COMBINED ANALYSIS OF ELECTROENCEPHALOGRAPHIC DATA BY MULTIPLE ANALYZER AND ELECTRONIC COMPUTER (HALFWAVE ANALYSIS METHOD)

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A method of automatic combined analysis of 20 electroencephalograms at the same time by means of a multiple amplitude analyzer and the "URAL-2" electronic computer is examined.

The element adopted for EEG analysis is a single halfwave, the amplitude, duration, area and sign of each halfwave being determined.

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Electrophysiologists are becoming increasingly concerned with the automatic quantitative analysis of electroencephalograms (EEG) [2]. In this paper we examine a concrete variant of a combined program of analysis of electrophysiological data using a multiple amplitude analyzer and the "URAL-2" digital computer. As a result of complete automation of the process of recording the electrophysiological data [1] and feeding it into the electronic computer [4], practically all the existing methods of mathematical analysis can be used for EEG analysis [3].

In connection with the specific features of the method of multichannel magnetic recording of the original electrophysiological data and their analysis in the computer which we adopted, we used a single halfwave of each oscillation of the bioelectrical potential as element of EEG analysis. The halfwave is the part of the bioelectrogram between two neighboring intersections of the zero line.

We consider that to give a complete definition of the halfwave, the following of its most important parameters must be known: duration (T), amplitude (A), area (S), sign (±), index of shape of the halfwave (Φ), steepness of increment and decrement of the halfwave (plus φ and minus φ). In addition, we have available instantaneous values of the EEG (Fig. 1a) obtained with commutation frequency.

So far the program we have used uses only the first four indices: duration, amplitude, area, and sign of the halfwave. A segment of the EEG is illustrated in Fig. 1a and halfwaves with the corresponding parameters are shown. In the case examined the frequency of quantization in time (commutation frequency) was 50/sec, while the magnitude of the instantaneous EEG values was assigned in a five-rank binary code (30 analysis levels).

The number of discrete points on the O–O interval determined the duration of the halfwave (T) with corresponding accuracy, so that T can be expressed either by the number of steps of quantization in time (t_k) or in seconds (one commutation interval is equal to 20 msec). The amplitude of the halfwave (A) is expressed either in discrete levels or in microvolts (one discrete level is equal to 10 μV). The area of the halfwave (S) correspondingly is determined either in relative units (number of discrete levels) or as the product of the numbers of microvolts and seconds (μV · sec).

The series of values of T, A, and S with the corresponding signs measured during investigation of a segment of the EEG yields a number of statistical distributions and special indices providing adequately complete information on this EEG segment as a whole. In the histograms of the distribution shown in Fig. 1b-f, the corresponding index expressed as a percentage is plotted along the ordinate. Either the amplitude of the halfwave or their duration, in relative or absolute units as discussed above, is plotted along the abscissa.

The distribution $n_A = f(a)$, shown in Fig. 1b, determined the probability of appearance of instantaneous values (a) of a certain magnitude.

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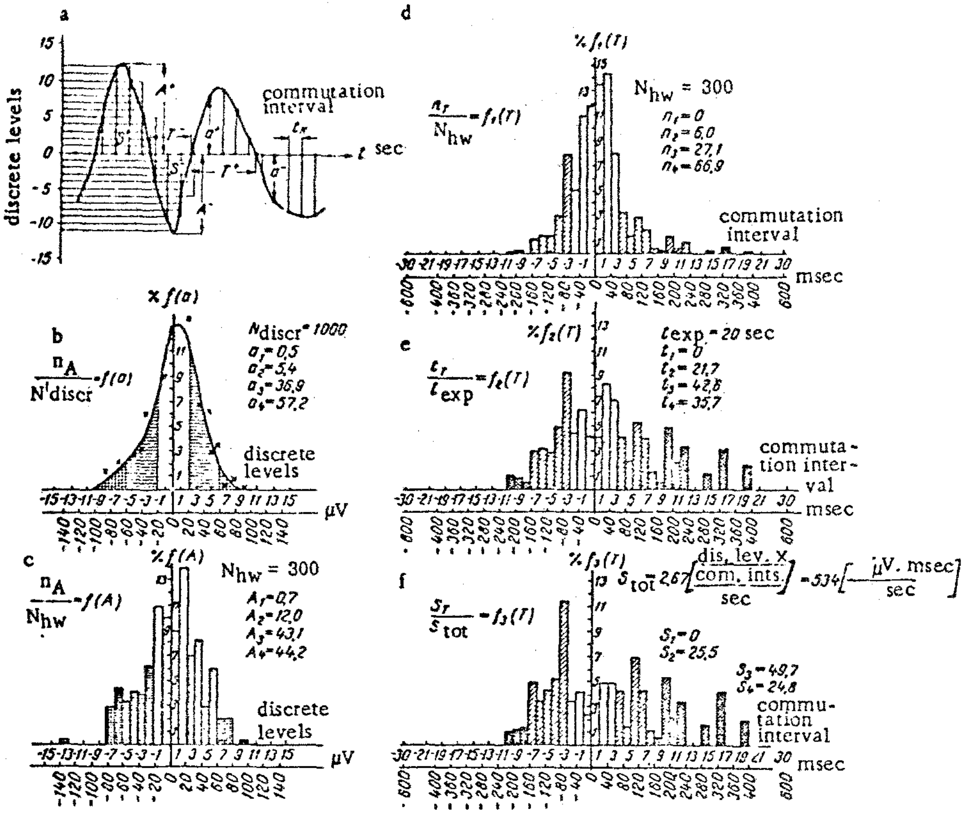

