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A psychophysiological study on eye movement:

Some observations of eye movements during waking state with closed eyes by electro-oculograph.

Sachio Nakamizo

Introduction

In psychology, there have been two types of problem concerning eye movements. The first, being traditional in the field of psychology of vision, is whether or not the eye movement is one of the factors that determine the occurrence of visual phenomena, for instance, visual illusion, figure-ground reversal, auto-kinetic illusion and others*. The purpose of this kind of studies is to discover the determinants of various visual phenomena among the physical properties of the ocular movements. It seems to be reasonable to consider that the eye movements have some effects on vision, because of the evidence that the eye-balls involve the retinal photoreceptors transducing the physical energies of outer world into the physiological signals, that is, the inputs to the central nervous system.

The second, mainly in the field of psychophysiology, is whether or not the eye movements are concomitants of higher mental activities, for instance, the change of cognitive content (Antrobus and Singer, 1964), mental imagery (Lorens and Darrow, 1962) and attention (Amadeo and Shagass, 1963) and others. The purpose of

* A more detailed description of this problem was given by Woodworth and Schlosberg (1953).

this kind of studies are to examine the correctness of assumption that mental processes are associated with the ocular movements and to indicate psychophysiologically the functional significance of the ocular movements as motor discharge of the central nervous system. It seems possible to suppose that there are some relations between the eye movements and brain activity, because of the fact that the retina is generated as results of the functional differentination of the brain.

In this paper, we are much interested in the latter problem. There has been considerable attention to the eye movements in the field of psychophysiology since the following discovery by Aserinsky and Kleitman (1953, 1955); two contrasting types of eye movements corresponding to the stages of sleep. One is slow eye movement that appears slow, pendular rhythmical swings of the eye-balls prominently at the onset of sleep, and the other is rapid eye movement to be regarded as one of the indicators of paradoxical sleep. Since then, a large number of observations* on the eye movements during sleep have been made and the presence of these types of eye movements is fully confirmed, but we have as yet very little information with regard to the neural mechanism involved in the production of both movements.

Subsequently, the eye movements similar to those during sleep have been observed during waking state with closed eyes. Some researchers consider that the rapid eye movements during waking state with closed eyes are associated with visual imagery in accordance with the following suggestion by Dement and Kleitman (1957); the occurrences of rapid eye movements during sleep may signify that eyes of sleeping subject are scanning the dream imagery involved in dreaming. That is, it is assumed that the same

* For further references on the eye movement during sleep, readers are referred to Dement (1964).

mechanism which produces visual fixation and scanning with open eyes, may be active in the period of the occurrence of the rapid eye movements with closed eyes.

The others consider that the rapid eye movements during waking state with closed eyes may be regarded as a non-specific concomitant of attentive activity. Shimazono (1966) supporting this hypothesis considers that they are closely related to the changes of level of anxiety or mental tension on the basis of observation on the ocular responses to visual and non-visual stimulus and to chlorpromazine and amobarbital.

In the present paper, we shall try to show the results of the observations on the eye movements under the condition of visually induced attention with closed eyes and to consider the relationships between the eye movement and mental processes.

Method

Subjects:

Seven normal subjects, five males and two females between the ages of 21 and 30 years, were employed in this study.

Apparatus:

Electro-oculograph (E O G) was used for recording the eye movements because of the only simple technique which could record adequately the eye movements when eyes were closed. E O G electrodes were silver discs, 5 mm. in diameter and attached about 10 mm. above upper lid and about 10 mm. below the lower lid with adhesive tape to record vertical eye movement, and about 10 mm. lateral to each external canthus for horizontal eye movement. These electro-oculogram were recorded by 13 channels SANEI Model EG-139 electroencephlograph. This apparatus consisted of A. C. amplifier and recording system and the time constant of the amplifier, 0.3 seconds, was employed mainly.

Recording procedures:

Following attachment of electrodes, subject sat down the arm chair and took a chin-rest in a shielded room. Subject were instructed to relax. The E O G was first recorded for a five minute resting period, and then, for a three minute under the condition that subjects with closed eyes were required to pay attention to the spot-light stimulus on eyelid, 2.5 cm. in diameter, of which intensity was controlled by experimenter. Instructions for the above-mentioned condition were as follows: "When you feel the changes of light intensity on your eye-lids, press the button in your right hand as fast as possible. And you must focus attention on the spot-light."

