The Method of Indirect Restoration of Human Communicative Function

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***Abstract*— The substantiation of the method of indirect restoration of human communicative function with using the specialized technical means, is carried out. It has been established, that indirectly, the communicative function can be restored by proper processing of the electroencephalographic and electromyographic signals, that arise during the implementation of this function.**

***Keywords*— communicative function, indirect restoration, electroencephalographic signal, electromyographic signal, correlation coefficient**

I. INTRODUCTION

The communicative function is the most important means of information exchange between people and can be fully realized with the full functioning the speech units of central nervous system, the respiratory system and the organs of vocal apparatus. However, there is an increase in the number of people with limited or lost communicative function, in particular due to the failure of these three systems or injuries. Therefore, the task of finding ways to restore the communicative function, as the most important means of communicating people, is actual to medicine [1].

Today, this problem is solved by rehabilitation of the vocal apparatus and the respiratory system using complexes of medical, therapeutic, surgical measures, etc. However, in cases, where the classical methods of rehabilitation do not give an adequate result, it is important to develop effective technical means of compensation or restoration of this function using indirect methods, based on the selection and processing of biosignals, that arise in the process the implementation of communicative function. Such technical means will enable the effective rehabilitation of the communicative function in cases, where it is impossible to restore the functioning of separate organs of the vocal apparatus. In the field of biomedical engineering, there are a number of indirect methods, that can be used for the task of human communicative function restoration. The basis of these methods is the selection and processing of electroencephalographic (EEG) [2], electromyographic (EMG) signals, registered from facial mimic muscles [3]-[4], and EMG signals, selected from the surface of the patient's neck [5]. However, these methods have the disadvantages, associated with their lack of informativeness: in the structure of EMG signals, registered from facial mimic muscles, will contain information only about the work of the articulation apparatus; in the structure of EMG signals, registered from the surface of the neck, will contain information about the work of vocal folds; the processing of EEG signals requires eliminating all artifacts, associated with the work of other parts of the brain (vision, hearing, etc.), taking into account the methods of encoding and transferring speech information in the streams of nerve impulses in the neural structures of speech centers the brain and the features of reflection of these processes on the surface of head the patient.

Therefore, the development of a method, that would allow the indirect restoration of human communicative function with the use of specialized technical means, is relevant to medicine. Such a method may be based on the parallel registration and subsequent processing of the biosignals group, that arises during the implementation of the communicative function.

II. THE METHOD OF INDIRECT RESTORATION OF HUMAN COMMUNICATIVE FUNCTION

The method of indirect restoration of the communicative function is proposed, which is based on the parallel selection and processing of two groups of biosignals [6]-[8]: 1) EMG signals, registered from the neck surface near vocal folds (in the structure of these biosignals will be shown the signs of the main tone (MT) presence); 2) EEG signals, registered from the head surface near the speech centers. In the structure of the last group of signals, electrical images of the nerve impulses will be displayed, which these centers will send to the corresponding organs of the vocal apparatus as if pronouncing a particular word or phrase. The scheme of EEG and EMG signals selection for the task of restoration the communicative function is shown in Fig. 1

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The essence of the proposed method of restoring the communicative function is as follows:

1) in accordance with the acoustic theory of speech production [9], the elementary units of speech signals are phonemes - separate sounds. They may be vowel and consonant vocalized and unvoiced;

2) forming a certain code sequence in the form of sections, corresponding to vowel, consonant vocalized and unvoiced sounds (based on the results of EEG and EMG signals processing), using the selection, it can be put in correspondence with a certain word, that is best suited to the resulting combination of sounds. There fore, to restore the communicative function, it is enough to get the such code sequence;

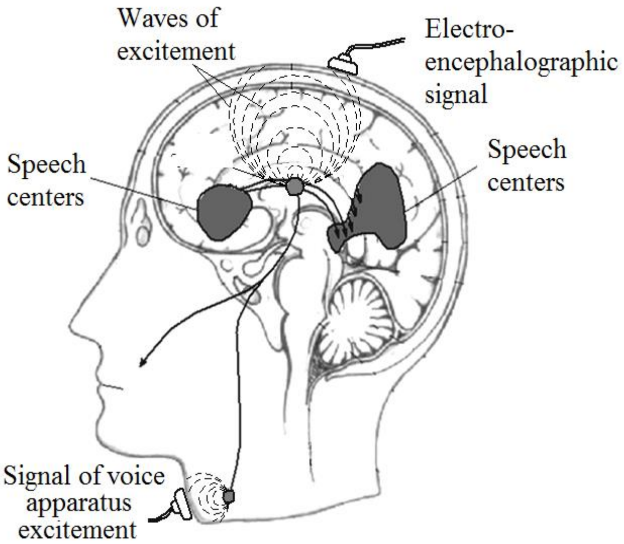
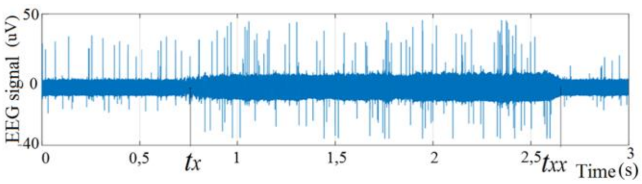


