall (Zendo). The photograph shows the disciples with the recording electrodes, practising Zen meditation.

stimuli with several modalities were examined. And the blocking time of alpha pattern to repeated click stimulations was measured.

Our experiments were made at the usual Zen-training hall with cooperations of the Zen priests and their disciples as our subjects (Fig. 2). But the stimulation experiments were performed in air-conditioned, sound-free shield room of our laboratory.

The cooperative 48 subjects were selected among the priests and disciples in both Soto and Rinzai sects. Their ages ranged from 24 to 72 years old. According to their experience in Zen training, these subjects could be classified into the following 3 groups:

- group I: 1 to 5 years experience (20 disciples)
- group II: 5 to 20 years experience (12 disciples)
- group III: over 20 years experience (16 priests)

As control subjects, we selected 18 research fellows (23 to 33 years of age) and 4 elderly men (54 to 60 years of age). They have had no experience in Zen meditation, and their EEGs were recorded under the same condition with opened eyes as the Zen disciples.

RESULTS

1. EEG changes of Zen-masters during Zen Meditation

First we show the typical EEG changes of a certain Zen master in detail. He is a priest with over 20 years experience in Zen meditation. Before Zen meditation the activating pattern is predominant because his eyes are open (Fig. 3). After Zen meditation has started, the well-organized alpha waves of 40–50 μ V., 11–12/sec. appear within 50 seconds in all the regions and continue for several minutes in spite of opened eyes (Fig. 4). After 8 minutes and 20 seconds, the amplitude of alpha waves reaches to 60–70 μ V. predominantly in the frontal and the central regions (Fig. 5). Initially, these alpha waves alternate with the short runs of activating pattern, but a fairly stable period of the persistent alpha waves ensues on the progress of Zen meditation. After

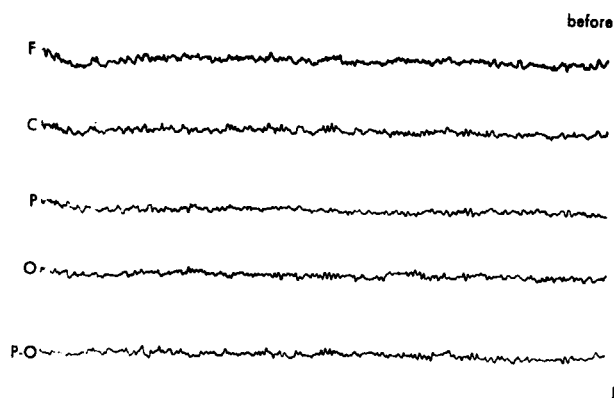


Fig. 3. An activating pattern of a priest with opened eyes before Zen meditation. F: frontal, C: central, P: parietal, O: occipital regions of the midline of the scalp. P-O: parieto-occipital bipolar lead. Calibration shows 1 sec. and 50 μ v. (as the same in the following figures.)

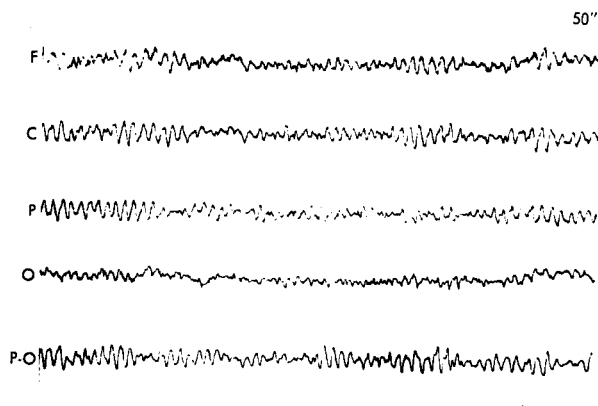


Fig. 4. The well-synchronized alpha waves of $40\text{--}50\ \mu\text{v}$, $11\text{--}12/\text{sec}$. appear within 50 sec. after the beginning of Zen meditation in all regions without regard of opened eyes. Notice that the appearance of alpha waves are more marked in frontal, central, parietal regions than in occipital.

27 minutes and 10 seconds, rhythmical waves of $7\text{--}8/\text{sec}$. appear for 1 or 2 seconds (Fig. 6). And 20 seconds later rhythmical theta train ($6\text{--}7/\text{sec}$., $70\text{--}100\ \mu\text{V}$.) begins to appear (Fig. 7). However it does not always occur. After the end of Zen meditation alpha waves are seen continuously and 2 minutes later alpha waves still persist (Fig. 8). It seems to be the after-effect of Zen meditation.

In the control subjects, EEG changes are not observed; As shown in Figure 9, a control subject shows the long lasting activating pattern of opened eyes. Another 2 control subjects of 58 and 60 years of age also show beta dominant type of EEG with short runs of small alpha waves. But neither increase of alpha amplitude nor decrease of alpha frequency are observed on their EEG of opened eyes (Fig. 10 a, b). The

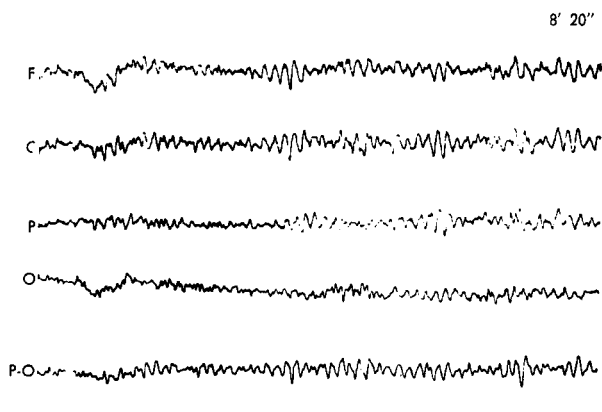


Fig. 5. After 8 min. and 20 sec. in meditation, the amplitude of alpha waves increase to $60\text{--}70\ \mu\text{v}$. predominantly in the frontal and central regions.

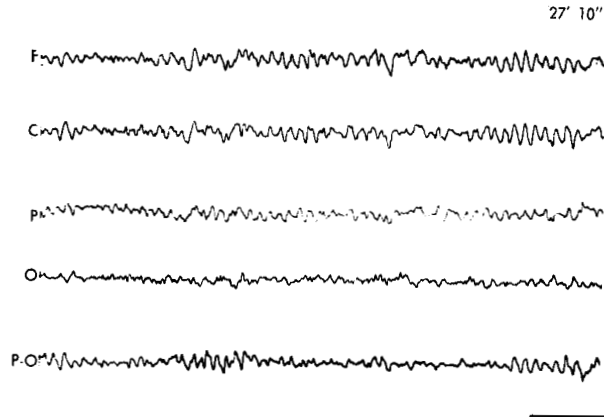


Fig. 6. After 27 min. and 10 sec. in Zen meditation, the 7-8/sec. alpha waves are seen for 1 or 2 sec. predominantly in the frontal and central regions. The decrease of alpha frequency occurs.