Fig. 1. Diagrams of distribution functions of halfwave parameters of the EEG during an interval of 20 sec. Explanation in text. a) Segment of EEG with halfwave parameters; b) distribution of instantaneous EEG values (1000 measurements); c) distribution of halfwave amplitudes (3000 halfwaves); d) number of halfwaves); e) time occupied by halfwaves of given duration (in percent of recording time); f) area of halfwaves of given duration (in percent of total area of EEG).

The distribution $n_A = f(A)$ (Fig. 1c) is similar to the first, but it examines the maximal amplitudes of the halfwaves and not instantaneous values of the EEG.

The histogram $n_T = f_1(T)$ (Fig. 1d) shows the relative number of halfwaves as a function of their duration.

The distribution $t_T = f_2(T)$ shown in Fig. 1e is also differentiated by halfwave durations and shows the relative time occupied by halfwaves of a given duration within the time limits of the recording. By means of this distribution the α- and β-indices which are used in clinical practice for describing the human EEG [2] can easily be obtained.

The distribution $S_T = f_3(T)$ given in Fig. 1f shows the contribution made by halfwaves of a given duration to the total area of the electroencephalogram (area of the electroencephalogram between the EEG curve and the midline). In our opinion this last distribution reflects changes in the EEG most fully, because every change in duration, amplitude, or shape of the halfwaves is reflected in a change in area of the halfwave. The total area of the EEG during the recording time is designated in Fig. 1f, as S_{tot}.

To facilitate examination and analysis of the extensive digital material contained in the distribution, we used the usual method of reducing the number of components of the spectrum by subdividing the whole range of the spectrum into a series of subranges. Each subrange contains several single discrete spectral levels. The sum of the value of the spectral levels included in the subrange determines the value of the corresponding index. Absolute or relative aggregated values of the magnitudes examined and of the four indices are shown in Fig. 1 on the right side of each distribution. In the case of amplitude distributions the boundaries of the ranges are chosen conventionally and their values are as follows: a_4, A_4 from 0–20 μV

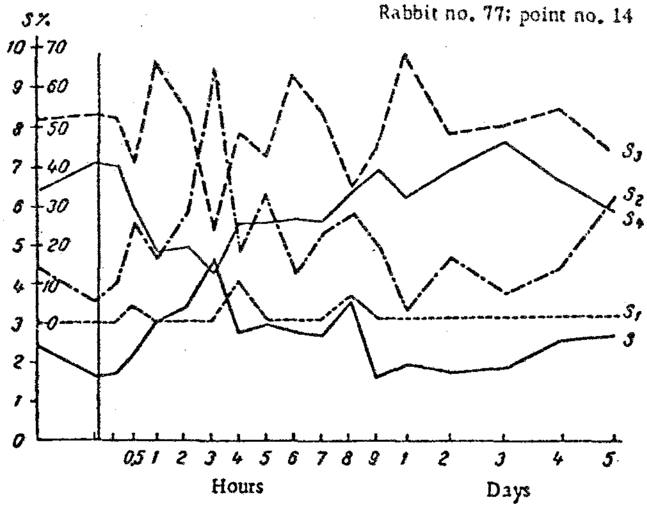

Fig. 2. Dynamics of changes in cortical electrical activity of a rabbit at 1 point (left hemisphere, occipital region). Dose of irradiation 1,500 R. Continuous line shows aggregated electrical activity S (in relative units). Indices (in percent): S_1, frequencies below 1 cps; S_2, frequencies of 1-3 cps; S_3, frequencies of 3-8 cps; S_4, frequencies over 8 cps. Vertical line indicates moment of irradiation. For clarity curves S_1-S_4 are raised three divisions above the abscissa.

(0-2 discrete levels); a_3, A_3 from 20-60 μV (2-6 discrete levels); a_2, A_2 from 60-100 μV (6-10 discrete levels); a_1, A_1 over 100 μV (over 10 levels).

