Measurements of Electroencephalogram with a 24-Channel Portable EEG System

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Electroencephalograms (EEGs) from healthy young adults have been measured with a 24-ch portable EEG system in relaxed states as well as in doing some simple arithmetic exercises. The EEG signals were analyzed by means of fast Fourier transform. Alpha waves were clearly appeared in EEGs recorded in relaxed states in occipital regions. In contrast, they were disappeared almost completely in EEGs during the arithmetic exercises, while increased contribution from gamma waves were observed in the power spectra.

Key words: Electroencephalogram, EEG, alpha waves, gamma waves, portable EEG system

1. Introduction

Electroencephalogram (EEG) is defined as a record of a time series of electrical activity caused by systematic neural activities in a brain. 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 100 . V and in adults more commonly 10 and 50. V. In more restricted sense, the frequency range is classified into several frequency components, i.e. delta rhythm (or wave) (0.5-4 Hz), theta rhythm (4-8 Hz), alpha rhythm (8-13 Hz), beta rhythm (13-30 Hz), and gamma rhythm (30-60 Hz). In the normal adult、slow components, delta and gamma rhythms, are sparsely represented, and fast components, alpha and beta rhythms, predominate [1].

Individual EEG shows quite different forms in their amplitudes, frequencies and shapes among subjects depending on their ages, especially among children, as well as their physical conditions. Even among normal EEGs large differences are recognized in subjects' various physical states such as sleep, wakefulness, and arousal, eyes open or closed, excited or relaxed, ingestion of medications, and so on.

Alpha waves are known to be associated with relaxed wakefulness. Beta waves are seen in individuals

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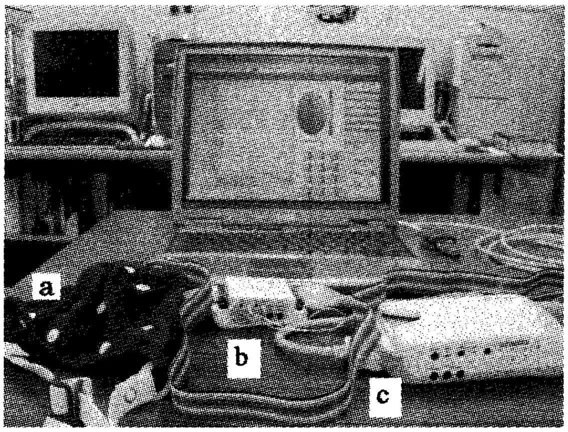
who are awake, alert, with eyes open, and who may be concentrating on something. Delta waves are associated with sleep in adults but are also seen in infants. Their abnormal appearance in awake adults can be indicative of a brain tumor. Theta waves are also seen in adults sleeping and in children. Their abnormal appearance in adults is typically seen in psychopaths.



In the diagnosis of epilepsy, it is sometimes necessary to measure patient's EEG over a period of one or more days. In such a case it is required to use portable EEG equipment that is wearable by the patient during the period. We have introduced a 24-channel portable EEG system that meets the condition and applied it to some healthy volunteers in order to get some experience. Measurements have been made while the volunteers were involved in doing some simple arithmetic as well as at rest. The results include the spectrum analyses of the measured EEG signals and the brain mapping where the frequency or voltage data are displayed on the brain projections.

2. Portable EEG System

The portable EEG system (TEAC Polymate AP-1000) consists of an electrode application system (Electro-Cap), an amplifier (HeadAmp AP-U010), a measuring unit (AP-U001), a battery unit, and a notebook personal computer (PC) (Fig.1). The electro-cap is made of an elastic spandex-type fabric with recessed, pure tin electrodes attached to the fabric. These electrodes on the cap are positioned according to the International 10-20 method of electrode placement [2]. With this electro-cap one can measure 19-channel EEG signals simultaneously. The labels of electrode

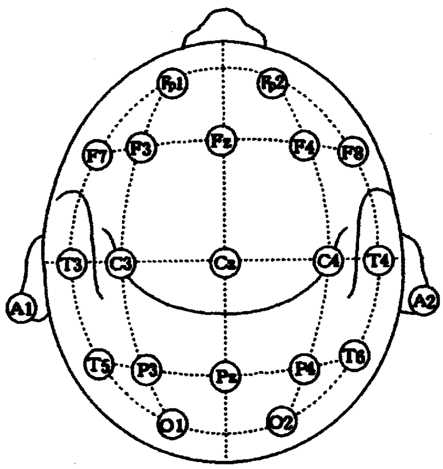


Fig. 2. Labels of electrode placement according to the International 10-20 system.

placement are shown in Fig.2.