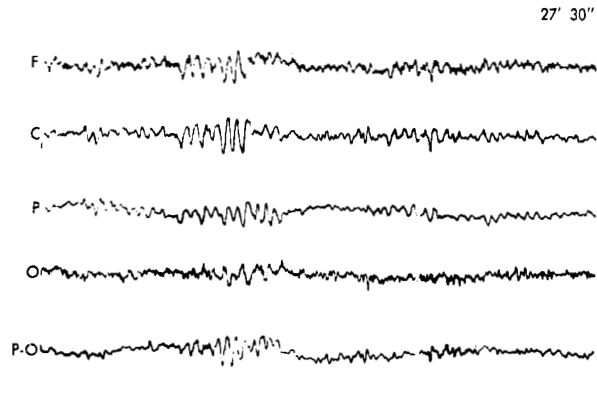


Fig. 7. 20 sec. later than in Fig. 6. The rhythmic theta train (6-7/sec. 70-100 μ v.) is clearly seen in the all regions. This shows the utmost change on EEG during Zen meditation.

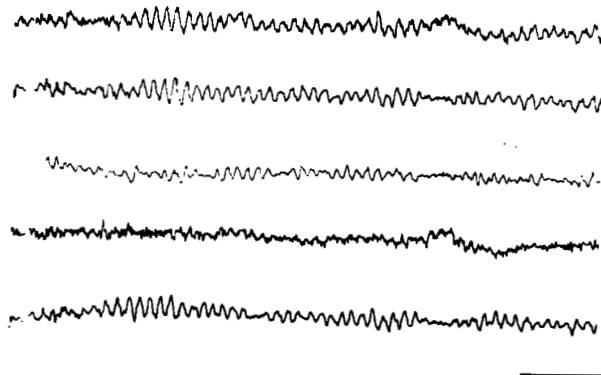


Fig. 8. 2 min. after the end of Zen meditation, the alpha waves still persist. It seems to be the after-effect of Zen meditation.

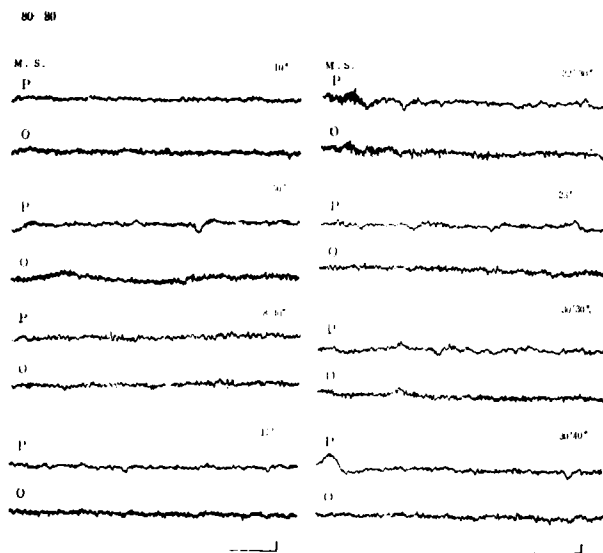


Fig. 9. EEG of the control subject (23 years of age, medical student) with his opened eyes, sitting in the same hall as the Zen priest. The long-lasting activating pattern is marked and no changes are observed. EMG is partially superimposed by his body movement.

aging process of the control subjects does not likely influence EEG changes during Zen meditation.

Sometimes the theta waves appear as Zen meditation progresses. These changes are clearly shown in EEG of another Zen master of 60 years of age (Fig. 11). Figure 12 shows large alpha waves with 70–100 μ V. in amplitude and 8–9/sec. in frequency after 24 minutes of his Zen meditation. And 30 seconds later, the rhythmical theta train (6–7/sec. 60–70 μ V.) begins to appear (Fig. 12). The appearance of the theta train becomes distinct through the stable periods of large and slow alpha waves. From the above-mentioned results it is pointed out that a series of EEG changes in the course of Zen meditation are observed; The activating pattern (of opened eyes) before Zen meditation \rightarrow appearance of alpha waves at initial stage \rightarrow increase of alpha amplitude \rightarrow decrease of alpha frequency \rightarrow appearance of rhythmical theta train in later stage of Zen meditation.

This series of changes can not always be observed in all Zen subjects. Some subjects only show the appearance of alpha waves through the all meditation period and others show the typical series of electrographic changes. But from our findings, the changes of electroencephalogram during Zen meditation are classified in the following four stages:

Stage I: a slight change which is characterized by the appearance of alpha waves in spite of opened eyes.

Stage II: the increase in amplitude of persistent alpha waves.

Stage III: the decrease of alpha frequency.

Stage IV: the appearance of the rhythmical theta train, which is the final change of EEG during Zen meditation but does not always occur.

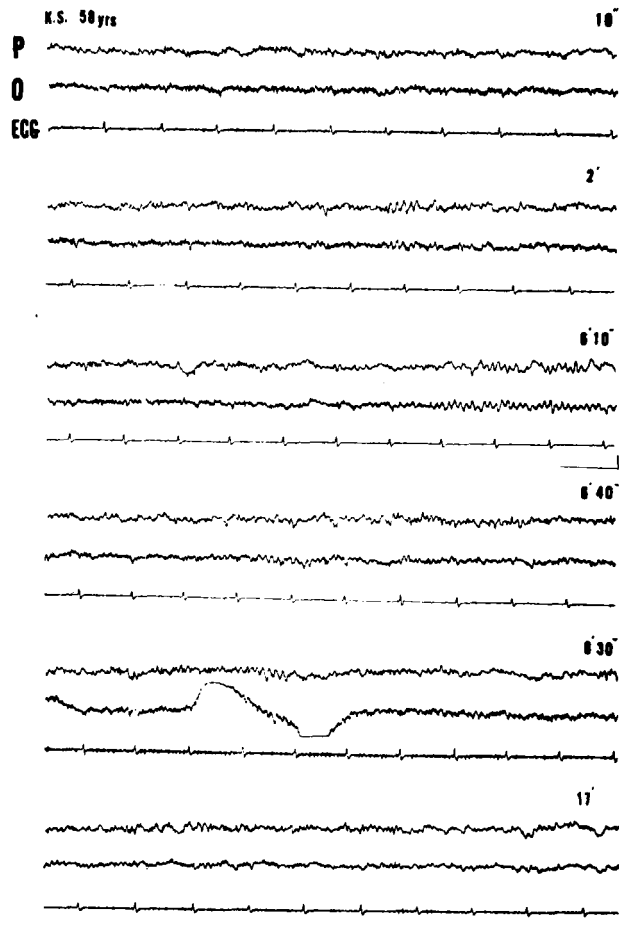


Fig. 10. a) Another control subject (58 years of age) with opened eyes. Few alpha waves are seen. But neither increase of alpha amplitude nor decrease of alpha frequency are observed in the full course of the recording.