To obtain indices of the distributions connected with halfwave duration, the following boundaries were conventionally chosen between the ranges (for rabbits): n_1, t_1, S_1—less than 1 wave/sec (durations of half-waves between 26 and 30 commutation intervals); n_2, t_2, S_2—1-3 waves/sec (9-22 intervals); n_3, t_3, S_3—3-8 waves/sec (4-8 intervals); n_4, t_4, S_4—more than 8 waves/sec (less than 8 intervals). All indices are given as percentages of their total sum.

The combined program as described above was used to analyze electrophysiological material obtained during investigation of the cortical electrical activity of rabbits subjected to whole-body irradiation by γ-rays in lethal doses. Graphs were plotted to show the dynamics of the change in aggregated cortical activity at 20 recording points simultaneously at various periods before and after γ-ray irradiation. By means of simultaneous analysis of the results pertaining to several indices, EEG components responsible for changes in the aggregated activity can be detected. It is clear from Fig. 2 that the increase in activity 3 h after irradiation (rabbit no. 77, dose 1,500 R) was caused by a considerable increase in the relative proportion of slower EEG waves (S_2), which in the currently accepted view are evidence of the development of inhibition processes.

The form of presentation of the results, its clarity and demonstrativeness, are extremely important. Besides the ordinary curves, we also plot graphs in the form of distribution diagrams for each EEG trace. To detect changes in the EEG resulting from external stimulation, diagrams obtained by superposition of values of the distribution index in the background on the value of the same index after exposure are used. This type of superposition is illustrated in Fig. 3. Changes in aggregated electrical activity taking place in the rabbit EEG as a result of whole-body irradiation in a dose of 1000 R at various times after exposure may be seen in the diagram. An increase in the relative proportion of slow waves is clearly visible in the EEG 4 h after irradiation (Fig. 3b).

It is interesting to assess the computer time necessary for analysis of electrophysiological data by the combined program in a concrete example. In our investigations the recording time of the experiment was 20 sec. The mean number of experiments on each rabbit was 20 and 20 recording points were used at the same time. Analysis of the 400 20-second EEG cuts (one rabbit) by the complete program requires

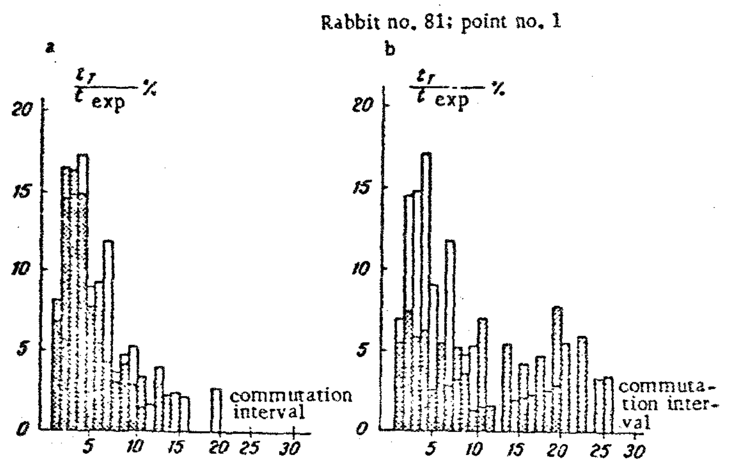

Fig. 3. Distribution $t_T = f_2(T)$ for left hemisphere, frontal region. Dose of irradiation 1000 R. a) First trace 15 min after irradiation; b) trace during depression (4 h after irradiation). Positive and negative halfwaves of equal duration are summated. Unshaded columns indicate background exceeds irradiation, columns with single shading, irradiation exceeds background, columns with double shading, areas identical.

about 3 h of computer time on the "URAL-2" (including the time of feeding the initial data and the time of printing results of the analysis). The total volume of information fed into the computer during analysis of the EEG of four rabbits was about 2 million numbers expressing instantaneous values of the EEG.

The suggested combined program provides almost exhaustive material for comprehensive description of the EEG. We hope that the application of multiple amplitude analyzers with magnetic recording and the use of modern computer techniques for EEG analysis by the halfwave method will help to facilitate progress in electrophysiological research practice.

LITERATURE DATA

1. V. M. Anan'ev, Byull. Éksperim. Biol. i Med., No. 1, 91 (1966).
2. V. A. Kozhevnikov and R. M. Meshcherskii, Modern Methods of Analysis of the Electroencephalogram [in Russian], Moscow (1963).
3. Mathematical Analysis of Electrical Phenomena in the Brain [in Russian], Moscow (1965).
4. V. A. Nazarov, Byull. Éksperim. Biol. i Med., No. 1, 95 (1966).