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The technique for determining on EMG signals the precursors of start of limb movement

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ABSTRACT

In this paper we have developed a technique allowing automatic detection of the precursor of movement beginning based on the analysis of electromyographic signals. Methods for determining the beginning of movement and the moments of movement planning are of urgent need in neuroscience, and a separate problem is the use of muscle electrical activity signals (electromyograms) to accurately determine the beginning of hand movement due to the complexity, short duration and noise of the original signals. We have found out that in the case when the movement starts on a certain sound signal, the moment of the movement beginning is detected with a some time delay.

Keywords: signal analysis, delay time, motor activity, electromyograms, filtering, motion

1. INTRODUCTION

Currently, scientific interest is attracted by the processes occurring in the human body related to the performance of motor activity.[1–7, 20, 21, 23, 26–29] The relevance of this research area is related to the possibility of applying the results in such areas as rehabilitation, prosthetics, robotics, etc. Registration and analysis of electroencephalogram (EEG)[8] is one of the most objective ways to study the workings of the human brain during movement. However, the use of EEG for the analysis of motor activity, mainly involves conducting an experiment with a previously developed elaborate plan, according to which movements are performed simultaneously with a special signal. In this case, there is the problem of accurately determining the moment of the start of movement.[10] A promising way to solve this problem is analysis of a signal of muscle electrical activity — electromyograms (EMG).[11] The analysis of EMG signals, in turn, is difficult due to the low amplitude of the potentials, the strong nonstationarity, the presence of various artifacts, and the poor structuring of the initial data.[12–14, 22] In view of the above, there is a need to develop methods for analyzing EMG signals and using them for a detailed study of motor activity.

2. METHODS

In this work, we used the data of ten test subjects, who had no pathologies of the central nervous system. During the experiment, simultaneous registration of EMG and EEG in the vertical position of the body was carried out. The duration of the recording was 150 minutes. During the recording of the signals, breathing was spontaneous. During the experiment, the registration of non-invasive EMG signals from the muscle was implemented as shown on Fig. 1a. The subject was instructed to perform the arm flexing and the subsequent extension of the arm with an intermediate fixation in the upper position on the beep. Registration was carried out using a multichannel electroencephalograph-analyzer EEG-21/26 "Encephalan-131-03" model 10 (NPKF "Medical-MTD", Russia)[9] with a set of standard sensors. Signals were recorded at a frequency of 250 Hz with a 12-bit resolution.

The experiment consisted of four sessions, including two half-hour sessions with a raise of a hand on a beep and two sessions with a spontaneous raising of a hand. Before and after the active experiment, the background recording was recorded without the subject performing special instructions for 15 minutes. To detect the moment

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of the movement beginning, the EMG signal was filtered in the 1–10 Hz frequency band, for the real time analysis was data processing was based on application of bandpass Type II Chebyshev filtering (1) over similar frequency range.

$$G_n(\omega, \omega_0) = \frac{1}{\sqrt{1 + \varepsilon^2 {T_n}^2(\omega_0/\omega)}} \tag{1}$$

Time series was smoothed by a sliding window 2 seconds long, after which the derived signal was found along the smoothed row.

Comparing the original signal of the EMG and the resulting derivative, it was found that at the time points corresponding to the beginning of the movement, the value of the derivative exceeded the threshold value (0.5 of the maximum value of the series). Thus, comparing the received signal with the threshold value at each moment of time, the moments corresponding to the beginnings of movement were obtained. Figure 1b shows the smoothed time series of the EMG (red) and its derivative (in blue). The dashed line corresponds to the threshold value used to detect the start of movement in the automatic mode, the black solid line shows a typical fragment of the EMG signal recorded from the muscle. The green risks mark the moments of the sound signals corresponding to the commands. From Fig. 1b and 1c, it can be seen that a sharp increase in the amplitude of the recorded signal corresponds to the moments of performing the movements. The moments of short negative spikes before movement can be considered the precursors of the movement.

3. RESULTS

The threshold value was chosen in accordance with the optimal ratio of sensitivity and the false positive rate of the movement. Fig. 1d shows the dependence of the sensitivity of the technique and the percentage of false positives (dotted lines) on the threshold value for detection. Trial threshold values were enumerated in the range from zero to the maximum value of the series in increments of 0.05. It is easy to see from the graph that the maximum difference falls on the value corresponding to 0.5 of the maximum value of the series, which was later used to calculate the distribution of delays between the time the sound signal was presented and the moment the motion began. The advantage of the approach is its simplicity and speed compared with more precise and complex methods that require individual training.[15,16]

From Fig. 1b, it can be seen that there is a time delay h between the moment the sound signal is presented and the detected moment of the start of movement. To determine the characteristic delay time, Figure 1e presents the statistical distribution of the value of h during the execution of the experiment, constructed for the optimal threshold value. It can be seen that the mode of distribution falls on the time corresponding to 1.6–1.8 s. The narrowness of the distribution obtained is evidence in favor of the idea that the preparation time for movement can be estimated and then taken into account in the experiment without a sound signal.