2. EEG changes and the degree of Zen training

In accordance with the subjects' years spent in Zen training, 23 Zen disciples were classified into 3 groups—within 5 years, 5–20 years and over 20 years. Also, the evaluation of the mental states in the Zen sense of these disciples were used and their Zen master divided them into 3 groups; low (L), middle (M) and high (H). This evaluation was made independently without regard to their EEG changes.

Then the authors attempted to relate these degrees of Zen training in the 4 stages (I, II, III and IV) of the EEG changes. Figure 13 and 14 show the results. In the vertical line the stages of EEG changes are plotted and the horizontal line shows the subjects' training years (Fig. 13). It is clear that the more years spent in Zen training, the more EEG changes are seen. The correlation of EEG changes with mental state,

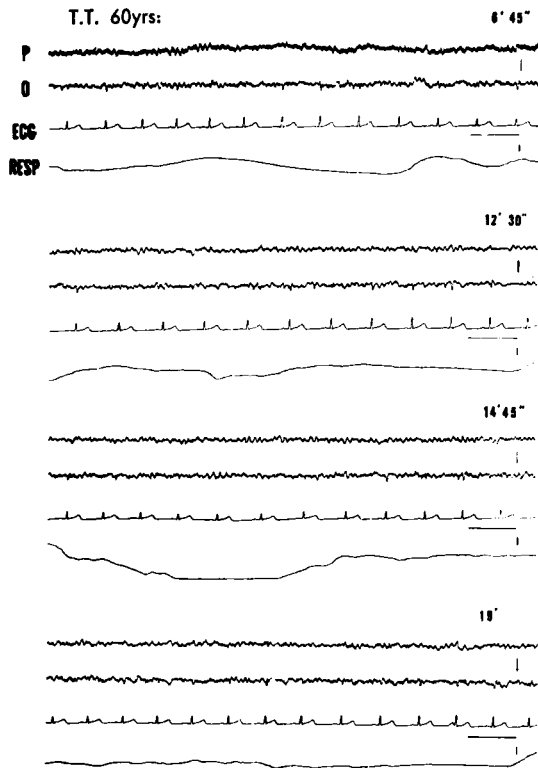


Fig. 10. b) Same result in the aged control subject (60 years of age). Notice that the EEG does not change in the aged control subject with opening eyes, even though for a fairly long time the recordings are performed.

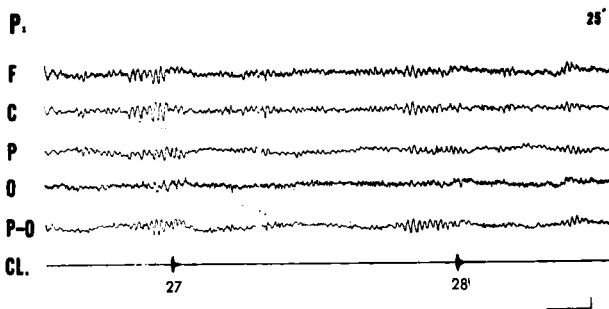


Fig. 11. This Zen priest (60 years of age) shows the theta waves on his EEG during Zen meditation.

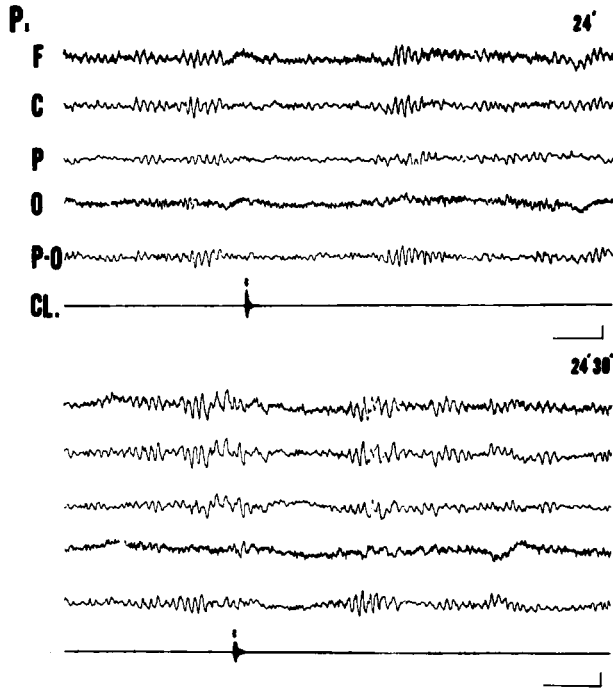


Fig. 12. Zen priest's EEG (48 years of age) during his Zen meditation. The large alpha waves are seen (above). 30 seconds later, the rhythmical theta train also appears and is blocked by the click stimulus (below).

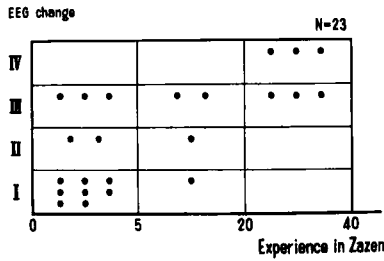


Fig. 13. The relationship between the grade of EEG changes (I, II, III and IV, from lower to higher) in vertical line and the disciples' years spent in Zen training in horizontal line. There is a fairly constant relationship.

which was evaluated by the Zen master, is shown in Fig. 14. It shows the close relationship between the evaluation by the master and the degree of EEG changes. From these findings, it will be concluded that the degrees of EEG changes during Zen meditation are parallel with the disciples' proficiency in Zen training. The 4 stages of EEG changes reflect physiologically the mental state during Zen meditation. This will be discussed later.

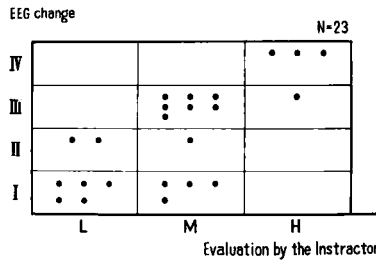


Fig. 14. The correlation of EEG grades (I-IV) with the disciples' mental states, which was evaluated by the Zen master, classified as low (L), middle (M) and high (H). The close relationship is recognized between both.