Fig. 1. The scheme of selection the excitation signals of the organs of vocal apparatus and EEG signals

3) division into separate sounds is proposed to perform by the presence of MT signs in the EMG signals structure (for vowels) and the changes of MT value (for vocalized consonant sounds). However, if the mentally pronounced word begins with a unvoiced consonant sound, the probability of error in the recognition of the word only by EMG signals increases;

4) it is proposed to form the window of the beginning and the end of the mentally pronounced word, based on the results of the EEG signals processing, with the subsequent segmentation of this window to the sections corresponding to vowel, consonant vocalized and unvoiced sounds, already on the results of the EMG signals processing.

The process of forming a code sequence from vowel and consonant sounds is shown in Fig. 2.



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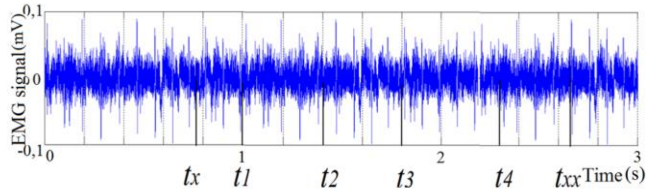

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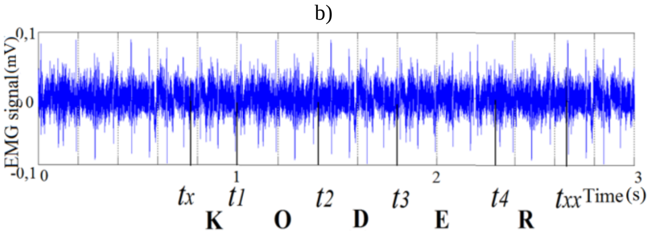

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Fig. 2. The process of forming a code sequence

Fig. 2 illustrates: the formation of the time moments of the beginning t_x and the end t_{xx} of speech process by the results of EEG signals processing (upper figure); the setting of time points for the presence of MT signs, which are indicators of vowels and consonants vocalized phonemes (middle figure), based on the results of EMG signals processing; and the process of identifying vowels and consonants vocalized phonemes (bottom figure) and next speech recognition. In more detail, the proposed method is described in works [7]-[8].

Such a method can be technically implemented using a single electroencephalograph, as illustrated in Fig. 3.

However, the application for the selection of EEG and EMG signals of one electroencephalograph is only possible in the case of expansion the frequency band of input signals, since the upper limit frequency in most modern electroencephalographs does not exceed 100 Hz (since they are designed to selection and processing of low frequency EEG rhythms), which is insufficient in the selection of EMG signals, because their structure contains the signs of MT, when pronouncing vowel or consonant vocalized sounds (the value of MT frequency may be in the range of 80-450 Hz [10]).

III. EXPERIMENTAL RESULTS

For the selection of EEG signals was used the electroencephalograph Neurokom (KhAI Medika), and for the selection of EMG signals was practically implemented one channel of biopotentials amplification of the electroencephalograph Neyrokom, with the extension of its transmission bandwidth.

In the process of recording, 16 signals were registered from the corresponding electroencephalogram electrodes in a monopolar mode using the system of electrode overlaying «10-20%». Duration of recording was 2 minutes. In this case, the patient was offered during the first minute of recording to try not to think about anything, and during the second minute - intensively "mentally" repeat the word "up" [11]-[12].

