Changes of basic rhythms of EEG during mental task performance

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Abstract

The purpose of this study is to investigate the relationship between EEG basic rhythm and mental task performance.

A new apparatus for describing the pattern of EEG time interval histograms was used and the records were taken from the subjects reclining on a bed in three states: (1) eyes closed and waking (2) curved line tracking task (3) figure tracking task.

The following results were revealed:

(1) The pattern of histograms in EEG basic rhythm during the eyes closed and waking state were divided into three types, unimodal, bimodal and multimodal type.

(2) In the tracking test, the peak of histogram in a resting period disappeared spontaneously and the pattern became entirely flat along the horizontal axis.

(3) In spite of the attentive state, it is surmised that the pattern of basic rhythm during task performance returned gradually to the pattern shown during the eyes closed and wakeful state.

The implications of these observations for the analysis of relationship between basic rhythm and mental task performance were discussed.

1. Introduction

It is well known that visual perception, attention and mental imagery are associated with varying degrees of alpha blocking, sometimes together with suppressed or argumented beta rhythm.

Glanzer et al. (1964)[1] examined the effects of mental activity to brain waves and they found that the Kappa wave was in direct proportion to the degree of difficulty in the task performance. In their study, the tasks were mathematical addition and concept tasks. There was no significant effect on the alpha wave during mathematical addition, and it was noted that the occipital alpha was diminished only in concept task performance.

Berlyne (1965)[2] using irregular, unsymmetrical or complex figures in their experimental study showed that the representation of incongruous or curious pictures gave rise to desynchronization in EEG. He used desynchronization as an index of the orientation reaction.

In our laboratory*, some changes of alpha rhythm during perceptual task performance, i.e. attenuation or reappearance as an index of mental task performance have been investigated for the past 10 years and in a previous paper, the author (1966[3], 1967[4]) published the finding that the alpha percent was significantly less when irregular patterns were presented than when regular patterns were shown.

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More recently, Kanoh and Kitazima (1971)[5] reported a significant relationship between the attenuation of alpha wave and reasoning or schematization of stimulus figures in visual perception. They devised a more adequete apparatus for EEG measurement and equipment for the presentation of stimuli. The conclusions in those research showed contradiction and discrepancies each other.

The present study was designed to reexamine such contradictions and at the same time to use a new data processing unit to describe the pattern of EEG time interval histograms.

2. Method

Sixteen adults with ages ranging from 21 to 28 were selected and it was noted that they were physically, psychically normal. All subjects were males and their occupation is taxi driving. The EEG recordings and on line data processing were made with a new apparatus (Fig. 1) using bi-polar electrical leads from C_z to O_z. The original records through the band pass filter (3–18 H_z) were analysed automatically by electronic computer and terminal output was indicated on the memoscope in the form of time interval histograms.

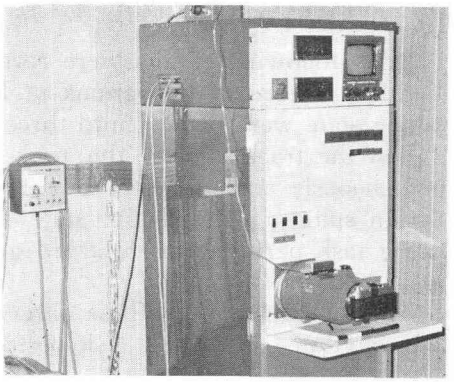

Fig. 1. EEG apparatus combined with data processing computer.

A set of mental tasks, which were developed as an aptitude test for an operator of the National Railway Board of Japan (Mitsui, 1967[6], 1968[7]) were used in this experiment. One (labeled: STT2) is the visual tracking task along a complicated curve line and it is assumed that the task includes concentration and maintenance of attention. Another (attentive distribution test: Y) is the task of exploring numbers in regular order from zero to forty eight and in this case it was assumed that the task includes the distribution of attention, because this task requires an exploration some numbers successively and simultaneously to retain the preceding number. The experiments were conducted in the EEG test room at Hokkaido Administration Center of Occupational Car drivers and S_s lay reclinig on a bed in the room. The first recordings were taken in an awakened state with eyes closed (Called: Rest Recording) and the second were taken when subjct S_s was performing the visual tracking task without hand writing and the third exploring task (Called: $Task_1$ and $Task_2$).

3. Results and discussion

Examples of the original EEG records and photo histogram of basic rhythms are shown in Fig. 2 and Fig. 3. The visual inspection of these histograms confirmed the same results as seen in the previous findings (Mori, 1972[8]). The histograms were divided into modal types according to the number of peaks in distribution curve and the skewness. The example represented in Fig. 2 has a higher peak than the others and this histogram was classified into an unimodal type which had a peak at 110 ms on the obscissa. Thus, it may be seen that this subject