3. EEG changes during Zen meditation and hypnosis

The mental state in hypnosis is generally considered as "trance". Some may think that the mental state of Zen meditation will be a trance-like state. The authors compared the EEG changes in hypnotic trance with those of Zen meditation. Figure 15 shows the EEG in hypnotic trance. In this hypnotized subject, a university student of 20 years, the catalepsy is manifested. As shown in this figure few alpha waves are seen, but the activating pattern is more prominent than EEG in Zen meditation. The series of EEG changes during Zen meditation is not observed in the course of hypnotic trance.

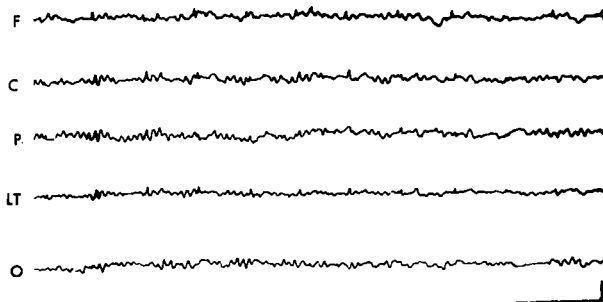


Fig. 15. EEG in hypnotic trance. The catalepsy appears in this hypnotized subject with closed eyes and his EEG shows random alpha waves with more prominent beta type of activity. (The authors are indebted to Mr. K. Fujisawa, M.A. for this finding.)

4. EEG changes during Zen meditation and sleep

In the course of EEG recording during Zen training, the disciples sometimes fall into a drowsy state, which becomes clear on EEG pattern. One of the typical examples is shown in Fig. 16, in which the drowsy pattern appears temporarily. At this time the click stimulus is given, then the drowsy pattern turns into the alpha pattern and alpha arousal reaction is observed. This electrographical change is usually accompanied with a floating consciousness from sleep to wakefulness according to the

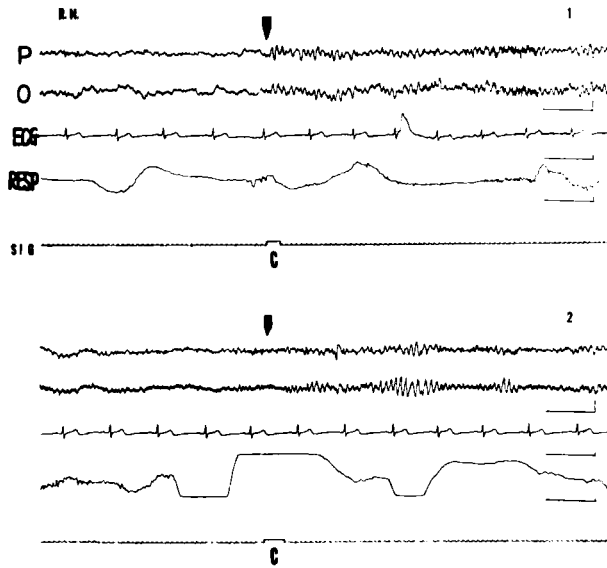


Fig. 16. The drowsy pattern appeared in Zen dicycle during his Zen training turns into alpha waves by the click stimulation (c) and the alpha arousal reaction occurs (cf. Fig. 11 and 12). RESP: Respiration.

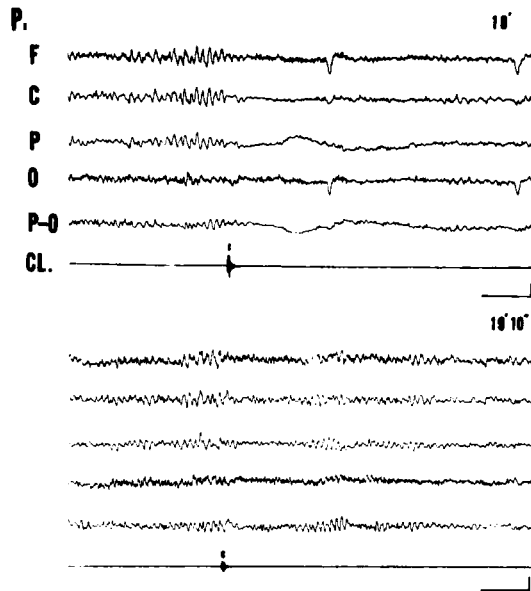


Fig. 17. On the contrary, the rhythmical theta train in Zen meditation shows no distinct alpha arousal reaction by the click stimulation.

disciple's introspection. This state is different from the mental state in Zen meditation. The sleepiness, which is called "Konchin", is suppressed in Zen training.

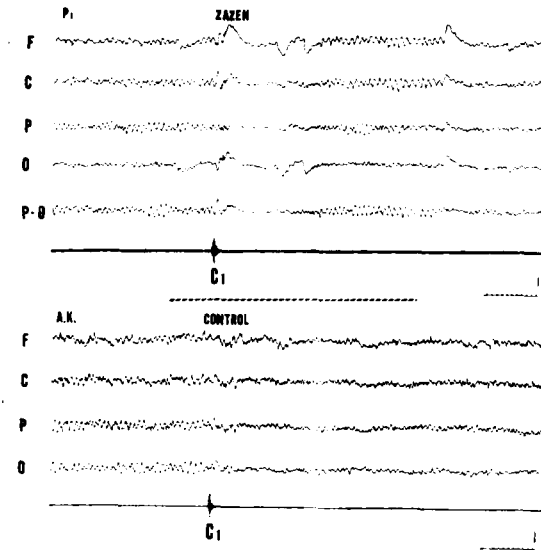
As mentioned before the rhythmical theta train appears in some Zen priests during their Zen meditation. The theta train is also seen in the sleep pattern. But the electrographical difference exists between the theta waves in sleep and the rhythmical theta train in Zen meditation. This difference is evident in the following examples; Fig. 17 shows the result of electroencephalographical response to click stimulus in a certain Zen master (Fig. 17). The rhythmical theta train is clearly seen on EEG during his Zen meditation. At this time, the click stimulus is given. The rhythmical theta train is blocked by the stimulation and reappears spontaneously after several seconds later. The alpha arousal reaction, which is often seen by the stimulation in drowsy state, is not observed. Therefore the rhythmical theta train in this instance has an "alpha activity"⁵⁾ which is similar to the waking alpha rhythm.