The analog signals from the electro-cap are amplified by HeadAmp (60mmW × 30mmH × 86mmD, 60g). HeadAmp is a highly sophisticated amplifier system with 33 inputs (25 channels) designed for the measurement of electrophysiological signals such as EEG, ECG (electrocardiogram), EMG (electromyogram), EOG (electrooculogram), sphygmogram, breath sensor signals, etc., at an independent sampling frequency between 1 Hz and 1000 Hz. It has low-pass and high-pass filter functions which are controllable by software in the PC.

The amplified signals are transferred to the measuring unit where the analog signals are converted into digital signals of 16-bits. The measuring unit has dimensions of 90mmW × 44mmH × 158mmD, and weighs about 300g. The signals are stored either in PC-card memory (640MB~2GB) or directly in a hard disk of the PC via USB cable for on-line display and for subsequent analyses. A 640MB PC-card can store 24-hour EEG data from 16 channels sampled at a frequency of 200 Hz. The data are recorded according to the polysonography (PSG) format specified by the Japanese Society of Sleep Research. The signal amplitude for each channel can be set independently, which allows EEG (~± 50 μV) and ECG (~mV) measurements separately. All the units except the PC can be pocketed in a measuring vest.

3. Measuring Techniques of EEG

The EEG signals from four healthy male volunteers (age 21 and 22) were recorded after having informed them our purposes and safety of the measurement. After the electro-cap was fixed to the volunteer's head (Fig. 3), 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. Pair of reference electrodes was placed on left and right 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

Fig.3. Electrode cap with electrodes placed according to International 10-20 placement system

adjusted.

EEG measurements were done in two processes. First, EEG was recorded at 200 Hz while each subject was seated on an armchair at a relaxed condition with his eyes closed. The subject was frequently asked to open and close his eyes during the measurement in order to check his state of consciousness. Ten-minute measurements were repeated several times in order to obtain stable EEG records of the subject. The EEG signals were displayed online on the PC for monitoring. The recorded data was stored in the hard disk of the PC for subsequent analyses.

Second, the subject was assigned to do some simple arithmetic exercises, known as Hyaku-Masu Keisan or “Hundred Squares Arithmetic” in which he had to carry out addition, subtraction, and multiplication for a hundred combinations (10×10) of ten single- or two- digit numbers in a column and a raw, respectively. The EEG was recorded while the subject was doing arithmetic and writing down the answers. The measured EEG data was stored in the same way mentioned above.

4. Analyses of EEG signals

Typical EEG signals recorded with the present system for one of the subjects in relaxed state with his eyes closed are shown in Fig. 4. Ten artifact free 2.56s epochs (each epoch consists of 512 points) of EEG from the subject were digitally filtered by means of a fast Fourier transform (FFT) into six (or seven in some cases) frequency bands: i.e. delta (2-4 Hz), theta (4-8 Hz), alpha1 (8-10 Hz), alpha2 (10-13 Hz), beta1 (13-20 Hz), beta2 (20-30 Hz), and gamma (30-60 Hz). Hamming window was used for the analyses. The corresponding frequency maps on the scalp are shown in Fig.5-a. It is clearly seen that alpha1 waves predominate in the subject’s relaxed state. The corresponding average power

