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The Experimental Study of EEG Alpha and Kappa Rhythms during Mental Arithmetic

By Tetsuo Yamaoka

I. Foreword

Against the classical report [1] that EEG α rhythms decrease or attenuate during the activity of the mind, some reports are made that even then the α rhythms do not decrease, sometimes increasing. [8)9)10)11)14)15)16)18)] When makes the matter more complicated that the rhythm of the same frequency as α rhythm is also distinguished as κ rhythm, which appears in the parietal area and the temporal area during mental activities, especially in such intellectual activities as reading, discrimination, learning, and mental arithmetic. [3)4)5)]

There are many divergences in mental activity; from the direct reaction to the stimulation of sense such further activities as distraction and perception, to mental image. The tendency of the EEG appearance during these activities is not always identical. In the analysis of the tendency of the EEG appearance during mental activitiy, therefore, the sufficient control of above mentioned factors will be needed. [19)]

Analysis in the past was for the most part performed under the condition of those manifold factors.

When the task of mental arithmetic as an activity of thinking is set, it is the general method that the task is given to the subjects by a visual or an auditory manner and its answer is orally given in process of time. In the process of this experiment, the

task to subjects act on them in order by visual and auditory stimula tions. On the other hand it can be thougth that the answers made orally by subjects have the same effect on them. Further, it can also be thougth that the task given in process of time during the experiment may also be to have a certain effect on the emotion of subjects. Under these conditions, it is hard to think that EEG measured in the experiment is the pure projection in the process of thinking by arithmetic.[21]

This research was aimed mainly to make clear the tendency of the appearance of the EEG by controlling the conditions in mental arithmetic; in addition to this, to examine the differences of the tendency among areas for measurement, and to investigate the relation between α rhythm and κ rhythm.

II. Method

Subjects are eight men of sound health; university students and postgraduate students from 21 to 26 years old. Each of them is given a task of mental arithmetic before the experiment. The tasks are consist of two kinds of exercise; mental multiplication and mental addition. They are given separately to the same subject. The task of mental multiplication is to accumulate 1 by 3; that of mental addition is accumulate 3 to 50. Here the former is as a difficult exercise, and the latter as an easy one.

Subjects sat at ease in their chairs in an electrically shielded room and began, in closing their eyes, the mental calculation in accordance with the sign from the next room. The calculation was stopped by the sign from the next room, and they stopped it with the sign and entered the answer of that moment in their cards. Two minutes were given each exercise and the EEG was measured during the experiment. Areas for measurement were divided into six; each side of parietal, occipital, and temporal areas. The measurement was done in each part by an electroen-

cephalograph in the next room by monopolar lead. In the same way two kinds of EEG were measured for two minutes for the purpose of comparison and reference; one was when subjects kept quiet in opened eyes, and the other was when subjects kept quiet in closed eyes.

The instrument was an electroencephalograph for SANEI-MODEL machine. A recorder by pen writing was used. Speed of sending was 10 mm/sec.

By the direct measurement of the recorded EEG, the rhythms were divided into ten cycles, and analysis was made by the percentage of frequency of EEG*. The items of ten cycles are as follows: 0-5, -6, -7, -8, -9, -10, -11, -12, -13, 13-, c/s. The items from 6 to 13 c/s are divided in every one cycle through regular grades. Among them the rhythms from 8 to 13 c/s which belong to the band of α rhtyhms were divided into two parts, that is, alpha-slow (α_s) of 8-10 c/s and alpha-first (α_f) of 11-13 c/s.

Thus, frequency in EEG appearance was analyzed on the basis of ninety-six samples, that is, under four conditions of opend eyes-resting, mental multiplication and mental addition, and in three parts of right parietal, right occipital and rigth temporal areas, with each subject.

*In the present way of experiment only the percentage of frequency is computed, though automatic analysis by analyzer shows the rate of energy of each rhythm.

III. Results

Fig. I (a-b) shows by the averaged rate, the tendency of the EEG appearance in eight subjects in each area for measurement under each condition. In the following spectrograms under ten classifications, Fig. Ia is in opened eyes, Fig. Ib in closed eyes resting, Fig. Ic in mental multiplication with closed eyes, and Fig. Id in mental addition with closed eyes. We can see that β rhythms are dominant when in opened eyes, while α rhythms are dominant, 13 c/s at the height

when in rest, in mental multiplication, and in mental addition when in closed eyes. There can not be seen a specific difference with regard to the variation of spectrogram, among the areas for measurement.

