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Improvement of Nociceptive Spike Clusterization with Shape Approximation

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Abstract Cluster spike analysis is widely used for studies of neuronal activity when electrical signals are sorted out and grouped according to the different shapes. We recently applied this method to sort out the nociceptive spikes in the trigeminal nerve implicated in generation of migraine pain. However, the electrical noise leading to less accuracy of calculated spike parameters often hinder the correct sorting of nerve signals. In this study, in order to improve the accuracy of calculations, we explored the prior approximation of spike shapes before applying clusterization. The prior fitting of spike shapes allowed us to extract signal parameters much more precisely and detect the strongly increased number of spike clusters which is close to the expected number of fibers in the trigeminal nerve. Prior approximation improved cluster analysis outcomes and, importantly, revealed new clusters that demonstrated the different functional properties, suggesting that their function was previously hidden within the multiple firing.

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1 Introduction

Analysis of spikes recorded by different electrophysiological techniques is the most reliable current approach to evaluate the function of the neurons in the central and peripheral nervous system [1–4]. Given a large number of synapses and complicated morphology of neurons, spiking activity is typically very heterogeneous, thus, requiring advanced methods for separation of multiple spikes. One of the commonly used approaches for obtaining physiologically relevant information on the neuronal activity is the clustering of spikes [3, 5]. Thus, the cluster spike analysis based on signal grouping according to the amplitude and the shape of spikes is commonly used to identify spikes originating from different cells. Basically, there are various ways for spike features extraction: principal component analysis [5, 6], wavelet analysis [7, 8], or the direct calculation of the parameters [9].

To improve the quality of registration and to reduce the contribution of the noise to spike numerical description, different types of filtration, both analog and digital, are commonly used. However, all types of filtration, especially in the case of low signal/noise ratio, can modify the original signal, thus affecting physiological conclusions.

Recently, we applied clusterization method to sort out the nociceptive spikes generated in the peripheral branches of the trigeminal nerve in meningeal tissues [9]. This study provided a novel information on the neurochemical mechanisms of nociception in trigeminal nerve endings implicated in generation of migraine pain.

In the above study, we used the recordings with suction electrode [10] resulting in relatively low amplitude signals.