Electroencephalograms Measured During Simple Arithmetic Calculations and E-mail Keying on Cell-Phone Keypad

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Abstract: Electroencephalograms (EEGs) were recorded from eight healthy university students and two healthy high school students using a 24-ch portable EEG system according to 10-20 international electrode placement system. The records were obtained 1) in relaxed resting condition; 2) while simple arithmetic calculations, *"Hyaku-masu Keisann"*; 3) keying e-mail on cell-phone keypad; or 4) reading a book. Data were analyzed by FFT, and we obtained the absolute content and the percentage content of six frequency components (delta, theta, alpha-1, alpha-2, beta-1, beta-2) for the records from Fp1, Fp2, F3, F4, P3, P4,O1, and O2 electrodes. The relation between the occurrence of various EEG frequency components and light assignments has been studied. Some differences have been noticed among EEGs of adults and teenagers.

Keywords: electroencephalogram, EEG, Fourier transform, signal analysis

1. Introduction

The electroencephalogram (EEG) is a record of a time series of evoked potentials caused by systematic neural activities in a brain. The discovery of human EEG is credited to Hans Berger (1873 - 1941), a German neuropsychiatrist, when he measured his son's EEG in 1925. In his first report of 1929, he recorded his one-channel EEG on photographic paper with recordings from 1 to 3 minutes duration using a bipolar recording technique. Berger found that recordings could be made through the intact skull and scalp, i.e. without opening the skull. He reported appearance of alpha and beta rhythms [1].

The measurements of the human EEG signals are performed through electrodes placed on the scalp, and they are usually recorded on paper against time. The voltage of the EEG signal corresponds to its amplitude. The typical amplitudes of the scalp EEG lie between 10 and 100μV, and in adults more commonly 10 and 50μV.

The frequency range of the EEG extends from ultra-slow to ultra-fast frequency components that play no significant role in the clinical EEG. Clinically meaning frequencies lie between 0.1 Hz and 100Hz. In more restricted sense, the frequency range is classified into several frequency components, or delta rhythm (0.5-4Hz), theta rhythm (4-8Hz), alpha rhythm (8-13Hz), beta rhythm (13-30Hz), and gamma rhythm (30-60Hz). Alpha and beta rhythms are further grouped into alpha-1 (8-10Hz),alpha-2 (10-13Hz), beta-1 (13-20Hz) and beta-2 (20-30Hz), respectively. EEGs are related to alertness, level of attention, and degree of mental efforts [2].

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Modern EEG measurements are performed using an Electro-cap System. Electro-caps are made of an elastic spandex-type fabric with recessed, pure tin electrodes attached to the fabric. The electrodes on the standard cap are positioned according to the International 10-20 method of electrode placement [3] (Fig.1). With electrodes pre-arranged on the cap, the EEG can be measured rather easily and rapidly.

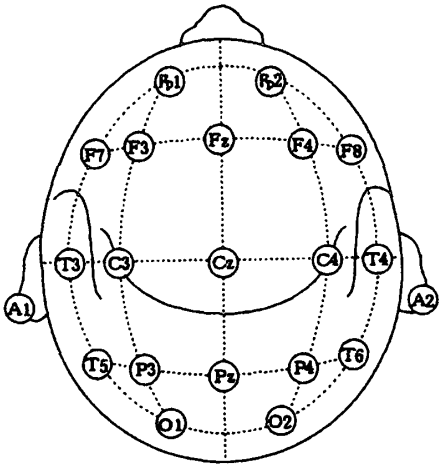

Fig.1. Electrode placement according to the International 10-20 System.

The purpose of the present work was to differentiate the EEGs measured in eyes closed relaxed conditions and at some light tasks. Using this Electro-cap system and a 24-channel portable EEG system (TEAC Polymate AP-1000), we have measured EEG from eight healthy university students (age 21, all males) and two high school students (15y boy and 16y girl) and analyzed EEG signals in the frequency domain. The EEGs were recorded during simple arithmetic calculations as well as keying e-mail on the numeric keypad of cell-phone, which is simple but may be a frustrating and tedious work for some people.