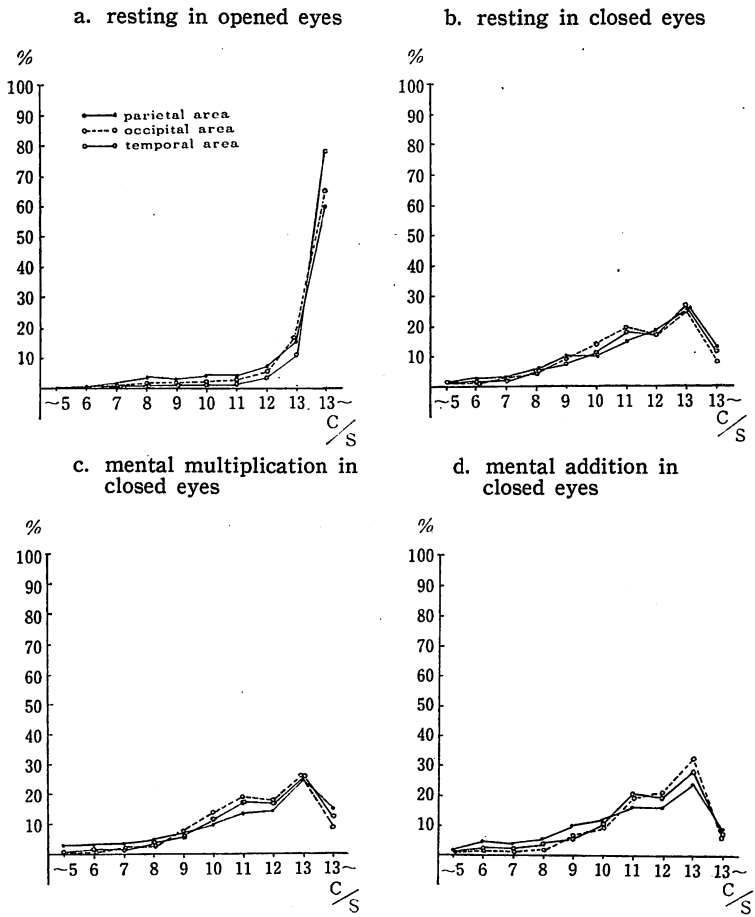


Fig. I. EEGs during four mental activities.

Fig. II (a-b) shows the same relationship when the bands are limited only to α rhythms. In Fig. IIa, the tendency of ap-

pearance of all α rhythms of 8-13 c/s is shown under each condition and by every area for measurement. Comparing the whole band of α rhythm in opened eyes with closed eyes, the parietal area has heigher rate of appearance than other areas in opened eyes, and the occipital area in closed eyes.

In three conditions of mental activities in closed eyes, α percent is higher rate in order of occipital, temporal and parietal areas. In occipital area, α percent is higher rate in conditions of mental activity, and in temporal area and parietal area, α percent is higher rate in order of rest, mental multiplication and addition. In the relationship between α_s and α_f, the latter appears much on the whole under all conditions, but there can not be seen a certain tendency in the relationship between the conditions of mental ac-

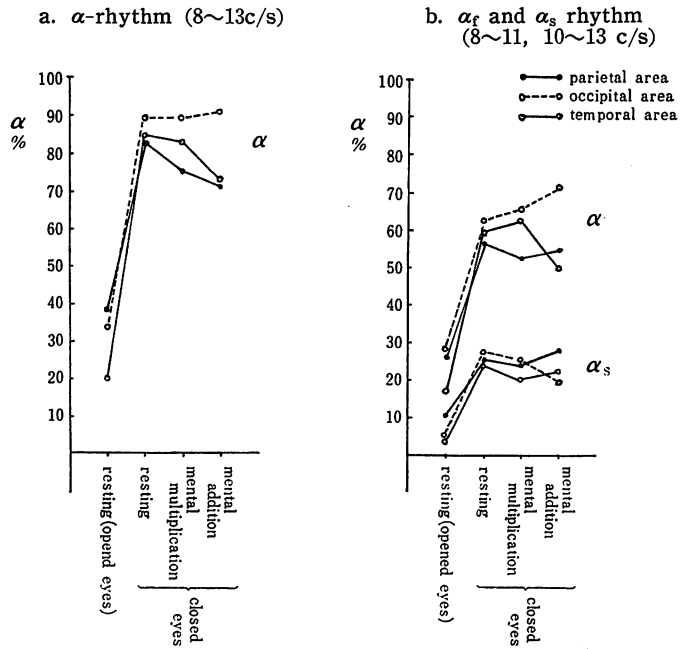


Fig. II. α rhythm during four mental activities.

tivity and the areas for measurement.