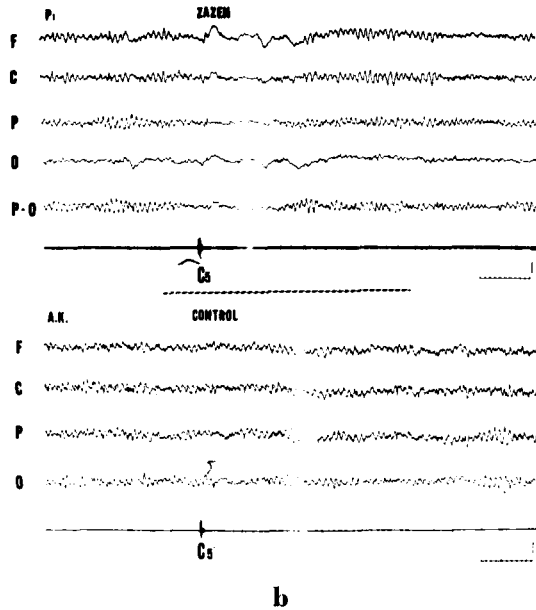
Just before falling into sleep or in the hypnagogic stage, large alpha waves are often seen. These waves are similar to that of Zen meditation. But the large alpha waves seen in stage II or III of Zen meditation persist much longer than the pre-sleep pattern. This difference will be discussed later in detail.

5. EEG response to click stimulation in Zen meditation

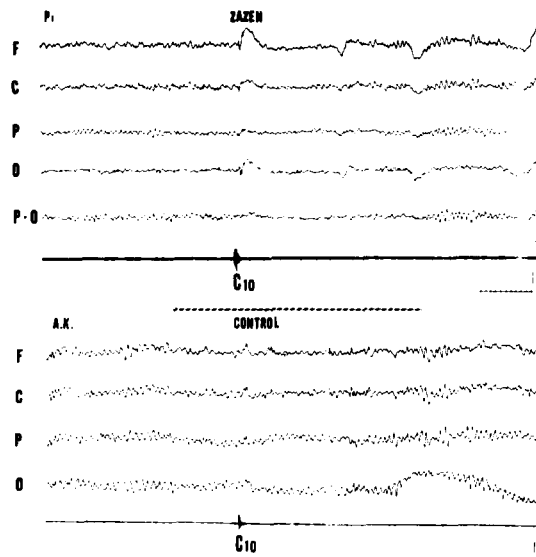
In the preceding chapters a series of EEG changes in Zen meditation was described. In this chapter, the authors will deal with the results of alpha blocking to the repetitive click stimuli with regular intervals.

The click stimulation was performed at the stage of long-persisted alpha waves of a certain Zen master. To the first stimulus the alpha blocking occurs for 2 seconds. With the regular intervals of 15 seconds, the click stimuli are repeated 20 times, the alpha blocking is always observed for 2–3 seconds (Fig. 18 a, b, c, d, e). On the other hand the same stimulation is performed in alpha pattern of control subjects with closed





b



c

eyes. The more the stimulation repeats, the less the alpha blocking time (Fig. 18 a, b, c, d, e). The same experiments were performed on 3 Zen masters and 4 control subjects and the alpha blocking time to each stimulation was measured. The measurement of the alpha blocking time leads to the following results; In control subjects, the alpha blocking time decreases rapidly (Fig. 19), but in Zen masters, the alpha blocking

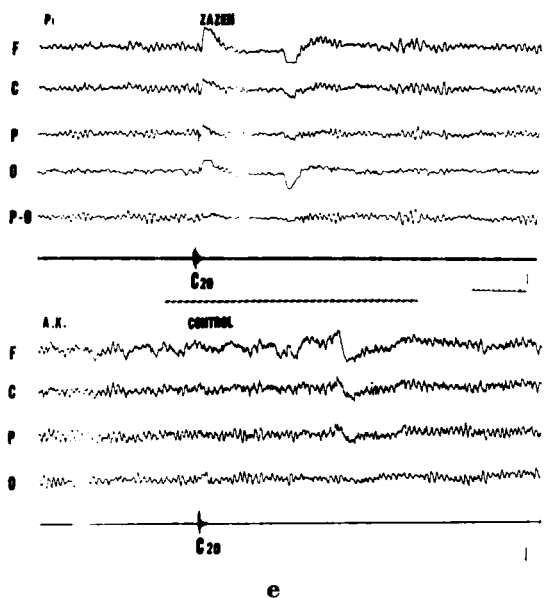
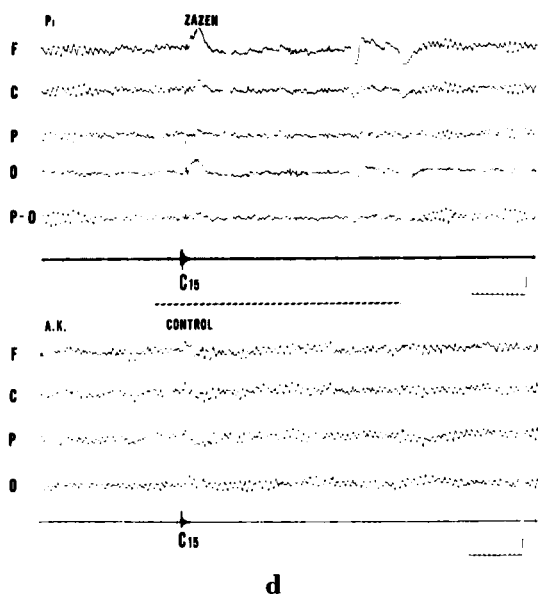


Fig. 18. (a. b. c. d. e.) The difference of alpha rhythm in Zen meditation with opened eyes (above) from that of resting state with closed eyes in control subject (below). The repeated click stimulations produce the regular alpha blocking in Zen priest but quick habituation in control subject (shown in b, c, d, and e).

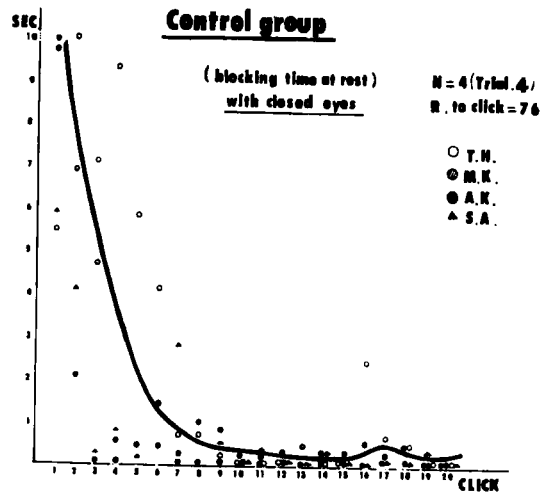


Fig. 19. The results of measurements of alpha blocking time in 4 control subjects with closed eyes. The vertical line shows the alpha blocking time in seconds and horizontal line the number of clicks. The alpha blocking time decrease rapidly. The habituation of alpha blocking is clearly seen.