2. EEG Recording and Analysis

The features of the EEG system and measuring techniques we employed are described in detail in our previous paper [4]. Briefly, the EEG signal from the volunteers were recorded after having informed them our purpose of the measurements and safety of the measurement. After the Electro-cap was fixed to the volunteer's head conductive gel was injected through a small hole at the center of each electrode to obtain good electric contact between the electrodes and the scalp. A pair of reference electrodes was placed on right and left earlobes, and the EEG signals were recorded based on the corresponding reference electrode on the same side of the head, respectively. The third electrode was placed at the center of the forehead. The impedance of each electrode was checked before the measurements, and in case it exceeded 3 kΩ electric contact between the electrode and the skin was properly adjusted.

We recorded EEG signals at a sampling rate of 200 Hz under following conditions: 1) relaxed and resting on a chair with eyes closed; 2) while doing some simple arithmetic calculations well known in our country as "*Hyaku-masu Keisan*", literally a hundred box arithmetic calculation, in which each subject was asked to repeat simple operations (i.e. additions, multiplications, or subtractions) for a hundred (10 x 10) combinations of 10 single-

or double- digit(s) shown on both the top raw and the left side column of the 10 x 10 array, respectively (Fig.2); 3) EEG was also recorded either while the subjects (university students) were keying e-mail into his own cell phone or 4) other subjects (high school students) were reading his or her favorite book. After each Hyaku-masu Keisan, EEG in relaxed and resting condition with eyes closed was recorded. Measurements were performed in a room surrounded by metal panel walls, but without special electromagnetic shielding. We applied a notch filter in order to suppress noise on power line. Totally, eight EEG records were obtained for each subject. The measured signals were stored via USB cable directly in a PC for further off-line analyses.

百枡計算・引算

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4										
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Fig.2. *Hyaku-masu Keisan*, a hundred box calculation (subtraction).

For each EEG record the FFT analysis with a rectangular window function was performed for 20 artifact-free epochs, where each epoch consisted of 512 sampling points (i.e. duration of 2.56s). We analyzed absolute content and percentage content of six frequency components (delta, theta, alpha-1, alpha-2, beta-1, beta-2) for the records from Fp1, Fp2, F3, F4, P3, P4,O1, and O2 electrodes.

3. Results

Fig.3 shows the percentage frequency contents for the EEG from one of the adult subjects. Note that alpha rhythm is prominent in the relaxed resting condition with eyes closed, while it is significantly suppressed during Hyaku-masu Keisan and e-mail keying-in. The similar trend was seen for the EEG of every subject.

Fig.4 shows the average of the percentage frequency components of the eight adult subjects. Here, alpha band includes alpha-1 and alpha-2 and beta band includes beta-1 and beta-2. Error bars indicate the standard deviation for the corresponding data points. In the resting condition with eyes closed, alpha rhythm clearly dominates (percentage contents 40% - 47%) the EEG at any locations on the scalp considered here, while percentage content for beta rhythm was small (19% - 26%) except for occipital lobe (O1 and O2) (ca 40%). When the subjects was engaged either in the Hyaku-masu Keisan (Fig.4b, 4c, 4d) or in keying e-mail (Fig.4e), percentage content of the alpha rhythm was drastically suppressed (10% - 20%) and beta rhythm dominated (16% - 61%) EEG. Moreover, the percentage content of beta rhythm