In addition, to examine the effects of eye-closing on the eye movements, subjects were required to fixate their eyes on a target about 1 m. front of faces and to close their eyes when experimenter signaled to them. Eye movements were recording continuously during the experimental session.

Results

Figure 1 shows the sample tracings of horizontal components of eye movement in resting period using various kind of time constant of amplifier. From the figure, it will be found that the differences of time constant hardly influence on the recorded wave forms under this condition.

Figure 2 represents the sample tracings of horizontal components of eye movement during resting period with closed eyes. As is evident from the figure, the ocular motility measured as changes of corneo-retinal potentials differs inter-individually.

Figure 3 represents the sample tracings of horizontal components of eye movement during visually induced attention with closed eyes in comparison with those during resting. These examples

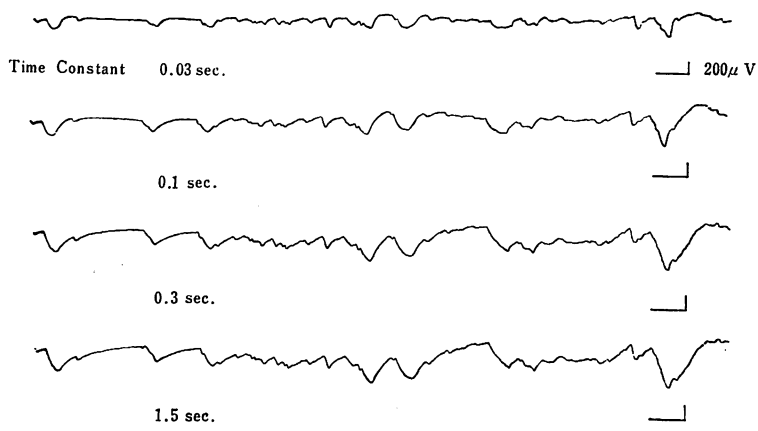


Figure 1. Sample tracings of horizontal eye movement recorded by means of various kinds of time constant.

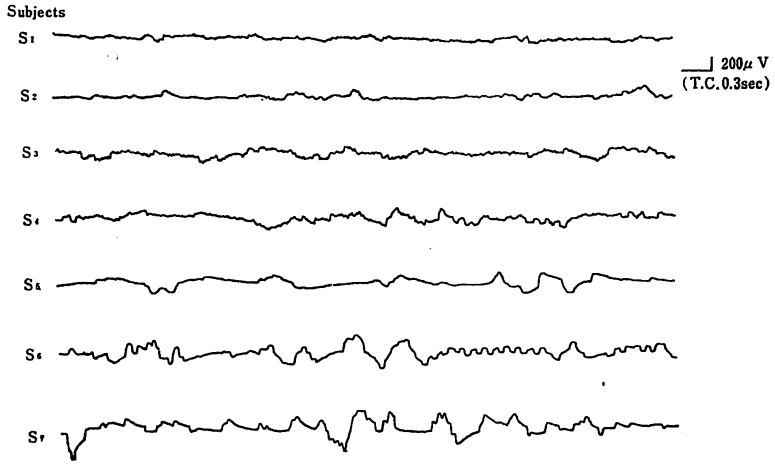


Figure 2. Sample tracings of horizontal eye movement during resting.