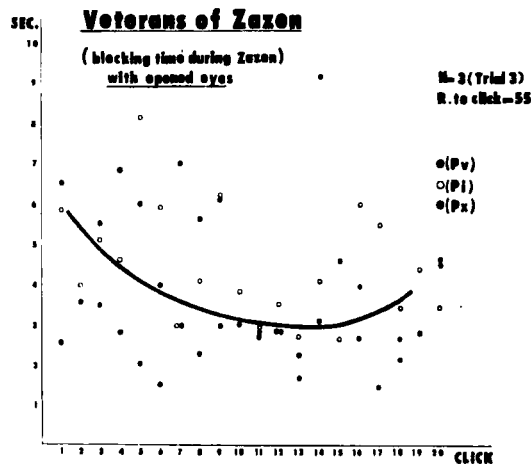


Fig. 20. The same graphic representation of the alpha blocking time in 3 Zen masters with opened eyes. There are some random changes in blocking time. But the habituation seen in control subjects is never observed even though the click stimulation is repeated.

time is fairly constant though some random changes are seen. (Fig. 20).

From the above mentioned results it is concluded that there is almost no adaptation of alpha blocking during Zen meditation.

DISCUSSION

It has become apparent in our study that the electrographic changes of Zen meditation are the appearance of alpha waves without regard to opened eyes. These alpha waves increase amplitude and decrease frequency with the progress of Zen meditation. And sometimes the rhythmical theta train appears in the later stage of the meditation. These findings are also parallel with the degree of Zen disciples' mental states in the Zen sense and their years spent in Zen training.

It is common that the concentration, mental calculation and efforts to perceive the objects—these mental activities elevate the level of consciousness accompanied by the activating pattern^{1,2,6,12,29,31,32}). Thus the activating pattern indicates the augmentation of level of consciousness^{20,24}).

Zen meditation is the concentrated regulation of inner mind. It will be, therefore, expected that Zen meditation will bring about the activating pattern. Nevertheless the lowering of cortical potentials is confirmed by our electrographic findings. This is rather paradoxical but is of prime interest to consider a relationship between the physiology of the brain and the level of consciousness.

According to the instructions of Zen meditation, the regulation of inner mind is strongly emphasized. And by obeying the rules of Zen training the well-achieved meditation has been completed. In the well-achieved meditation, it will be said that "concentration" without tension (that is the true concentration) is going on in the utmost inner world of psychic life.

From the electroencephalographic point of view, our results are coincident with EEG changes of lowered consciousness or vigilance. Mundy-Castle, A. C.^{23,24}) states that the persistent appearance of alpha waves indicates the brain function at the time of lowered vigilance. And many empirical observations of alpha waves point out its being not of action but of hypofunction of the brain^{7,20}).

In attempting to relate the various stages of the EEG pattern to corresponding psychological states and the behavioral correlates, Lindsley, D. B.²⁰) states that during more or less continuous relaxed state of wakefulness, amplitude modulated alpha waves are characteristic. The same concept is stated by Jasper, H.^{15,16}) in his sleep-wakefulness continuum; He introduces the concept of the cortical excitatory states reflected on these EEG patterns. According to Jasper's suggestion, it is said that the amplitude modulated alpha waves reflect the lowered level of the cortical excitatory states.

On the other hand, many agents which affect nerve cell metabolism, are known to alter the EEG^{4,13,17}). Kasamatsu, A. and Shimazono, Y.¹⁸) report that the large and slow alpha waves are observed in the earlier stage of N₂ gas inhalation, just before the loss of consciousness. In this state, subjects experience the relaxed consciousness or slightly elevated mood-changes. In the acute alcoholic intoxication the same effects are seen in both the EEG and consciousness¹⁸). Hirai, T.¹⁴) points out a decrease of the respiratory rate accompanied with the slowing of EEG pattern during Zen meditation. Sugi, Y. et al.³⁰) report the results of measurements of the respiratory rate, tidal volume and O₂ consumption during Zen meditation. They find a decrease of energy metabolism which is lower than basic metabolism. According to Sugi's suggestion, it may be due to the decrease of energy metabolism in the brain. It is possible that the decrease of energy metabolism also alters the electrographic pattern in Zen meditation.

From the foregoing surveys and discussions, EEG changes during Zen meditation

seem to indicate that the cortical excitatory level will be gradually lowered even by the "concentration" of inner mind.

From psychological point of view, both Zen meditation and hypnotic trance bring about the changes of consciousness. But the trance is called "Sanran" (confusion) and is strictly suppressed in Zen meditation. Therefore, some discussions will be needed about the difference of EEG changes between Zen meditation and hypnotic trance. The authors find out that there are no definite changes of subjects' electroencephalograms in hypnotic trance. There are many reports concerning the EEG changes in hypnotic trance but many of these indicate that the pattern does not differ from the waking EEG^{19,21}). There are no similarities of the pattern in hypnotic trance to EEG changes during Zen meditation.

Some scholars state that the sleep-like changes of EEG, more or less slight, are observed in hypnotic trance. Goldie et al.¹⁹ elicit a paradoxical electrographic effect in a drowsy hypnotized subject—the alpha pattern appearing in opened eyes' condition. Frank, B. J.⁹ reports that slow activity seen in deep sleep is recorded during the hypnosis. Lindsley, D. B.²⁰ points out that in accordance with the general relaxation, which occurs during hypnotic episodes, there is sometimes an increase in alpha pattern if slight drowsiness supervenes.

Fujisawa, K.¹⁰ studies EEG in the hypnotic state caused by sleep suggestion ("hypnotic sleep")^{9,7} and reveals the low voltage theta pattern which is similar to the drowsy pattern. He also points out that the drowsy-like pattern continues for a fairly long time as far as the rapport with the hypnotized subject is not lost and true sleep ensues if the rapport is lost. It is noticed that the slow rhythm in hypnotic sleep is more similar to the drowsy pattern than the rhythmical theta activity seen in Zen meditation.

Zen meditation is not a sleep from the disciples' introspections. But during Zen training, sometimes the slight drowsiness can be supervened likewise in a hypnosis. In the transitory state from wakefulness to drowsiness, large alpha waves are prominently seen and are prone to decrease in frequency just before the subject shows slight drowsiness²⁵). It may be said, therefore, that the large and slow alpha pattern during Zen meditation is a foregoing pattern of the drowsiness. Perhaps there is the lower threshold in a sweep or span of consciousness during Zen meditation. But in actual sleep, alpha waves recede, spindle burst and slow waves appear, and consciousness is lost. Such a series of electrographic changes does not occur in Zen meditation and consciousness is not lost, since in Zen meditation there is no lack of awareness of things going on externally and internally.