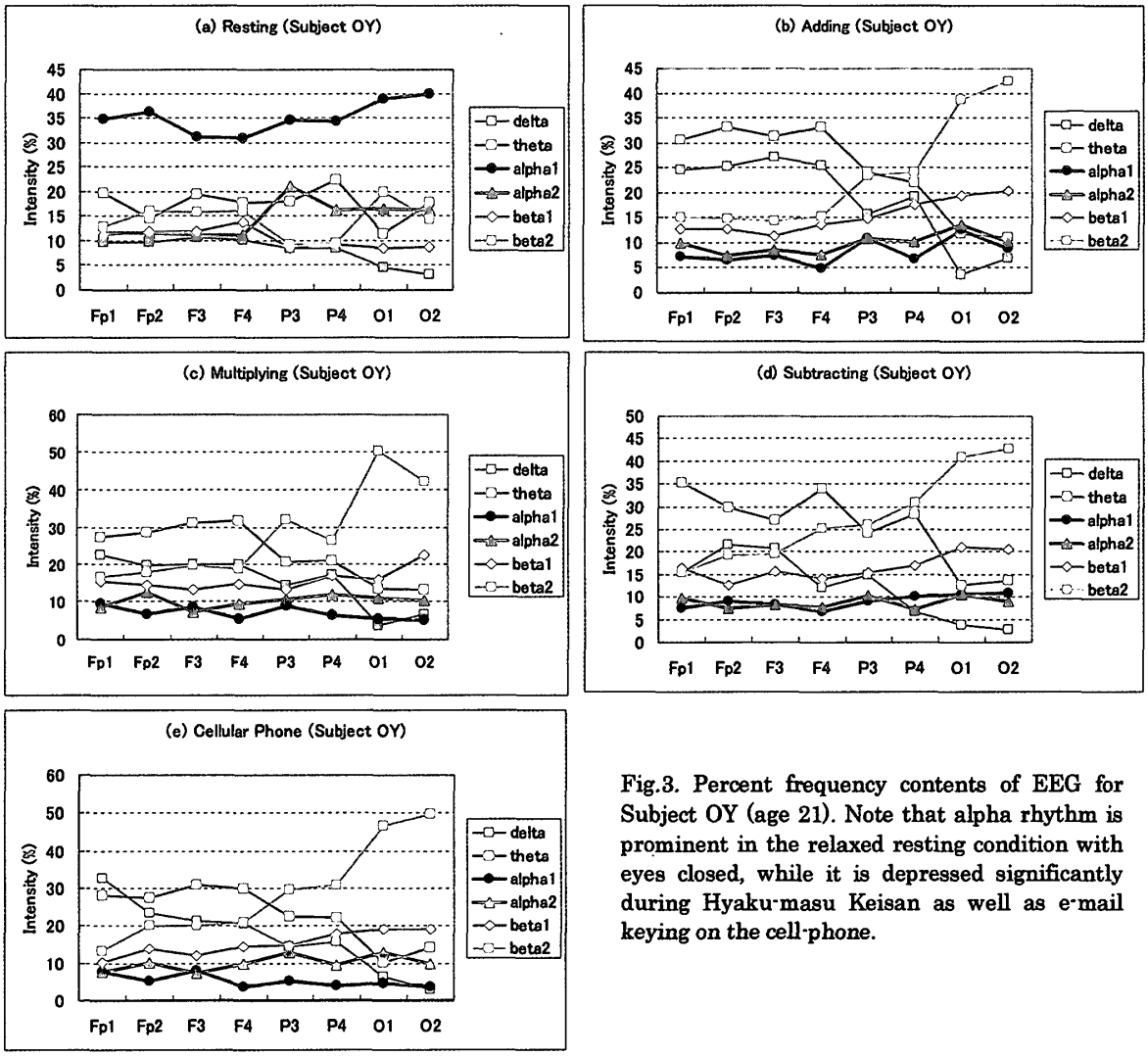

Fig.3. Percent frequency contents of EEG for Subject OY (age 21). Note that alpha rhythm is prominent in the relaxed resting condition with eyes closed, while it is depressed significantly during Hyaku-masu Keisan as well as e-mail keying on the cell-phone.

was more enhanced as the recording positions moved from frontal (ca. 20%) toward occipital lobe (ca. 60%). No significant differences were seen in percentage contents of alpha and beta rhythms among three arithmetic operations and e-mail keying. The beta rhythm became more enhanced in the occipital lobe (58%) than in the frontal lobe (17%).