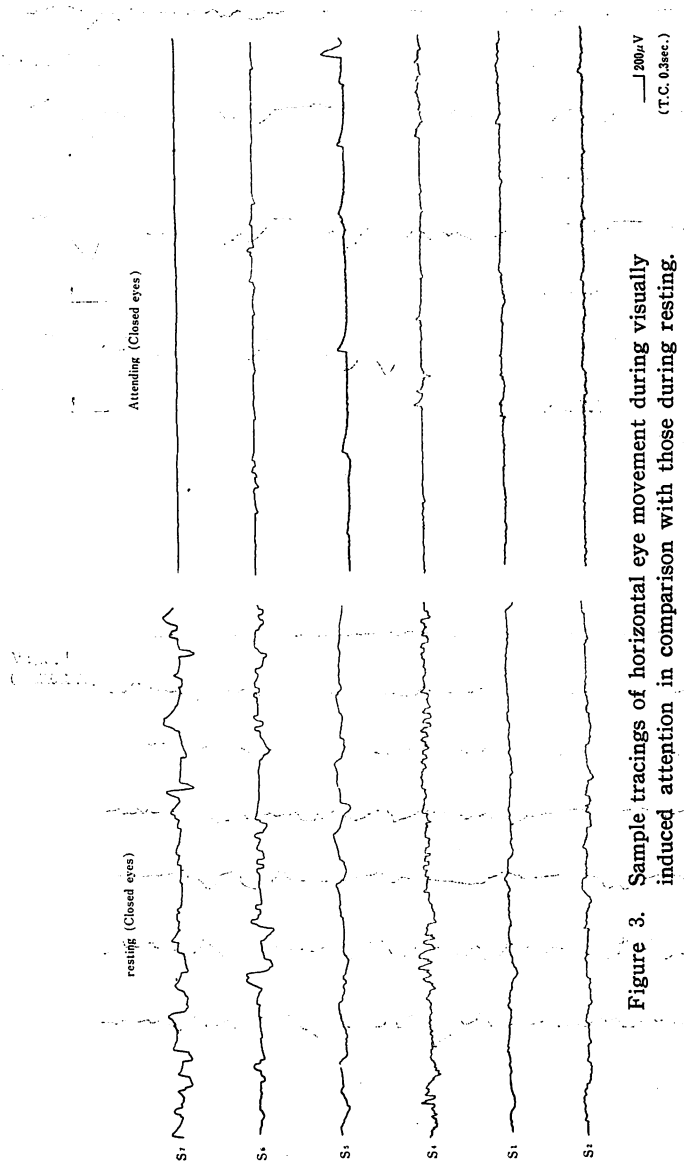


Figure 3. Sample tracings of horizontal eye movement during visually induced attention in comparison with those during resting.

illustrate that the ocular motility under the condition of visual attention to light stimulus decreases relatively rather than those in resting.

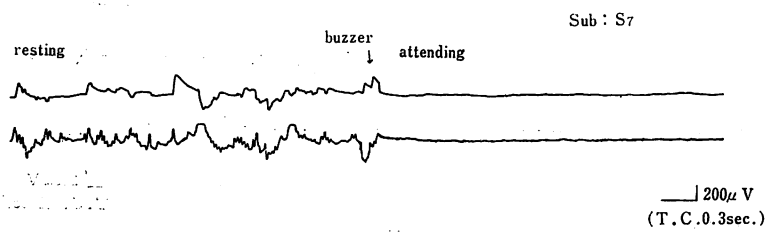


Figure 4. Sample tracings of horizontal and vertical eye movements during visually induced attention with closed eyes.

Figure 4 represents the typical sample tracings of horizontal and vertical components of eye movement under the condition of visually induced attention with closed eyes. It is apparent that the ocular motility abruptly decreases at buzzer-signal. It seems to suggest that there are sudden changes of involuntary oculomotor function when a buzzer-signal is presented to the subject and he starts to attend to the light stimulus with closed eyes.

Figure 5 represents the effects of eye-closing on the eye movement. Subjects, continuing to fixate their eyes on a target, were instructed to close their eyes at buzzer signal. It is readily found from the figure that involuntary eye movements occur just after eye-closing. It seems that these increases of ocular motility may result not from the interruption of light inflow, but from eye-closing itself. Figure 6 represents the sample tracings in another experiment, in which the eye movements were compared with under three conditions: (1) interruption of light in process of fixating on a light target, (2) eye-closing in process of similar fixation, (3) instruction that "You should make an effort not to move your eyeballs after eye-closing." From the figure, it is clear that there are significant differences of ocular motility between the first condition

and the latter two conditions. This suggests that the increases of ocular motility are due not to the interruption of light inflow, but to eye-closing itself.

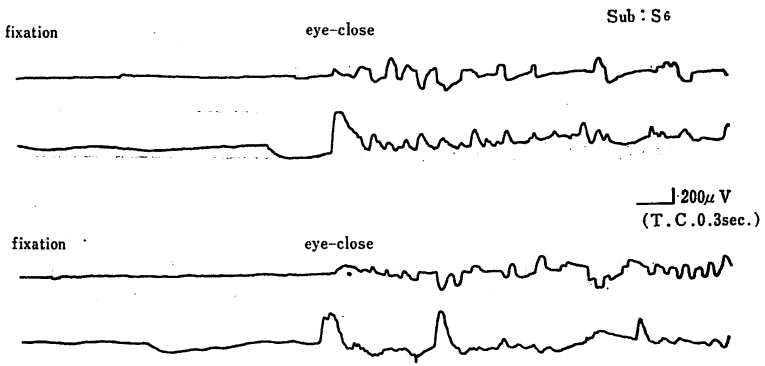


Figure 5. Effects of eye-closing on the eye movement.

