INTRODUCTION

Earlier, we indicated the possibility of constructing cross-intervalograms for analyzing the total bioelectrical activity of the brain and substantiated its efficiency [1]. This method allows us to reveal multiple time intervals between repetitious events in the electrical activity of the brain regions. The existence of these intervals is similar to the synchronization of events in the information processing system. Importance of this approach for indication of different functional brain states in health and pathology may be suggested. The essence of the method consists in finding the fragments of a special shape in a two-derivation EEG, determining the time interval values between the fragments recorded from one derivation and from the other derivation, calculating how many times the intervals of different size occur repeatedly, and showing the results in the form of a cross-intervalogram, a graph in which the interval values are plotted along the horizontal axis and the number of intervals, along the vertical axis. The maximums and minimums (or extremums) are the simplest variants of fragments of a special shape. In [1], we also indicated the possibility of constructing autointervalograms, when the interval values between the fragments occurring in one derivation are determined. Since autointervalograms contain peaks in the cases when periodically repeating events are present in the activity analyzed, the presence of peaks can be expected when the electrical activity of the brain influenced by periodic light stimulation changes.

The goal of this study was to clear up the possibilities of detecting responses of the human brain to periodic light stimulation using EEG autointervalograms. The objectives of the work were as follows: (1) development of computer programs for the construction of autointervalograms; (2) processing of the files with recordings of electrical activity of the patients whose EEG visually displayed a response to stimulation; (3) visual analysis of the autointervalograms; and (4) comparison between the results of the proposed method and the visual EEG analysis data and its calculated spectra.

MATERIALS AND METHODS

Six files assigned to the “brainstem” type according to the classification [2] proposed by us earlier were selected from the EEGs recorded in clinics. The pathological changes in patients whose files were selected (based on the neurological examination findings) were located predominantly in the oral divisions of the brainstem. The age of the patients varied between 17 and 60 years. We believe that, in our case, the fact that we selected the EEG of ill rather than healthy subjects, as well as the specific pathology, is of secondary importance. It is important that the response is revealed with the use of standard methods of analysis; this allows a comparison between them and the results of our method.

The electrical activity was recorded using a 21-channel computer-aided encephalograph (Mitsar) in the 0.5–30 Hz frequency band. The active electrodes were applied according to the international 10–20 system. Linked earlobe electrodes were used as a reference electrode. A signal from the Oz derivation, in which the response to light stimulation was the strongest, was processed.

The patients were in a dark screened chamber with their eyes open, in a sitting position. Flashes of light 50 µs in duration were presented at frequencies chang-
The use of EEG autointervalograms was studied. Stimulation was applied to the head at frequencies ranging from 2 to 22–28 Hz at a step of 2 Hz. The duration of stimulation was 3–4 s and was preset manually. The Mitsar WinEEG software for recording, analysis, and stimulation control was used.

The autointervalograms were analyzed visually. The presence in the intervalogram of a periodic sequence of peaks considerably surpassing the background peaks in height was a criterion of the presence of response to stimulation. The results of the analysis were summarized in the tables in which the presence or absence of response or its degree strength on a five-point scale was indicated for different stimulation frequencies, different programs, and different variants of their processing. In addition, the specific features of intervalograms worthy of note were fixed in text recordings. The results of visual EEG analysis and its Fourier spectra were entered into the same tables.

We developed several programs for constructing autointervalograms in the TURBO PASKAL 7.0 programming environment. These are the programs of recoding the WinEEG files to the files of individual derivations, calculating auxiliary tables, and constructing intervalograms using different modes. We also elaborated our own program for construction of Fourier spectra. (The WinEEG program of spectrum calculation and presentation incorporated into the package of programs is not intended for revealing responses to periodic light stimulation. It contains a number of supplements to Fourier series making its use for solving this task difficult, and, moreover, the graphic presentation of the spectra does not correspond to the task.)

The results described below were obtained using the following programs:

1. Program 1 of constructing the autointervalograms for the EEG curve maximums or minimums. In this program, division by the analysis interval value (which is equal to the duration of the stimulation interval; see above) is carried out for normalizing the graphs.

2. Program 2, in which, as in program 1, the intervals between the maximums and minimums are determined but, which is plotted in the graphs along the vertical axis, is the sum of the absolute values of the differentials pertaining to the EEG segments located either on the left or on the right of each of the pair of the extremums, for which the interval value between them is determined, rather than the number of interval coincidences. (By differential we mean the difference between the values of the adjacent EEG extremums. The arrows show two such extremums in Fig. 1). We call such a graph a hybrid intervalogram. In addition, in program 2, normalization is carried out to the number of the extremums revealed rather than the duration of the analysis interval, which decreases the dependence on the frequency composition of the oscillations.

3. Program 3, in which, first, in order to eliminate the intervalogram’s dependence on the duration of the recording processed and the frequency of stimulation, the number of recorded events is fixed. This number was taken to be equal to the number of flashes at 4 Hz minus 4 (the initial segments corresponding to four flashes were discarded. The stabilization of responses occurs approximately within this time interval). The number of flashes at 2 Hz was considerably fewer than at a frequency of 4 Hz, and when processing was carried out, it was taken to be the greatest possible. Second, assuming that one significant potential gradient was to appear in response to each flash, program 3 allows for the search for the differential that is maximal at each interval between the adjacent flashes.