Fig.5 shows the percentage frequency contents for the EEG from one (age 15) of the high school students. The big difference between Fig.5 and Fig.3 is that the contents of delta and theta rhythms are pronounced in Fig.5, especially in frontal lobe. These rhythms were strongly appeared not only in the relaxed resting condition (Fig.5a) but also during Hyaku-masu Keisan (Fig.5b, 5c, 5d) as well as in reading (Fig.5e). The contents of delta and theta rhythms were from four to five times larger than those of other rhythms. Fig.6 depicts average frequency contents for alpha and beta rhythms in the EEG from the two high school participants. Here also, alpha band includes alpha-1 and alpha-2 and beta band includes beta-1 and beta-2. On the contrary to the adult subject (Fig.3), the intensity of beta

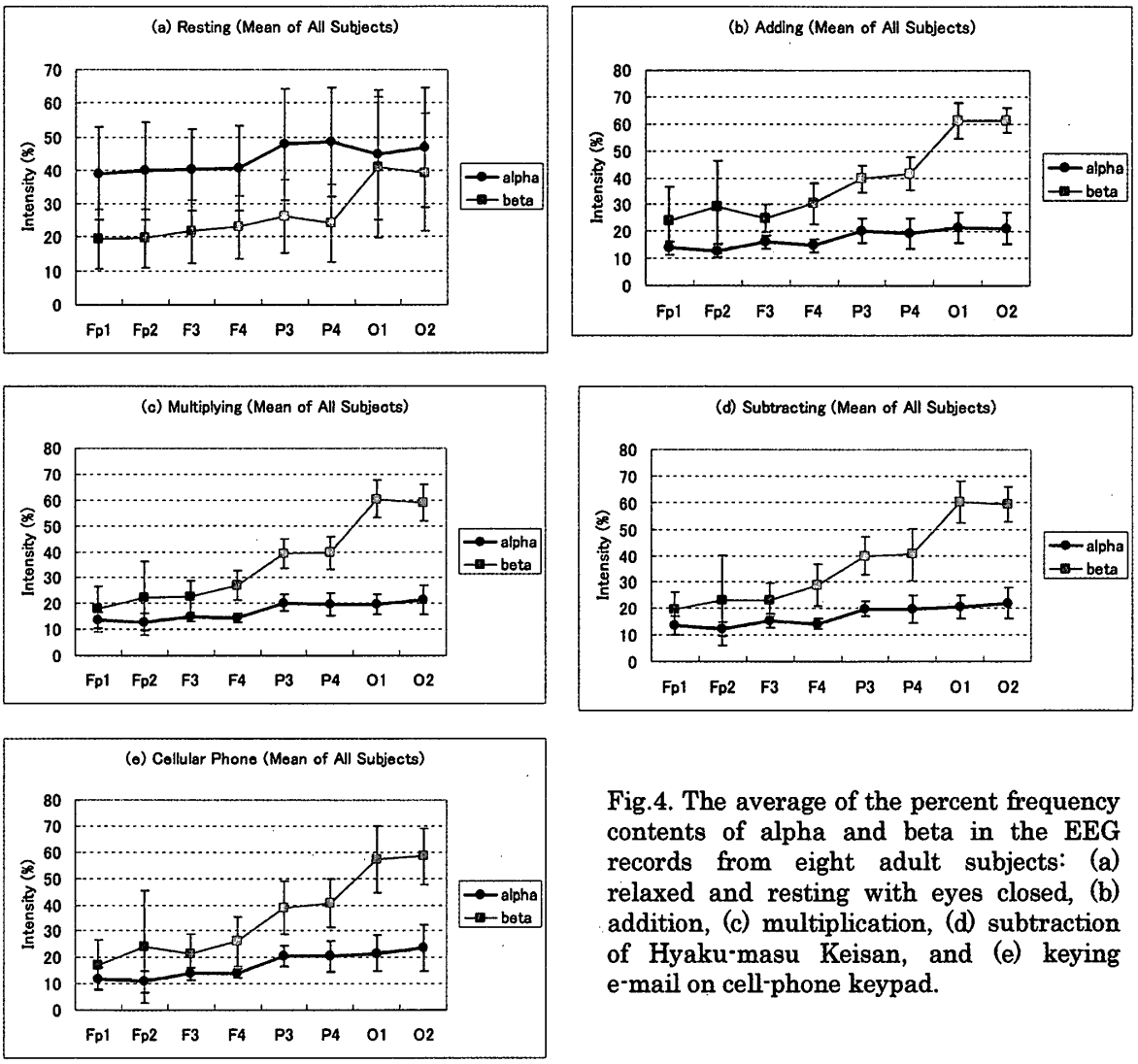

Fig.4. The average of the percent frequency contents of alpha and beta in the EEG records from eight adult subjects: (a) relaxed and resting with eyes closed, (b) addition, (c) multiplication, (d) subtraction of Hyaku-masu Keisan, and (e) keying e-mail on cell-phone keypad.