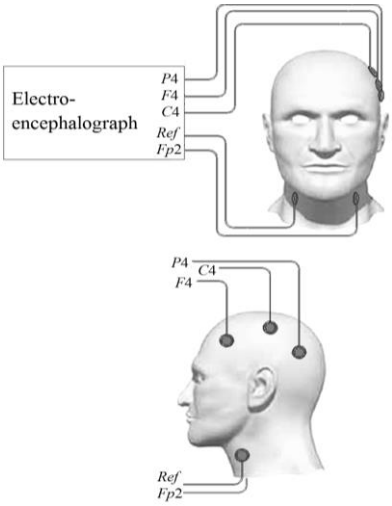
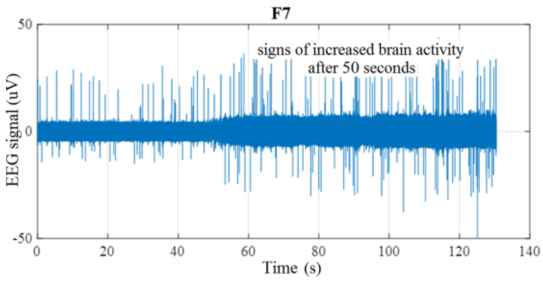


Fig. 3. The method of electrodes overlaying in the selection of EEG- and EMG signals using an electroencephalograph

As a result of the next processing of the selected EEG signals it was found, that on signals, recorded from certain leads, the intensity of the EEG amplitude is particularly intensive - its growth at the site characterizing the second minute of the recording. This can be explained by an increase in brain activity in the process of saying "mentally" the word "up". In Fig. 4 is shown an example of such signals and signals with no explicit changes.



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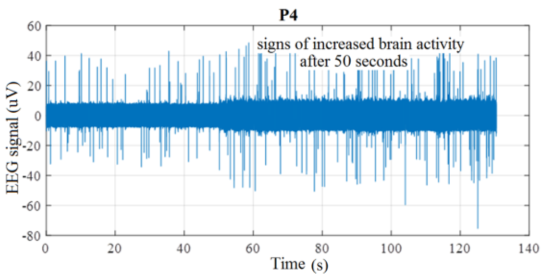

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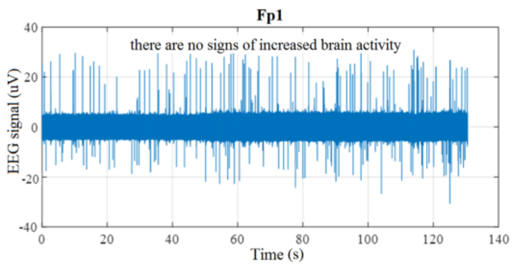

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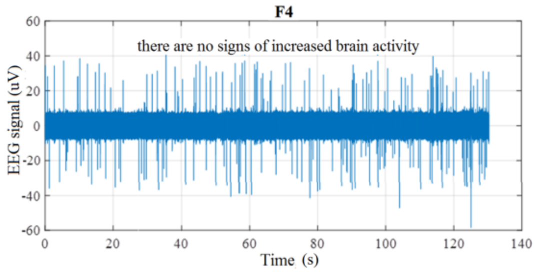

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Fig. 4. Example of registered EEG signals with signs of increased brain activity and without such signs

It was noted, that the increase in brain activity is observed in the structure of EEG signals, which are registered from the leads, located in the immediate vicinity of the centers of the language - the center of Vernicke, Brock and associative center.

Additionally, for the initial stages of "learning" the software and obtaining a reference signal, the signs of which appear in the structure of EEG and EMG signals, a parallel selection of voice signals, using a microphone, was performed. On the basis of these signals, the informative features of separate vowel and consonant vocalized sounds in the structure of EEG and EMG signals were performed.

During the experiment, the patient occasionally uttered one voice signal - the sound [*a*] with small intervals between the pronunciation.

Disposable electrodes were used to select EMG signals, which were superimposed on the neck surface in different places (Fig. 5).

In Fig. 6 shows examples of registered EMG signals and voice signals, that were synchronously recorded using the block, described above. In the structure of EMG signals, pulsation of blood vessels is clearly manifested, which is an artifact.

To evaluate the interconnection of selected EMG and voice signals, the value of the coefficient of mutual correlation was calculated in the Matlab environment by the expression:

$$K_{xy} = \frac{\sum\left(X - \overline{X}\right)\cdot\left(Y - \overline{Y}\right)}{\sqrt{\sum\left(X - \overline{X}\right)^2 \cdot \left(Y - \overline{Y}\right)^2}} \tag{1}$$

where: $\overline{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$ and $\overline{Y} = \frac{1}{n}\sum_{i=1}^{n} Y_i$ are the mean values of EMG (X_i) and voice signal (Y_i) samples, $n = 1,2,3,...,\infty$.