Even in the later stage of Zen meditation, in which the rhythmical theta train is seen on EEG, the sensibility is not lost and in fact the rhythmical theta train shows the marked blocking to sensory stimulation. From these findings, we will show the difference between both at Fig. 21 schematically; A series of EEG changes is common at a limit of alpha activities, but the sleep pattern diverges from this series in a downward curve, and turns to deep sleep.

From the above mentioned discussions, it can be said that during Zen meditation the level of the cerebral excitatory state is gradually lowered in a way that is different from sleep.

Next we will discuss the alpha blocking in Zen meditation. As described before, each click stimulus brings about a fairly constant alpha blocking continued for several seconds, even though the stimulation is repeated 20 times at regular intervals. But in control groups with closed eyes, the alpha blocking time is longer at 1st and 2nd stimulations but rapidly decreases and almost diminishes after 3rd or 4th stimulation.

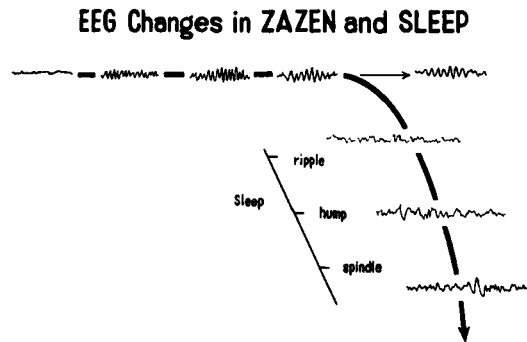


Fig. 21. A schematical representation of the difference between EEG changes in Zen meditation and in sleep. A series of EEG changes is common at a limit of alpha activities but the sleep pattern diverges from above horizontal train in a downward curve and turns to deep sleep.

So the habituation of alpha blocking is clearly recognized in this ordinary awakening state.

In Zen meditation the alpha blocking is less susceptible to habituation to sensory stimuli than in ordinary waking state. This fact is noteworthy to clarify the arousal state of consciousness in Zen meditation. During Zen meditation "concentration" without tension is maintained in the inner mind of the disciple while keeping the correct sitting form. These mental and physical conditions naturally lead to produce the certain constant experimental circumstances; A kind of concentration subserves the maintenance of a certain level of the consciousness on the one hand, and the sitting meditation form supports to keep the centripetal sensory inflows at a certain level on the other. In these circumstances, it would be supposed that the alpha blocking becomes less susceptible to habituation.

These findings are also supported by the introspection of our subjects in this experiment. The Zen masters reported to us that they had more clearly perceived each stimulus than in their ordinary awakening state. In this state of mind one cannot be affected by either external or internal stimulus, nevertheless he is able to respond to it. He perceives the objects, responds to it and yet is never disturbed by it. Each stimulus is accepted as stimulus itself and treated as such. One Zen master described such a state of mind as that of noticing every person one sees on the street but of not looking back with emotional curiosity.

However, it seems to be impossible to consider separately the continuous appearance of alpha waves and the alpha blocking, which is less susceptible to habituation in Zen meditation; The alpha blocking depends upon the cortical excitatory state, conversely the cortical excitatory state closely related to the centrifugal sensory impulses brought about alpha blocking.

Using the arousal reaction of EEG as a criterion response, Sharpless, S. and Jasper, H.²⁰⁾ studied a great variety of characteristics of the habituation. They classified two types of arousal reaction; a longer lasting one more susceptible to habituation and a shorter lasting one less susceptible. This finding, in agreement with other studies^{17), 20)} suggests that a longer lasting arousal reaction corresponds to the tonic activation on the cerebral cortex and a shorter lasting one to the phasic activation.

According to Jasper's suggestion, the alpha blocking, which is less susceptible to habituation, seems to be decided by the equilibrium of the tonic and phasic activation on the cerebral cortex. The authors want to postulate that there is an optimal activation mediated by the equilibrium of cortical excitatory state in a broad sweep or span of the waking consciousness. And perhaps its underlying neurophysiological basis may be an interaction between the cerebral cortex and the reticular activation systems of the diencephalic and mesencephalic portions in the brain stem²²).

The optimal preparedness for incoming stimuli, which maintains conversely the optimal level of the cortical excitatory state, is well reflected on both the alpha blocking, which is less susceptible to habituation, and on the series of EEG changes, which directs to the slowing of the pattern.

These EEG findings persist for a fairly long time and are constant though slight fluctuation is observed. There are also the fact that these persistent alpha waves can be often seen even after the end of Zen meditation. These findings suggest that in the awakening consciousness, there will be the special state of consciousness, in which the cortical excitatory level becomes lower than in ordinary wakefulness, but is not lowered as in sleep, and yet outer or inner stimulus is precisely perceived with steady responsiveness.

Zen meditation is purely a subjective experience completed by a concentration which holds the inner mind calm, pure and serene. And yet Zen meditation produces a special psychological state based on the changes in the electroencephalogram. Therefore, Zen meditation influences not only the psychic life but also the physiology of the brain. The authors call this state of mind as the "relaxed awakening with steady responsiveness".

SUMMARY

Zen meditation (ZAZEN) is a spiritual exercise held in the Zen sect of Buddhism. Apart from its religious significance, the training of Zen meditation produces changes not only in the mind but also in the body—these influences are of interest to scientific studies, from the stand point of psychology and physiology.

In the present study the EEG changes accompanied with Zen meditation have been revealed and described in detail. The authors discussed further these electrographic changes in relation to the consciousness with its underlying neurophysiological background, comparing with that of the hypnotic trance and sleep.

In our study, 48 priests and disciples of Zen sects of Buddhism were selected as the subjects and their EEGs were continuously recorded before, during and after Zen meditation. The following results were obtained;

1. The appearance of alpha waves were observed, without regard to opened eyes, within 50 sec. after the beginning of Zen meditation. These alpha waves continued to appear, and their amplitudes increased. And as Zen meditation progressed, the decrease of the alpha frequency was gradually manifested at the later stage. Further the rhythmical theta train with the amplitude modulated alpha-background was observed in some records of the priests. These EEG changes could be classified into 4 stages; the appearance of alpha waves (stage I), an increase of alpha amplitude (stage II), a decrease of alpha frequency (stage III) and the appearance of rhythmical theta train (stage IV).

2. These 4 stages of EEG changes were parallel with the disciples' mental states, which were evaluated by a Zen master, and disciples' years spent in Zen training.

3. These electrographic changes were also compared with that of the hypnotic trance and sleep. From the electroencephalographic point of view, the changes of stages I, II and III could not be clearly differentiated from those seen in hypnagogic state or the hypnotic sleep, though the changes during Zen meditation were more persistent and did not turn into deeper sleep pattern. The rhythmical theta train is suppressed by click stimulation and turns into a desynchronized pattern, whereas the drowsy pattern turns into alpha waves (the alpha arousal reaction).