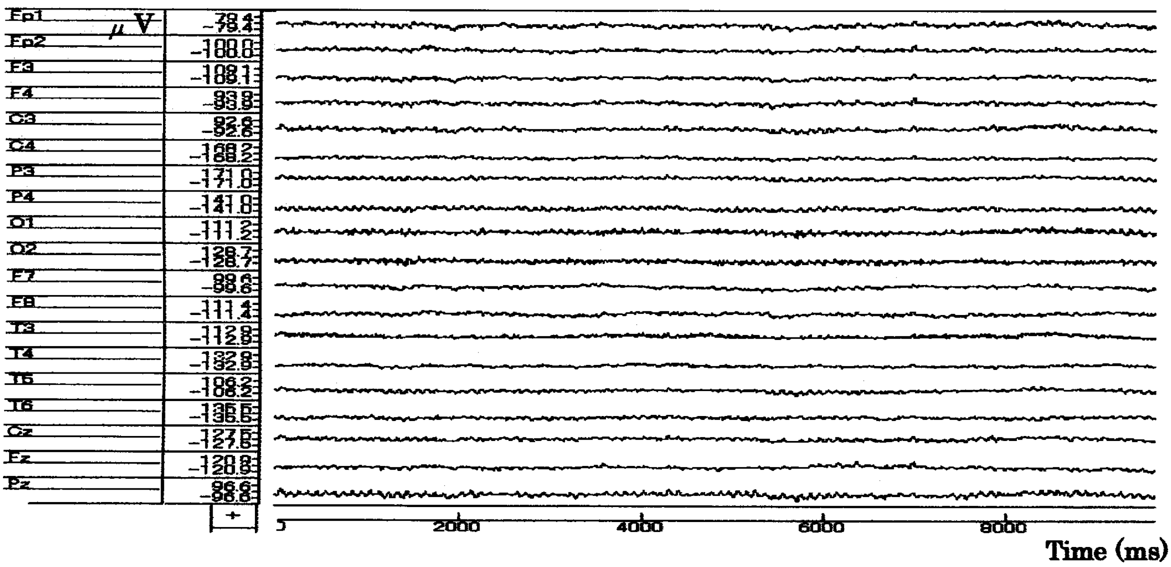


Fig.4. Typical EEG signals in relaxed state.