Average tendency in the spectrograms is mentioned above. Then, the data were investigated statistically how the tendency of appearance of α rhythms changed in three levels in "closed eyes"; activities of mind, areas for measurement, and subjects. The result is shown in Table 1.

Table 1 Analysis of variance
(Analysis of α rhythm under three conditions in closed eyes)

Variance	SS	df	ms	F	
Conditions of mental activity (A)	670.83	2	335.415	9.480	**
Areas for measurement (B)	1046.26	2	523.130	14.786	**
Subjects (C)	2794.77	7	384.967	10.881	**
A×B	515.68	4	128.920	3.643	*
A×C	1432.86	14	102.347	2.892	*
B×C	1180.69	14	84.379	2.383	
Error	990.62	28	35.379		
Total	8531.71	71			

As a result of the analysis of variance, significant differences were found at 1 % level, in each level of "condition of mental activity", "areas for measurement", and "subjects". In interaction effect, siginificant differences were found at 5 % level in "mental activity"×"areas for measrement", and "mental activity" ×"subjects" but not in "areas for measurement"×"subjects".

Table 2 Answers of tasks by subjects

Subjects	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Mental multiplication	2228×	209×	19983×	6561°	729°	62973×	19683°	2189×
Mental addition	285×	119°	105×	158°	229×	233°	236°	280×

mark ○ : right answer, mark × : wrong answer

The Table 2 shows the ultimate answers in mental arithmetic by subjects. They are three who made right in mental multiplication, and four in mental addition. Two subjects answered right

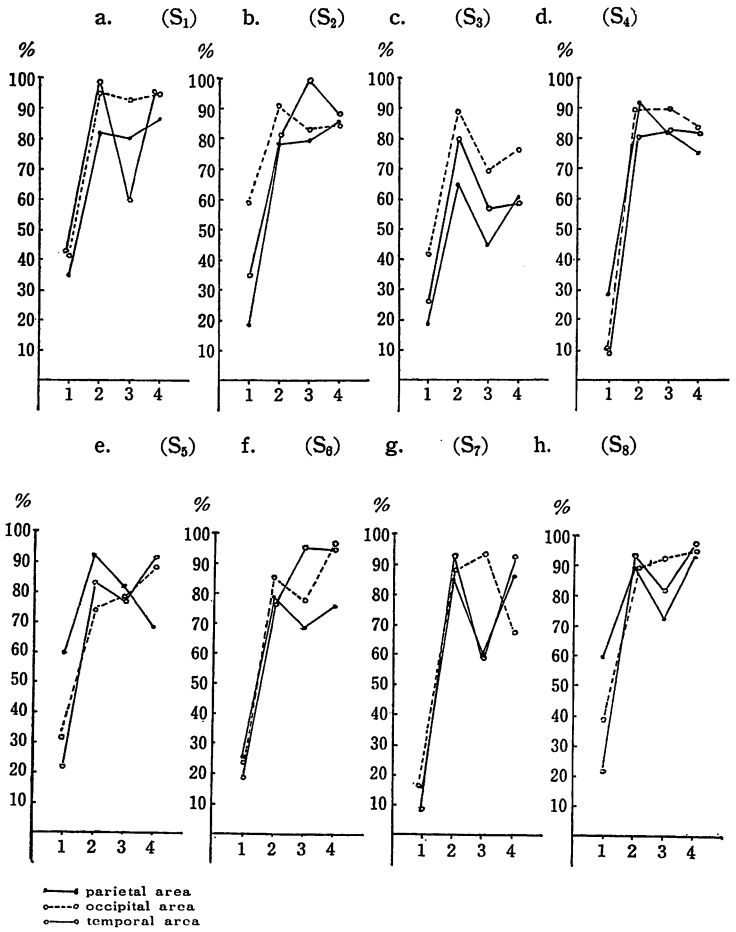


Fig. III. α rhythm during mental activities of each subjects.

in both operations. And three of the subjects gave wrong answers in both operations.

At the beginning of this experiment it seemed that mental multiplication was further difficult than mental addition, but the outcome is that both operations differed little in their hardness than expected.