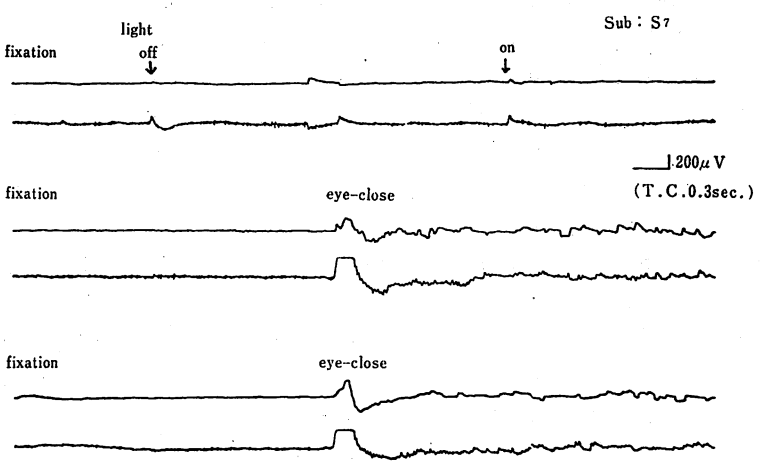


Figure 6. Effects of eye-closing and the interruption of light inflow on the eye movement.

Discusstion

We may now consider the problem of eye movements during

waking state with closed eyes.

According to Shimazono, et al. (1964, 1966), two types of eye movements, relatively slow and relatively rapid eye movements, are observed during waking state with closed eyes as during sleep. It is a general view that these two types may possess distinctly different relationships and their functional significance may be not the same (Dement, 1964; Shimazono, 1966; Tanaka, 1966; Sakamoto, 1965).

As stated in the introduction, there are two points of view concerning the rapid eye movements during waking state with closed eyes. We continue the discussion on both views. One is that rapid eye movements are a concomitant phenomenon of visual imagery on the basis of suggestion that the rapid eye movements during sleep are related dream imagery. Lorens and Darrow (1962) suggested that the increase in eye movement activity during mental multiplication relates to the visual images formed by subjects during calculation on the basis of their results that the increase in the eye movement rate occurs during mental multiplication in comparison with those during resting.

Recently, in his attempt to analyze imagery in physiological term, Hebb (1968) proposed the idea that the motor accompaniments of imagery are not adventitious but essential and eye movement is one of the motor components.

The other is that the rapid eye movements during waking state are taken as a non-specific indicator of attentive activity. Amadeo and Shagass observed that the rapid eye movement rate in ten subjects compared under three conditions: rest, directed visual imagery, and the state of heightened attention, showed significant increases in the latter two conditions and concluded that the rapid eye movements are concomitant of attention and their rate was one indicator of the level of attentive activity. They described that the

increased rapid eye movement rate found during specific imgery could easily be accounted for if one considered this condition as a particular instance of heightened attention.

Shimazono, et al. (1964, 1965, 1966), Sakamoto (1965) and Tanaka (1966), supporting the conclusion by Amadeo and Shagass, considered that the rapid eye movements during waking state were related to the level of anxiety or mental tensional state from their observations on the ocular responses of normals and chronic psychoses to visual, auditory and verbal stimulations and to chlorpromazine, amobarbital and metha-amphetamine.

However, our observations reported in this paper suggest that the reexamination of the validity of both hypothsis above mentioned must be the subject of future research. Firstly, the results of present study indicate that there are decreases of the ocular motility under the condition of visually induced attention as compared with those during resting (See Fig. 3). These contradictory findings to previous results suggest that the operational definition of attention becomes a serious problem, that is, how to define the attentional state by means of experimental procedure.

Secondly, results obtained by Lorens and Darrow (1962) are not in agreement with our previous observations that there were not always increases of ocular motility during mental multiplication with closed eyes. Figure 7 shows the sample tracings indicating the decreases of ocular motility during mental multiplication. Furthermore, as Amadeo and Shagass described, it is quite possible that there is no reason to believe that there should been more imagery during mental multiplication than the resting period.