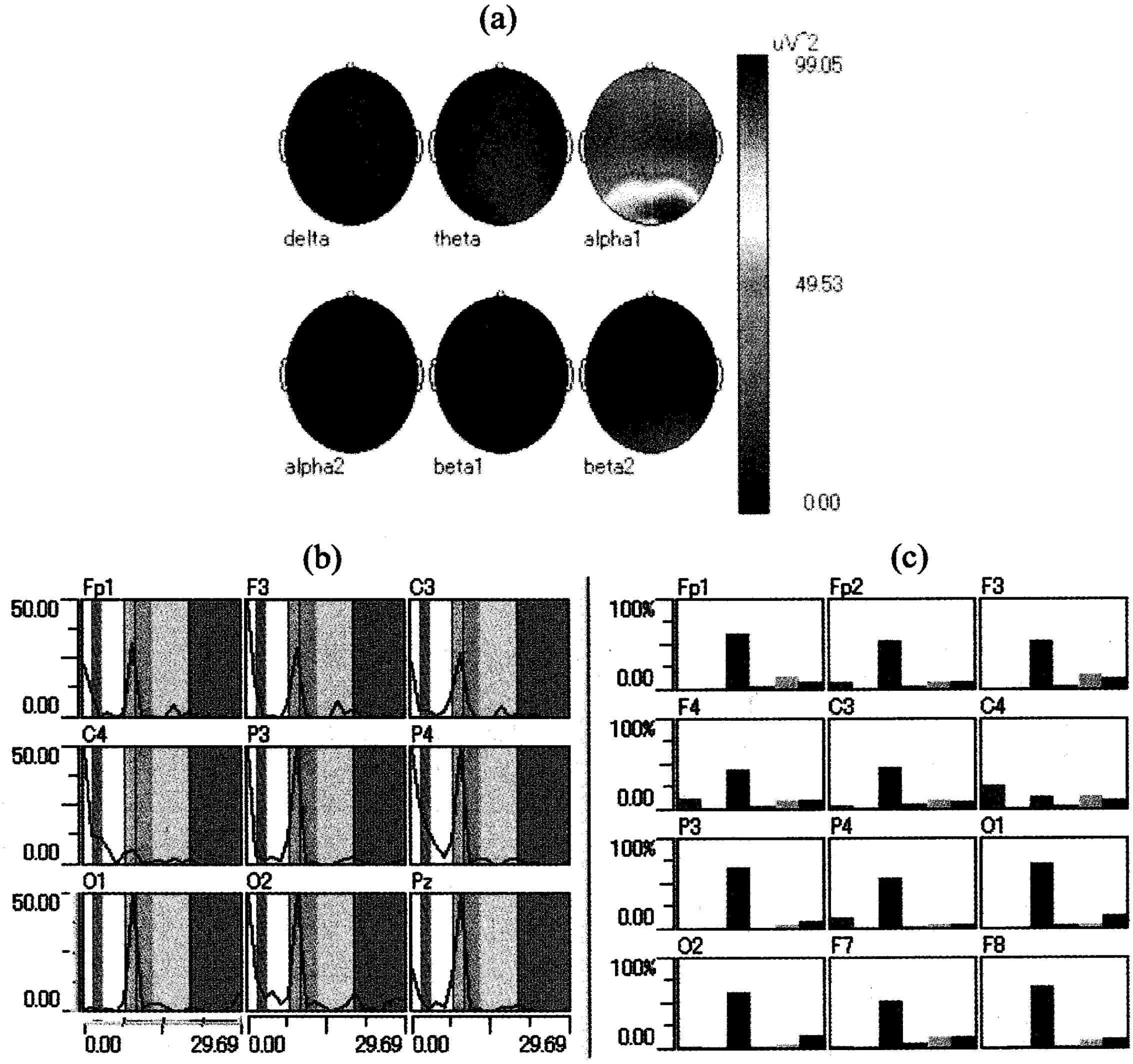


Fig.5. (a) Frequency map in relaxed state. Increased alpha1 is observed in occipital region. (b) Power spectra for selected electrodes. (c) Frequency contents in percentagewise for selected electrodes. Frequency bands are shown by color: delta (green), theta (yellow), alpha1 (red), alpha2 (pink), beta1 (light blue), and beta2 (dark blue).

spectra for the selected electrodes and their relative contents (percentagewise) are shown in Fig.5-b and -c, respectively. The contribution from each frequency component is classified by color, i.e. delta (green), theta (yellow), alpha1 (red), alpha2 (pink), beta1 (light blue), and beta2 (dark blue).

Increased power of alpha1 can be seen in occipital (C1, C2) and parietal (P3, P4 and Pz) regions. Alpha1 power is also high in frontal regions (Fp1, Fp2, F3 and F4) but not in right central region, C4. The similar tendency can be seen in frequency contents.

The results of FFT analysis of the EEGs recorded while the subject was doing simple arithmetic exercises (in this case, subtraction) are shown in Fig.5-a, -b, and -c. In Fig.5-a, an increased contribution from gamma waves in the occipital region is depicted on the frequency map instead of delta component. In Fig.5-b and –c, the gray striped region or bars signify gamma waves (30-60 Hz).