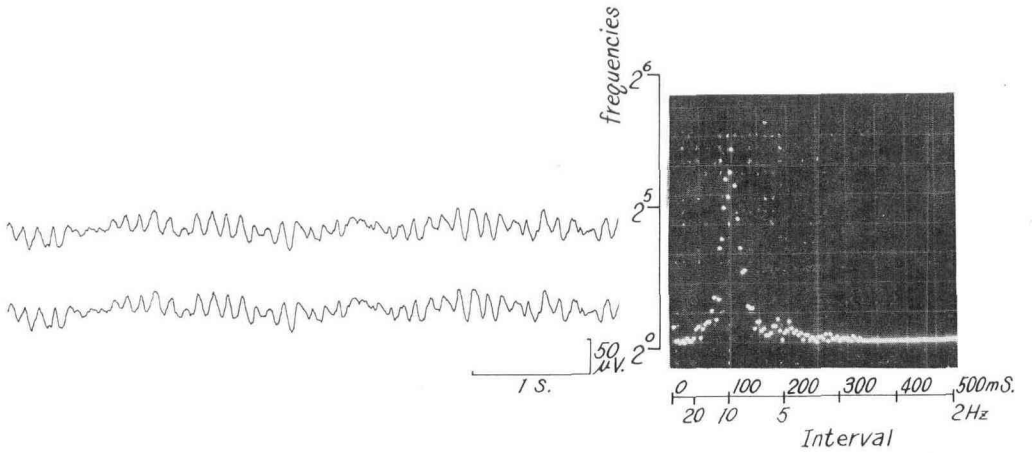

Fig. 2. Original EEG record and photo-histogram (Rest recording). In the histogram, obscisa are intervals in ms (top) and corresponding frequency H_z (bottom) and ordinate: frequencies of intervals.

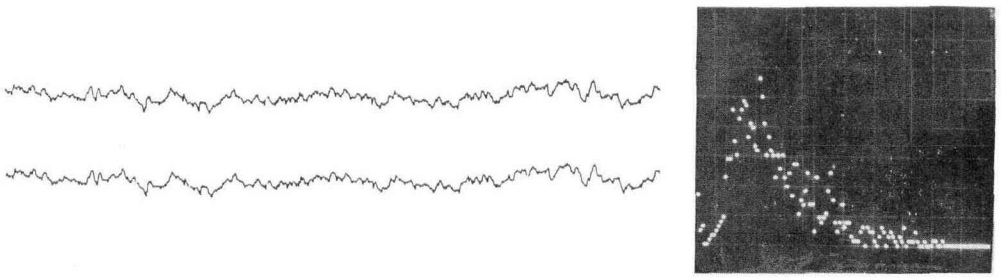

Fig. 3. Original EEG record and photo-histogram (Task recording).

showed pronounced alpha activity in Rest recording and regarding the task performance, the same subject showed an almost random pattern in his histogram. Here, the alpha rhythm disappeared immediately and the slow component among basic phythms increased considerably. Percentage calculations were caried out for each histogram and the results were shown in Tab. 1.

As may be seen in this table, the slow component among basic rhythms may be enhanced during task performance over all subjects. The mean appearance percentage of alpha rhythm during Rest was 43.4 with a standard deviation of 5.8 and that during Task_1 was 35.8 with 5.1. Using the following formula for testing the differences of mean value, the relationships were sought between the various sets of data describing the 16 subjects on two occassions:

$$Z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{\sigma_1}{N_1} + \frac{\sigma_2}{N_2}}}$$

X_1, X_2; mean value of alpha appearance
σ_1, σ_2; standard deviation
N_1, N_2; number of subjects in each test groups. This case, $N_1 = N_2 = 16$

TABLE 1, Appearance percent (%)among the range of basic rhythm

	Subject	Rest recording			Task$_1$ recording			Task$_2$ recording		
		β	α	δ & θ	β	α	δ & θ	β	α	δ & θ
1	H. S.	6	34	61	4	37	59	5	26	70
2	M. S.	7	40	53	7	27	65	8	33	59
3	K. T.	8	50	43	7	38	55	7	44	48
4	N. S.	4	41	56	11	32	57	8	28	65
5	A. M.	7	49	45	6	31	63	5	32	63
6	T. K.	14	36	50	6	38	56	9	41	49
7	U. Y.	9	50	41	5	40	54	7	41	52
8	M. A.	6	51	43	4	37	59	8	39	54
9	T. F.	6	40	53	6	38	56	6	40	54
10	F. M.	7	37	57	6	28	67	8	28	64
11	S. H.	7	36	58	7	35	57	6	37	56
12	M. N.	5	45	51	5	36	58	8	36	56
13	T. H.	7	41	52	5	30	64	8	30	62
14	E. T.	7	51	41	1	44	55	8	40	52
15	T. T.	6	48	46	9	46	45	6	37	56
16	H. T.	9	46	45	5	36	59	5	36	59
Mean		7.0	43.4	49.7	5.9	35.8	58.1	7.0	35.5	57.4
S. D.		2.1	5.8	6.2	2.2	5.1	5.0	1.3	5.3	6.0