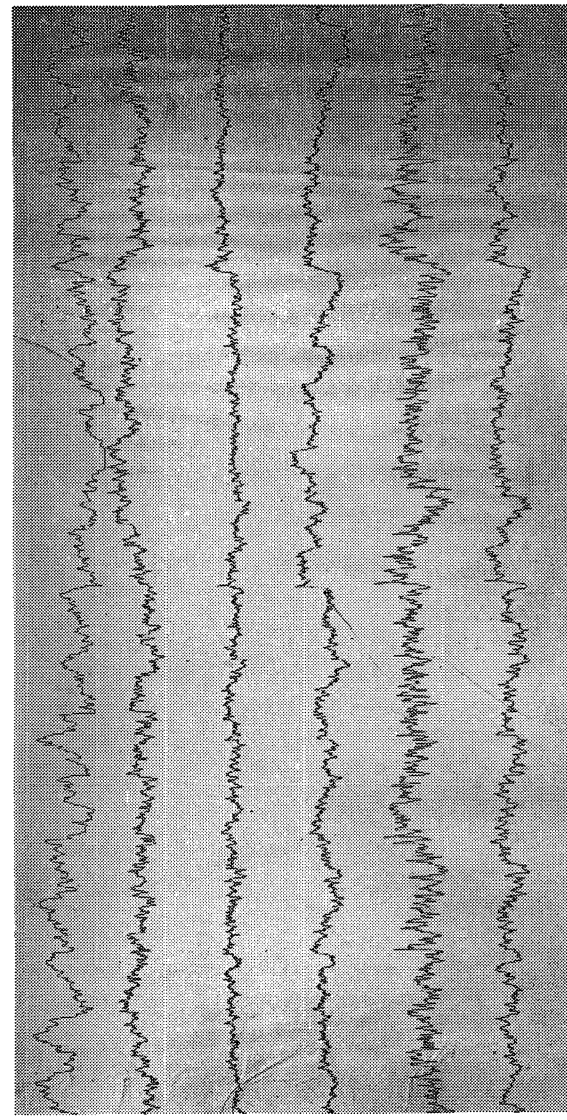
Fig. III (a-h) shows the percentage of the appearance of α rhythms of eight subjects, in each area for measurement, under four conditions. There is great difference between with "opened eyes" and with "closed eyes", while there is not a certain tendency in the difference between the condition of mental activity and the area for measurement.