rhythm exceeded that of alpha even in resting with eyes closed (Fig.5a). This trend was also seen in the other high school student (age 16). The contents of beta rhythm in other cases were almost the same as those of alpha rhythm in frontal lobe (Fp1, Fp2, F3 and F4), but they were from two to three times larger than those of the alpha rhythm in the occipital lobe (O1 and O2).

Table 1 shows the time required before each subject completed his or

No.	Subj.	Age	Add.	Mul.	Sub.
1	KK	21	2' 30"	1' 53"	2' 26"
2	OY	21	2' 09"	2' 10"	2' 12"
3	OA	21	1' 15"	1' 02"	1' 13"
4	HT	21	2' 28"	2' 36"	2' 59"
5	SY	21	4' 08"	3' 37"	4' 16"
6	NH	21	1' 46"	1' 44"	2' 22"
7	NM	21	2' 25"	2' 20"	1' 50"
8	UK	21	2' 18"	2' 54"	3' 03"
9	RE	16	1' 31"	1' 16"	2' 07"
10	RA	15	0' 56"	1' 09"	1' 17"

Table 1. Time required before each subject completed three types (addition, multiplication, and subtraction) of *Hyaku-masu Keisan*.

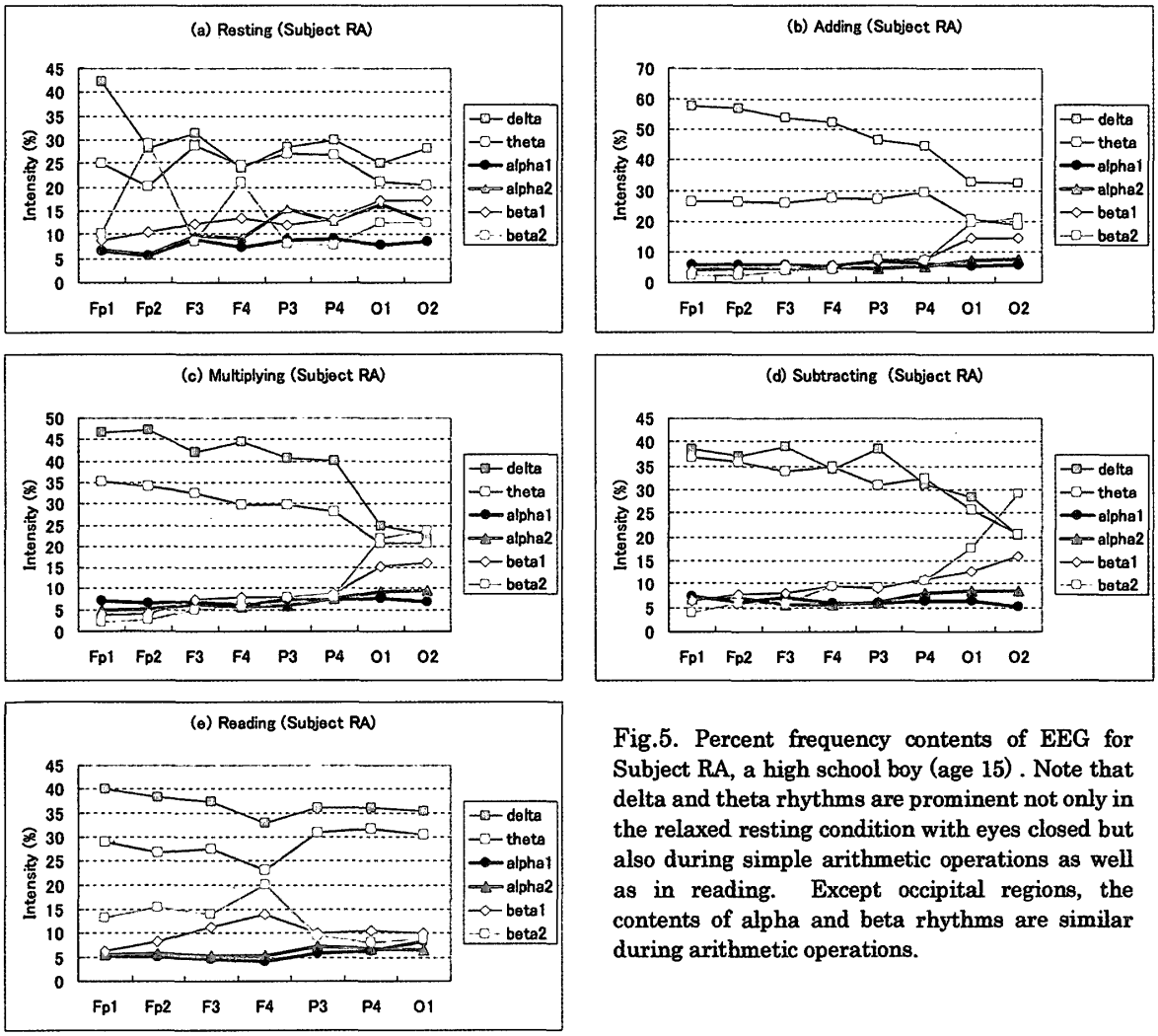

Fig.5. Percent frequency contents of EEG for Subject RA, a high school boy (age 15) . Note that delta and theta rhythms are prominent not only in the relaxed resting condition with eyes closed but also during simple arithmetic operations as well as in reading. Except occipital regions, the contents of alpha and beta rhythms are similar during arithmetic operations.

her Hyaku-masu Keisan. One of the adult subjects (OA) appealed that he was good at mental arithmetic because he had some training of calculation on the abacus. One of the high school students (RA) had experienced Hyaku-masu Keisan many times before this EEG measurements. Both subjects exhibited high ability in arithmetic operations.

4. Discussion

For adult subjects, it was confirmed that alpha rhythm dominates in the relaxed resting condition with eyes closed. Alpha rhythm was greatly depressed and beta rhythm became prominent during Hyaku-masu Keisan, i.e. simple arithmetic operations, as well as during keying e-mail on the cell-phone keypad. Beta rhythm is generally regarded as a normal rhythm and is dominant in those who are alert or anxious or who have their eyes open. They appear in various normal brain activities such as seeing, listening, touching, thinking, solving some problems, decision making, etc. In the present EEG records, the level of brain activity expressed by the beta rhythm was higher in the occipital lobe than in the frontal lobe. Both