Thirdly, the ocular motility measured as the changes of E O G ptentional level may differ inter-individually, notwithstanding it seems to be under the same condition. It is apparent from our observations that there are individual differences of the ocular mo-

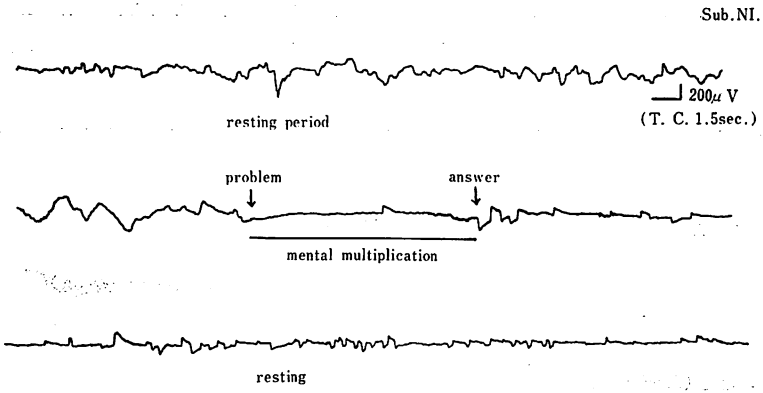


Figure 7. Sample tracings of horizontal eye movement during mental multiplications.

tility during resting with closed eyes. Figure 8 shows the sample tracings from the previous experiment (Nakamizo, 1969), in which the eye movements were compared with under three conditions: resting, tactile seaching (tactual pattern recognition) and imaging the same pattern, all conditions with closed eyes. Tracings of subject A indicate that the horizontal, small rapid eye movements appear during resting, and frequency of the rapid eye movements relatively decrease under the condition of tactile searching, and the ocular motility increase again during imaging. These changes of the ocular motility are not in agreement with tracings of subject B.

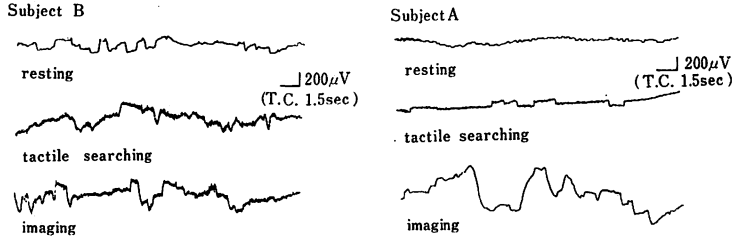


Figure 8. Sample tracings of horizontal eye movement under three conditions 1: resting, 2: tactilese arching, 3: imaging.

Figure 9 shows the sample tracings from the previous experiment, in which the eye movements during scanning a figure with opened eyes were compared with those during imaging the same figure with closed eyes. The pattern of eye movement during imaging differs from each other.

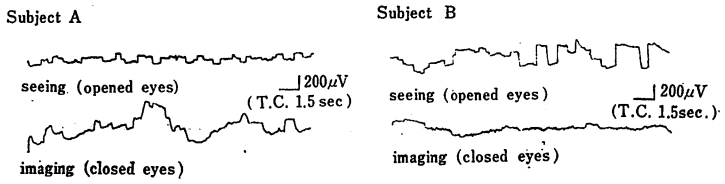


Figure 9. Sample tracings of horizontal eye movement during scanning and during imaging with closed eyes.

And lastly, it seems that the effects of eye-closing on the ocular motility are more important for the oculo-motor system. As indicated above, eye movements occurred just after eye-closing may not be under voluntary control. Its functional significance has not been understood and further studies on its relations to the acitvity of brain are necessary.

Summary

An psychophysiological investigation has been made on the relationship between the eye movements during waking state with closed eyes and mental processes. For the purpose, eye movement has been observed under the condition of visually induced attention with closed eyes and resting as control. Results of observation, that the ocular motility during visually induced attention tended to decrease in comparison with those in resting, contradict with the previous results that the increase of ocular motility is accompanied with attentive activity. Furthermore, our results of previous experiments have been presented and it is pointed out that the rela-

tionship between the ocular motility and mental states, for example, mental imagery or attention, has not always been confirmed clearly. Lastly, attention is drawn to the effect of eye-closing on the ocular motility.

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