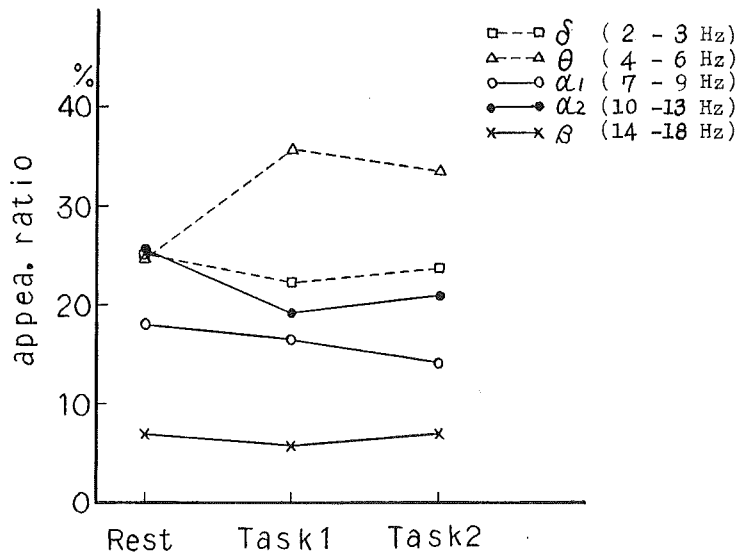

Fig. 4. Appearance ratio per band among the range of basic rhythm.

A significant difference between Rest and $Tast_1$ was obtained from $Z_1=4.0$. ($p<0.05$). In the $Task_2$ recording, the mean appearance percentage of alpha was 35.5 with S. D. 5.3 and there were no difference in Z between $Task_1$ and $Task_2$ ($Z_2=0.17$). For a more precise analysis, the appearance percentage divided into 5 bands were plotted in Fig. 4. It is of interest that the fast component of alpha rhythms (α_2) were diminished and that the slow component among basic rhythms (δ & θ) were enhanced inversely. This enhancement of slow component may be an artifact arising from the zero crossing method in this processing unit. Furthermore, it is assumed that the eye opening elicited the slow rhythm but these facts must be reexamined more profoundly.

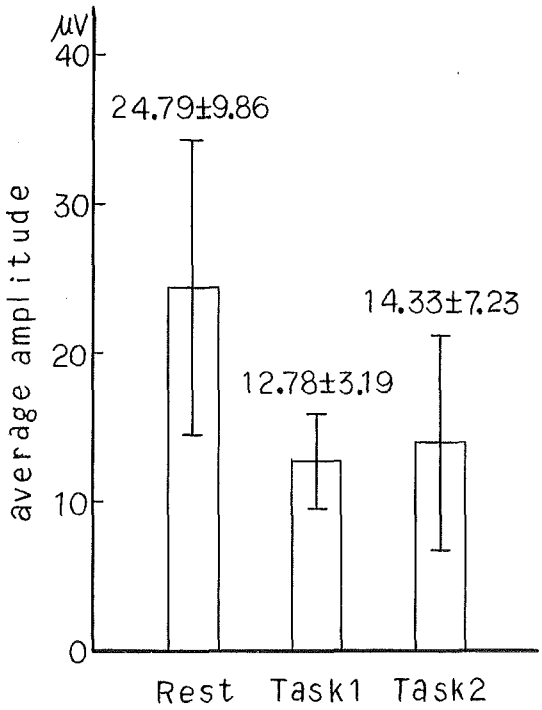

Fig. 5. Average amplitude and S. D.

The voltage (μv) displayed on the digital indicator of this unit is the average amplitude which was measured by means of an averaging system in a time constant of 5 seconds. The mean values and S. D. of μv for each subject were calculated and plotted in fig. 5 to compare with Rest recording and Task recording. The effect of attention to the average amplitude in task performance were shown in this graph and Z between Rest and $Task_1$, $Task_2$ were calculated according to the preceding formula:

Z_3; Rest and $Task_1$ is 5.2,

Z_4; Rest and $Task_2$ is 3.4.

4. Conclusions

Originally, this new apparatus was developed for the prevention of traffic accidents to administrate a Mass Screening Examination of EEG. Though it is difficult to attempt to draw any integrated conclusions with regard to the changes of basic rhythm in this paper, the most remarkable findings were revealed as follows:

1) The basic rhythm in adult EEG consists of the alpha component for the most part and it is assumed that the interval histogram of this rhythm during the eyes closed and wakeful state were divided into some pattern or types (unimodal, bimodal and multimodal) corresponding to individual differences.

2) During Task performance the peak of the histogram disappeared and the pattern became entirely flat along the horizontal axis. In spite of the attentive state during task performance, it was assumed that the basic rhythm would return to the eyes-closed pattern gradually while the changes of average voltage of basic rhythm

were also the same as the time intervals.

According to the study of histogram method by Grünewald *et al.* (1968)[90], it was asserted that the blocking reaction of the occipital alpha rhythm can not be correlated in a simple manner to the task performance which involved different degrees of mental 'effort'. They concluded that no simple quantitative relation exists between the attention and amount of changes of EEG during task performance if one assumes that the 'effort' is at least a rough measure of attention. Lastly, the interval histogram method seems to be ineffective for detailed analysis on EEG even if it may be effective for Mass Screening Examination of EEG.

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