4. DISCUSSION

In this section we discuss possible causes and background for the delay interval between stimuli and action. The obtained time interval may be associated with stimulus processing and motion planning. In this context, the use of EMG signals offers great potential for identifying various phases associated with the implementation of human motor activity. The modern concept of the closure mechanism of the conditioned connection[17] assumes that the association of foci of excitations corresponding to the conditioned and unconditioned stimuli can occur both at the level of the cortex and at the level of the subcortex. However, the focus of excitation that has arisen in the reticular formation has a nonspecific activating effect on various parts of the cerebral cortex and thus contributes to a generalized increase in the excitability of the cortex. With continued admission of specific afferent impulses to a certain limited cortical foci of excitation, gradually generalized excitement is concentrated in this focus, and then gives way to a significant part of its influence on the construction of movement to the underlying excitation foci that have the advantage of afferent proprioceptive impulses continue to flow to them. Recent studies indicate the presence of delays in the activation of sensorimotor processing in the human brain associated with the phases of formation, recognition of the stimulus, categorization-response, decision making and reaction of afferent neurons.[18,19,24]

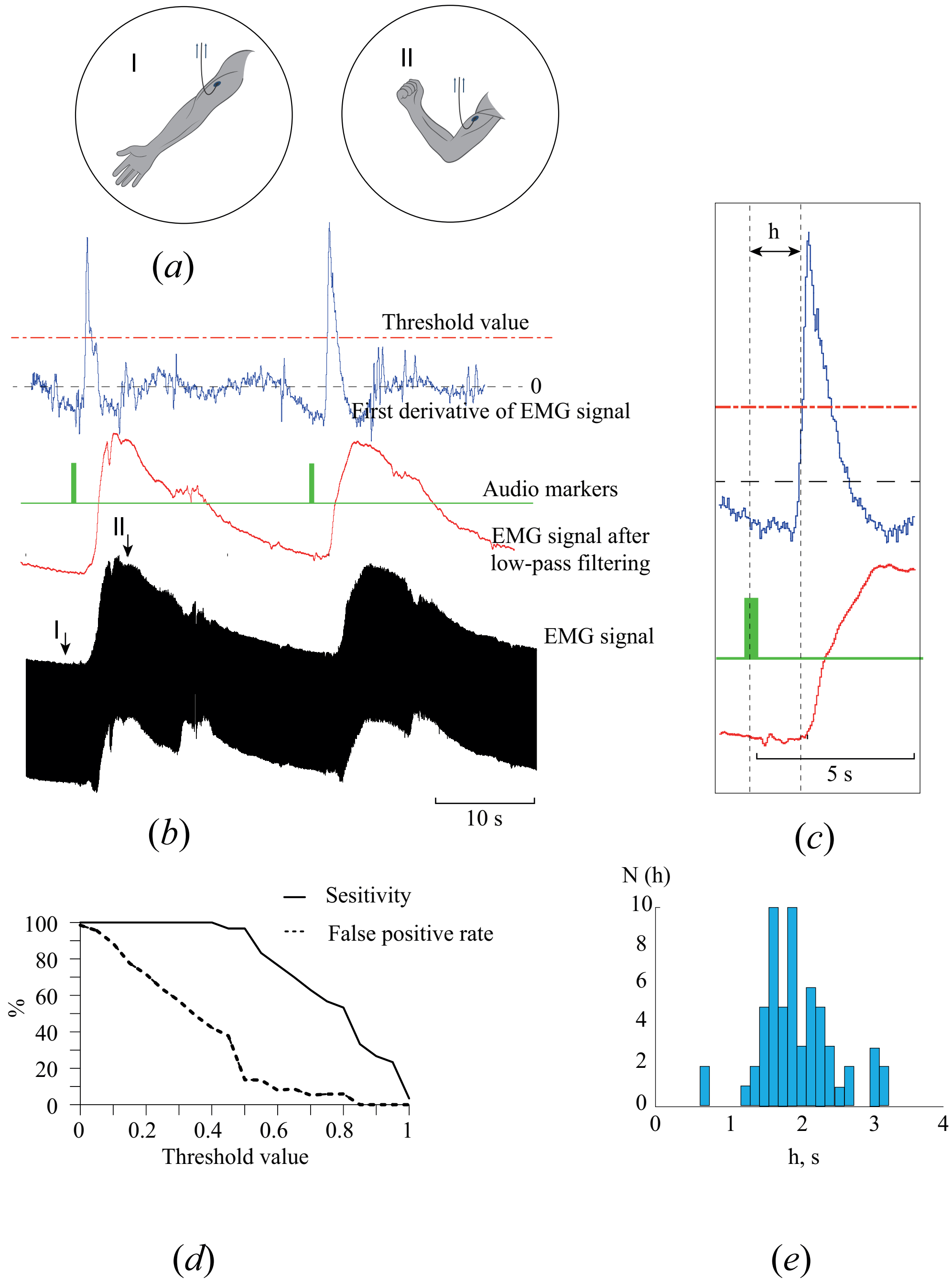

Figure 1. The motion design experimental setup (a), fragment of the original and processed experimental EMG signals (b), time delay estimation (c), dependence of sensitivity and false false positive rate on the threshold value (d), the distribution of time delays between the moment of presentation of the sound signal and the moment of the beginning of the movement, calculated via threshold of the smoothed EMG signal derivative (e)

5. CONCLUSION

Thus, a method was proposed in the paper, which allows automatic detection of patterns on myographic data in real time during movement in the elbow joint. It was established that in the case when the movement starts on a certain signal, the moment of the start of movement is detected some time after the signal. Possible causes and background of the obtained results are discussed. The results obtained can be used to isolate the phases of planned movement and allow you to advance in understanding the principles of functioning of the brain and human consciousness, and contribute to solving a number of applied tasks related to improving the quality of life of people.

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