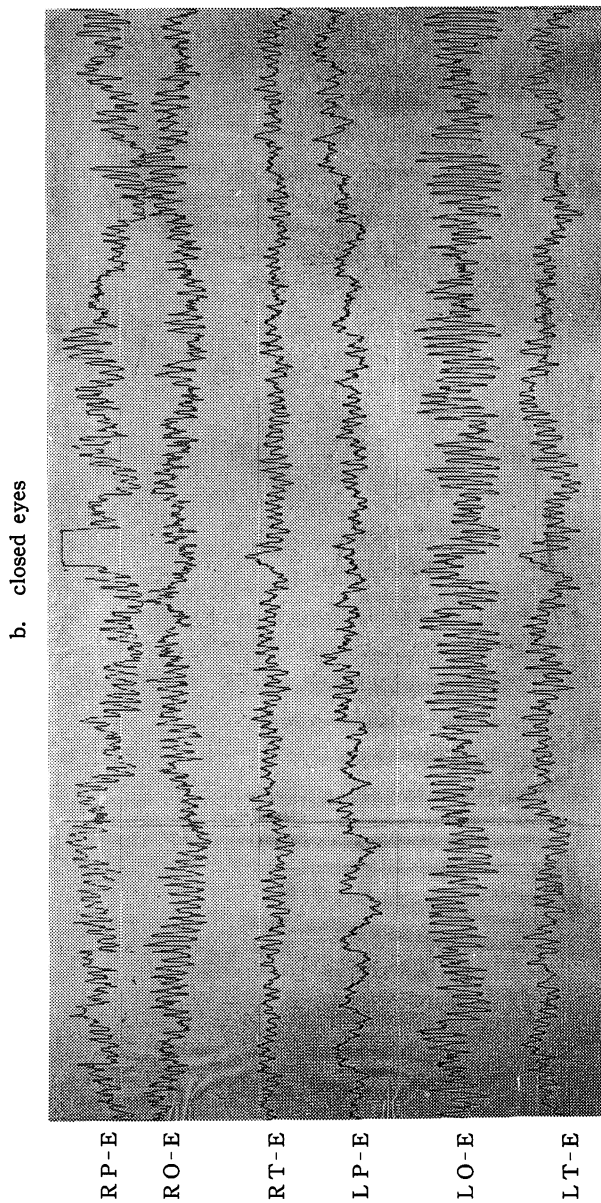
IV. Discussion

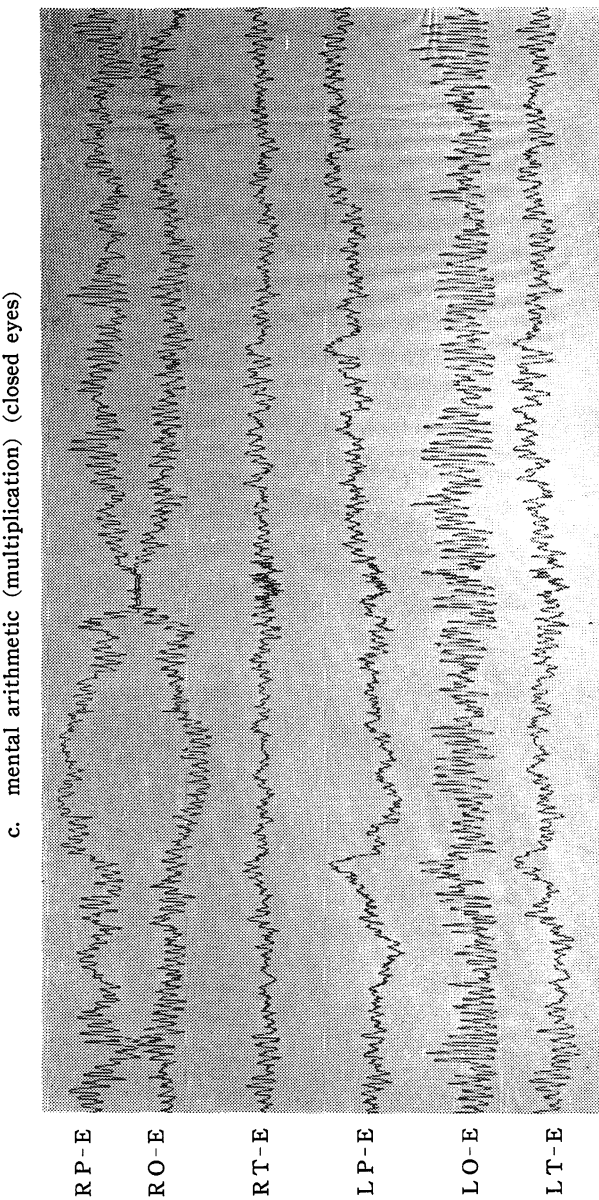
It has been said that during the activity of the mind, α rhythms decrease, while β rhythms increase. And it is said that this phenomenon also takes place merely by attention-set, in mental arithmetic [6)7)8)] and general activity of thinking, and in the imagination or in closed eyes. [13)17)] On the other hand, it has been reported that, in the smooth process of thinking, and according to the degree of hardness in mental arithmetic, the degree of appearance of α rhythms differs or does not sometimes decrease. [8)12)] The same band of frequency has different tendency of appearance on the different areas, that is, while the rhythms of the band decrease on the occipital area, but increase on the parietal and temporal areas, under such conditions as thinking, mental arithmetic, and discrimination. The former is called α rhythm, and the latter is named κ rhythm. [3)4)5)] So far, however, there was not a unifying result in these problems. It seems that it was due to the complex conditions. It was aimed in the report research to resolve the porblem by the control of the conditions in mental arithmetic.

The condition of mental arithmetic was controlled by putting

a. opened eyes




b. closed eyes
RP-E
RO-E
RT-E
LP-E
LO-E
LT-E


c. mental arithmetic (multiplication) (closed eyes)
R P-E
R O-E
R T-E
L P-E
L O-E
L T-E