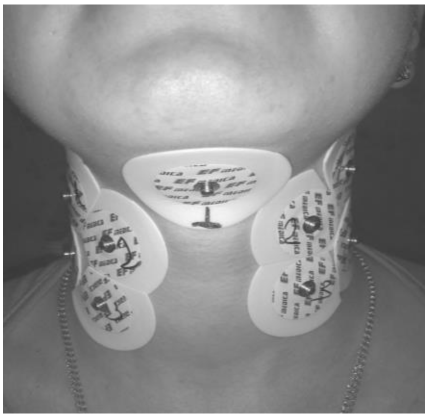
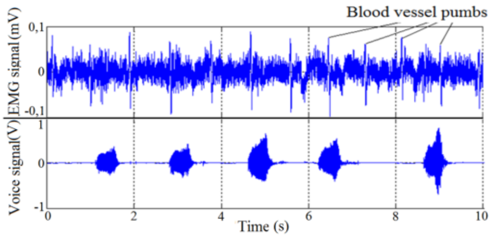


Fig. 5. Selection the electrode overlay scheme for registering the EMG signals



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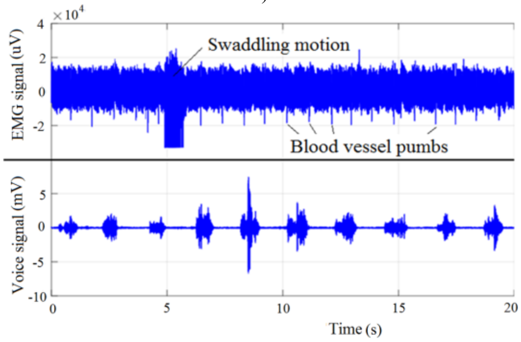

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Fig. 6. Synchronously recorded signals: upper figure - EMG signal and voice signal [*a*], bottom figure - EMG signal and voice signal [*l*]

Calculated K_{xy} values for identical EMG and voice signals are shown in Fig. 7. Calculations were made by the expression (1). At the same time, the values of this coefficient were calculated at identical time intervals. The first value of the correlation coefficient was calculated on the interval *t*1-*t*2, the second value - on the interval *t*3-*t*4, the third value - on the interval *t*5-*t*6, and so on. In Fig. 7 shows the value of this coefficient for only the first three sections. In this case, according to the expression (1), in Fig. 7, X and Y are marked the samples of EMG and voice signals within a given time interval.

From Fig. 7 it was concluded that there is an interconnection between the voice and the EMG signal, since the correlation coefficient between the corresponding values of the samples from the voice and EMG signals is different from zero. Consequently, in the structure of the EMG signals the signs of MT appear on the areas, corresponding to the pronunciation of vowels and consonant vocalized sounds.

In the paper [11], based on the task of indirect restoration of the communicative function, the proposed EEG and EMG signals are considered as a piecewise stationary random process, and the processing of these signals is carried out using the methods of spectral correlation analysis at defined time intervals - within the sliding window. Such elaboration makes it possible to detect the time moments of the MT appearance in the structure of EMG signals, and signs of the beginning and the end of speech process in the structure of EEG signals (Fig. 2).

The proposed method of selection and processing of EEG and EMG signals will provide the opportunity for indirect restoration of the communicative function, in particular by developing specialized technical means.

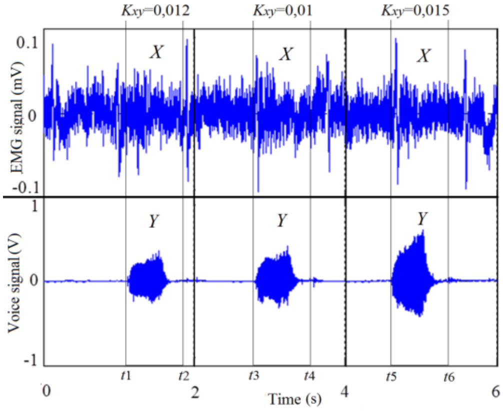

Fig. 7. The value of the correlation coefficient for individual samples from the registered EMG (upper figure) and voice signal (bottom figure)

IV. Conclusion

The method of indirect restoration of human communicative function, based on the results of processing the EEG signals, selected from the patient's head near the speech centers, and EMG signals, selected from the patient's neck near the vocal folds, is proposed. Such a method of restoration may be technically implemented on the basis of one electroencephalograph whith expansion the frequency band of input signals.

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