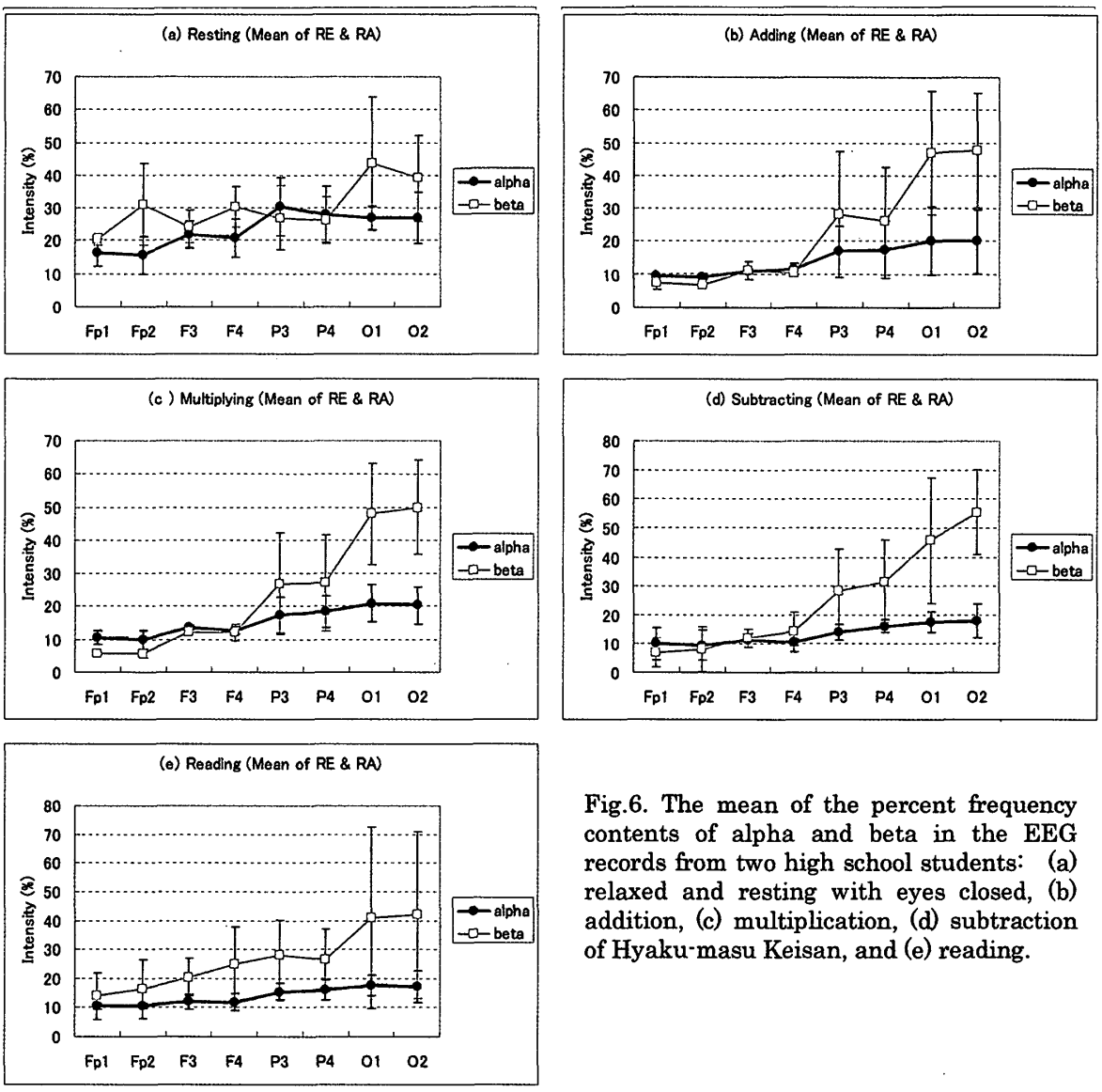

Fig.6. The mean of the percent frequency contents of alpha and beta in the EEG records from two high school students: (a) relaxed and resting with eyes closed, (b) addition, (c) multiplication, (d) subtraction of Hyaku-masu Keisan, and (e) reading.

alpha and beta rhythms seem to have occurred symmetrical on both sides of the brain [Fig.4]. No significant differences were noticed among the type of arithmetic calculations and keying-in task.

For young high school students, the percentage contents of alpha and beta were almost the same even at the seated condition with eyes close. This suggests a possibility that the subjects were at high tension due to juvenescence and inexperience of such kind of tests and that they were not relaxed after all. The EEG from young subjects showed significantly strong delta and theta rhythms in all records. In the normal adult slow components, delta and gamma rhythms, are sparsely represented, and fast components, alpha and beta rhythms predominate [2]. Theta and delta rhythms are considered to occur during deep sleep in dreamless states, in small children, and in various pathological conditions. There was no evidence that these young students were in some pathological conditions. Here also, no

significant differences in the frequency content were found among the type of arithmetic calculations and reading. In conclusion, we have confirmed the relation between the occurrence of various EEG frequency components and light assignments. Analyses of the present EEG using wavelet analysis method [5] are in progress. The study on any synchronous or asynchronous relation of EEG signals from both sides of the brain is our future plan.

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