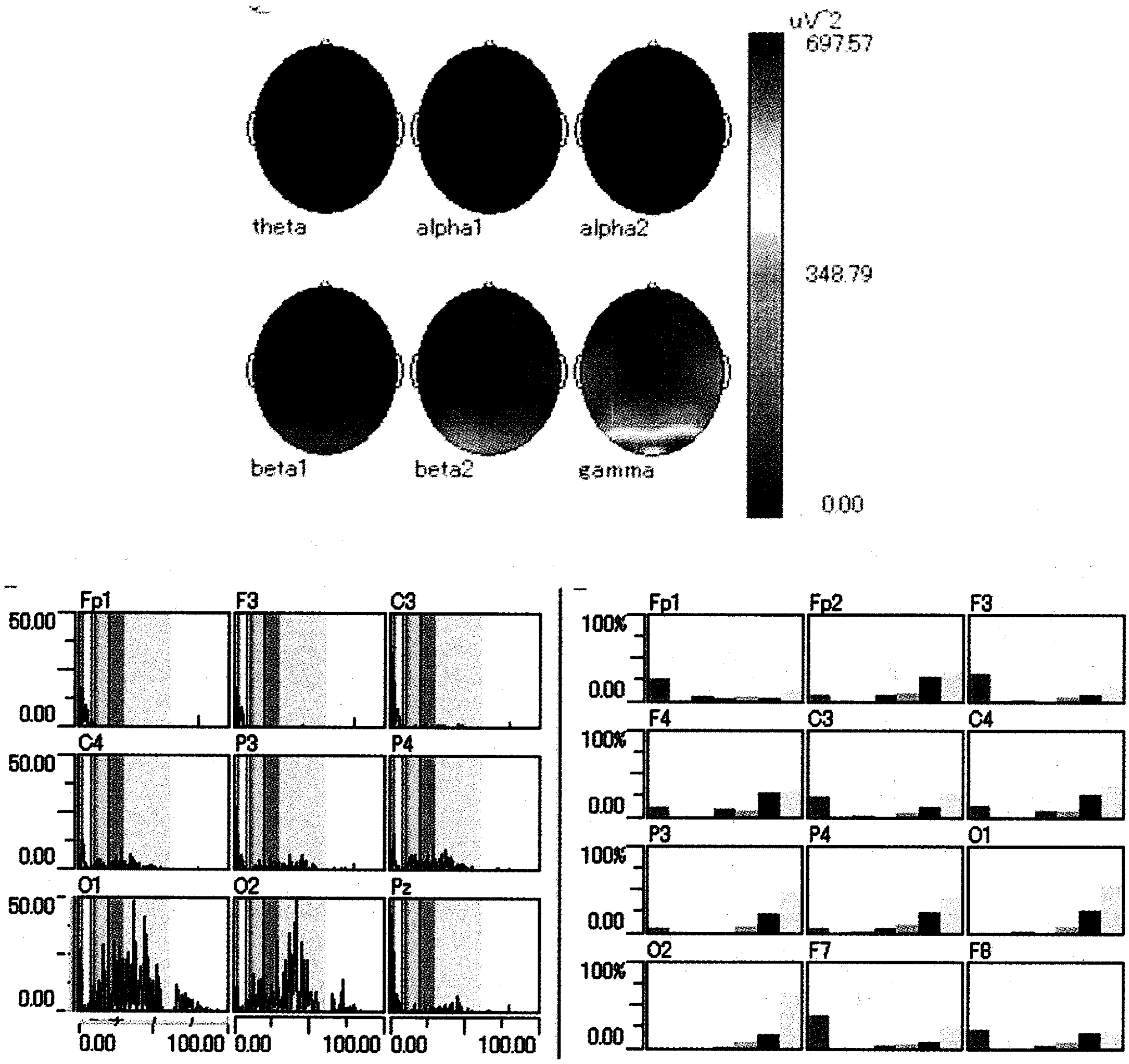


Fig.6. (a) Frequency map during arithmetic exercises. (b) Power for various frequency bands during arithmetic exercise. (c) Frequency contents in percentage wise during arithmetic exercises. Frequency bands are shown by color: delta (green), theta (yellow), alpha1 (red), alpha2 (pink), beta1 (light blue), and beta2 (dark blue).

In contrast to the EEGs in the relaxed state (Fig.4-a,-b,-c), alpha components are almost disappeared, while higher frequency components, gamma waves, are prominently appeared in both power spectra (Fig.5-b) and their relative contents (Fig.5-c) especially in the occipital (O1, O2) regions. Gamma waves are said to be generated in thinking hard, excited state, or angry. Gamma plays a role in the perception.

5. Summary

The EEGs from healthy young adults have been measured with a portable EEG system in relaxed states as well as in doing some simple arithmetic exercises. The EEG signals were analyzed by means of fast Fourier transform. Alpha waves were clearly appeared in EEGs recorded in relaxed states. They were, however, disappeared almost completely in EEGs during the arithmetic exercises, and increased contribution from gamma waves were observed in the power spectra.

Acknowledgements:

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