4. The alpha blocking to the repeated click stimuli with regular intervals was also examined in Zen meditation with opened eyes and the ordinary conditions of control subjects with closed eyes. The former showed a fairly constant blocking time (3-5 sec.) to every stimuli repeated 20 times and the habituation was not recognized. On the other hand, in control subjects the habituation of alpha waves occurred very quickly. This alpha blocking, which is less susceptible to habituation, is of importance to consider the neurophysiological basis of the mental state during Zen meditation.

These electroencephalographic findings lead to the following conclusions; In Zen meditation, the slowing of EEG pattern is confirmed on the one hand, and the dehabituation of the alpha blocking on the other. These indicate the specific change of consciousness. The authors further discussed the state of mind during Zen meditation from the psychophysiological point of view.

We would like to express our deepest thanks to Prof. Emer, Yushi Uchimura, Director of Neuropsychiatric Research Institute, Tokyo, for his invaluable criticism and encouragement. We are indebted to Mr. K. Fujisawa, M. A. who provided the materials of EEG in hypnotic trance.

(This article is dedicated to Prof. H. Akimoto in commemoration of his 60th birth day.)

REFERENCES

- 1) Adrian, E. D. and B. H. C. Matthews: The Berger Rhythm. Potential changes from the occipital lobes in man. *Brain*, **57**, 355-385, 1934.
- 2) Bartley, S. H.: The relation between cortical response to visual stimulation and changes in the alpha rhythm. *J. exp. psychol.*, **27**, 624-639, 1940.
- 3) Baker, W. and Burgwin, S.: Brain wave patterns during hypnosis, hypnotic sleep, normal sleep. *Arch. Neurol. Psychiat.*, **62**, 412-420, 1949.
- 4) Brazier, M. A. B. and Finesinger, J. E.: Action of barbiturates on the cerebral cortex. *Arch. Neurol. Psychiat.*, **53**, 51-58, 1945.
- 5) Brazier, M. A. B.: The electrical activity of the nervous system. 2nd. Ed., London, 1960.
- 6) Callaway, III. E.: Factors influencing the relationship between alpha activity and visual reaction time. *Electroenceph. clin. Neurophysiol.*, **14**, 674-682, 1962.
- 7) Dynes, J. B.: Objective method for distinguishing sleep from the hypnotic trance. *Arch. Neurol. Psychiat.*, **57**, 84-93, 1947.
- 8) Fromm, E., Suzuki, D. T. and de Martino, R.: Zen Buddhism and Psychoanalysis. George Allen & Unwin LTD., London, 1960.
- 9) Frank, B. J.: L'hypnose et L'EEG. *Electroenceph. clin. Neurophysiol.*, **2**, 107, 1950.
- 10) Fujisawa, K.: The psychophysiological studies of sleep. *Jap. Psychol. Research.*, **2**, 120-134, 1960.
- 11) Gastaut, H.: The brain stem and cerebral electrogenesis in relation to consciousness. Ed., Adrian, E. D. et al., *Brain Mechanisms and Consciousness*. Blackwell, Oxford, 1954.

- 12) Glass, A.: Mental arithmetic and blocking of the occipital alpha rhythm. *Electroenceph. clin. Neurophysiol.*, **16**, 595-603, 1964.
- 13) Grünthal, E. und Bonkáló, A.: Über Ermüdung und Schlaf auf Grund hirnbioelektrischer Untersuchungen. *Arch. f. Psychiatr.*, **3**, 652-655, 1940.
- 14) Hirai, T.: [Electroencephalographic study on the Zen meditation.] (Jap.) *Psychiat. Neurol. Jap.*, **62**, 76-105, 1960.
- 15) Jasper, H. H.: In, *Epilepsy and Cerebral Localization*, edited by W. Penfield and T. C. Erickson., Springfield, Thomas, 1941.
- 16) Jasper, H. H. and C. Shagass.: Consciousness time judgements related to conditioned time intervals and voluntary control of the alpha rhythm. *J. exp. Psychol.*, **28**, 503-508, 1941.
- 17) Jung, R.: *Neurophysiologische Untersuchungsmethode*. Bergmann, G. V., *Handbuch d. inn. Med., Neurologie I*, Berlin, Springer-Verlag, 1953.
- 18) Kasamatsu, A. and Shimazono, Y.: [Clinical concept and neurophysiological basis of the disturbance of consciousness.] (Jap.) *Psychiat. Neurol. Jap.* **11**, 969-999, 1957.
- 19) Kleitman, N.: *Sleep and Wakefulness*. Univ. Chicago Press., Chicago and London, p. 329, 1963.
- 20) Lindsley, D. B.: Psychological phenomena and the electroencephalogram. *Electroenceph. clin. Neurophysiol.*, **4**, 443-456, 1952.
- 21) Loomis, A. L., Harvey, E. N. and Habart, G. A.: Brain potentials during hypnosis. *Science*, **83**, 239-241, 1936.
- 22) Moruzzi, G. and Magoun, H. W.: Brain stem reticular formation and activation of the EEG. *Electroenceph. clin. Neurophysiol.*, **1**, 455-473, 1949.
- 23) Mundy-Castle, A. C. and Mckiever, B. L.: The psychophysiological significance of the galvanic skin response. *J. exp. Psychol.*, **45**, 15-24, 1953.
- 24) Mundy-Castle, A. C.: An appraisal of electroencephalography in relation to psychology. *Monogr. suppl.*, No. 2 of *J. nat. Institute f. personnel Research.*, 1-43, 1958.
- 25) Oswald, I.: Experimental studies of rhythm, anxiety and cerebral vigilance. *J. Ment. Sci.*, **105**, 269-294, 1959.
- 26) Schultz, J. H. and W. Luthé: *Autogenic Training*. Grune and Stratton, New York and London, p. 289, 1959.
- 27) Sharpless, S. and H. Jasper.: Habituation of the arousal reaction., *Brain*, **79**, 655-680, 1956.
- 28) Suzuki, D. T.: *An Introduction to Zen Buddhism*. (Ed. Humphrey, C.) Arrows Books.
- 29) Slater, K. H.: Alpha rhythms and mental imagery. *Electroenceph. clin. Neurophysiol.*, **12**, 851-859, 1960.
- 30) Sugi, Y. and Akutsu, K.: *Science of Zazen.—Energy metabolism*. Tokyo. 1964.
- 31) Walter, R. D. and Yeager, C. L.: Visual imagery and electrographic changes. *Electroenceph. clin. Neurophysiol.*, **8**, 193-199, 1956.
- 32) Walter, W. G.: The twenty-fourth Mausley lecture: the functions of electrical rhythms in the brain. *J. ment. Sci.*, **96**, 1-31, 1950.