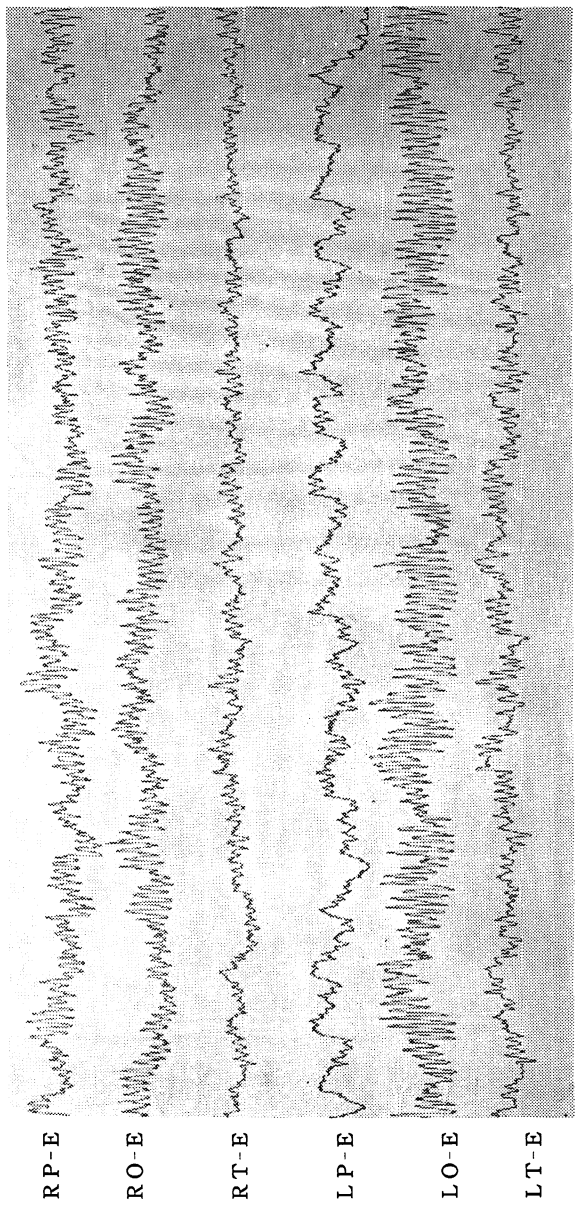


Fig. IV. EEG during mental actvities of a subject.

subjects in a state of closed eyes and giving each of them the task before the experiment. That is, in this condition release from visual stimuli and auditory stimuli is done. The tasks were continuous multiplication and continuous addition. And subjects could calculate them without being disturbed at thier own pace. Therefore what matter is how the band of α rhythms changes, not in the condition of closed eyes resting but in the condition of calculating. The EEGs measured simultaneously in each area— parietal, occipital, and temporal areas— were compared and examined, and the changes among measured areas were observed. Among them κ rhythm led from increasing its frequency during mental arithmetic while the rhythm from the occipital areas was distinguished as α rhythm, decreasing during mental arithmetic.

The result of this experiment showed as a result of analysis of variance, a significant difference at 1 % level in the condition for activity of the mind and in areas for measurement, but as it seen in Fig. I and II, between the band of 8-13 c/s rhythm when in mental arithmetic and the band when in closed eyes resting there was never property which was characterized as a relationship between α rhythm and κ rhythm. On the other hand, as is shown in Fig. III, there is no certain tendency of EEG appearance among subjects. In the analysis of variance there is also a significant difference at 1 % level within individual variations of each subject. Moreover, as to the effect of interaction three conditions of "activity of the mind", "the areas for measurement", and "the subjects", there is significance at 5% level in "mental activity" ×"the areas for measurement" and "mental activity"×"subject"; but no significance appears at the same level in area for measurement"×"the subjects". The task of mental arithmetic seemed not to be easy for subjects: those who answered correctly in mental multiplication were three and in mental addition four. There can not be seen a certain tendency between the right and wrong of

the answers and the EEG appearance. It is not right to say that mental multiplicaton is very much harder than mental addition, as is expected before this experiment. There is of course no certain tendency of EEG appearance in two calculations. Consequently it becomes clear that a certain tendency can not be seen in the frequency in appearance of the band of α rhythms between the level of closed eyes resting and that of two calculation in closed eyes. And it is also impossible to prove the relationship between the two kinds of EEG, which are characterized as α rhythm and κ rhythm. The variations according to the hardness of the task is not clear in this experiment but in another experiment by the auther it is reported that there were no different results between the tasks. Therefore the shift of the band of EEG frequencey is not affected by the interior activity of the mind and mental arithmetic. And the variation which was reported up to now has to do with the reaction to the outer stimulation and to the secondary changes caused by some activities of the mind, for example, fatigue by the continuous thinking or the change of the state of awakening.

V. Summary

Frequency in appearance of the EEG during mental arithmetic was examined through ninety-six samples. The conditions of experiment are consist of four kinds of mental activities. The areas of measurement are six of both parietal, occipital, and temporal areas of each subject. There could not be seen a certain difference, so far as it was observed by the percentage of appearance of α rhythm, between the EEG during mental arithmetic in "closed eyes" and resting in "closed eyes". The relationship between α rhythm and κ rhythm also could not be found between the EEGs from occipital area and that from parietal and temporal areas.

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