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POSTSYNAPTIC RESPONSES OF MOTOR CORTEX NEURONS OF CATS TO SENSORY STIMULATION OF DIFFERENT MODALITIES

A. S. BATUEV, D. N. LENKOV and A. A. PIROGOV

Biophysics Department, Leningrad State University
Leningrad, USSR

In the last few years the processes underlying the multisensory convergence at the cortical level have been studied by many authors (3, 5, 6, 15–17). It is well known that light chloralose narcosis enables revealing the responses of the motor cortex neurons to sensory stimulations of different modalities (1, 5–7, 10, 15–17). So far, the synaptic mechanisms of these reactions have remained obscure, especially those in response to activation of nonspecific afferent inputs (16). Some advance has been made only in the analysis of effects of electrical and natural stimulation of skin and extremity nerves (1, 2, 6, 10, 11, 17).

The present paper is devoted to the description of the PSP's of neurons of the cat motor cortex in response to the stimulation of different modalities: flashes of 50 msec duration and 0.3 J intensity, clicks of 0.5 msec duration and 70 db intensity and electrical shocks produced by rectangular pulses of 0.5 msec duration and suprathreshold intensity. Electrical shocks were applied to the sole of a contralateral forepaw by means of needle electrodes.

Acute experiments were performed in 26 cats weighing 2.5–3.8 kg. The animals were operated under mixed anesthesia (35–45 mg/kg α-chloralose + 15 mg/kg pentobarbitone) administrated i.p. and immobilized by d-tubocurarine or diplacine, administrated i.v. as needed. Intracellular recordings were obtained laterally in the anterior and posterior sigmoid gyri. The microelectrodes were filled with 2M potassium citrate solution according to Tasaki and co-workers (14). The stimulations with polarizing current were performed with a bridge-circuit (4). A bipolar

electrode to identify pyramidal tract neurons (PT) by means of antidromic stimulation was inserted stereotaxically (F: 5.5–6.5; L: 4.0–5.0; H: (−4)–(6) into the ipsilateral brain peduncle according to Stefanis and Jasper (13). The site of the electrode was checked electrophysiologically with respect to the latency, pattern and threshold of the antidromic gross potential of the cortical surface (13) and in some experiments it was also checked histologically.

Postsynaptic responses of 121 motor neurons were recorded, 27 of these cells were identified as PT neurons (Group I), the non-identified neurons were divided into two groups: (i) elements of the deep layers, the responses of which were similar to those of PT neurons and had a relatively high spike amplitude (20–67 mv); these elements are likely to be corticofugal pyramidal cells (Group II); and (ii) neurons with a spike amplitude of less than 20 mv, some of them being spontaneously active when extra- and intracellularly recorded (the interval between spikes is about 2–3 msec); these neurons were characterized by burst discharges (Fig. 1*B1,2*) and are likely to be interneurons (Group III). The latter assumption is supported by the comparison of the histograms of the latency distributions of EPSP's of the neurons of the different groups. Figure 1*A* shows that latency of response to electrocutaneous stimuli in 7 out of 18 cells of Group III are shorter than those in Groups I and II.

When all modalities of sensory stimulation were applied, a two-phase

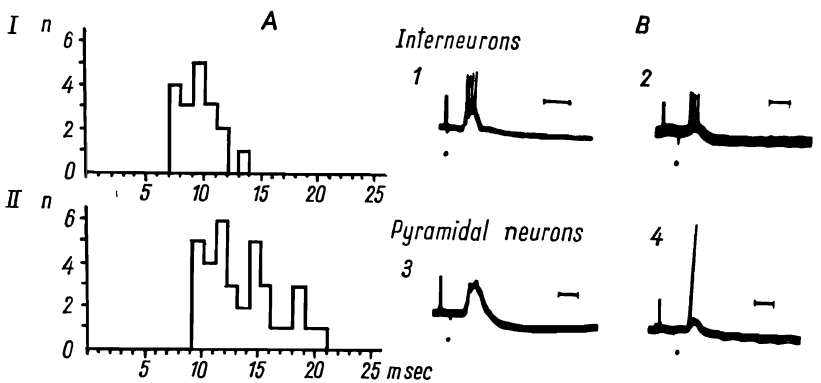

Fig. 1. Postsynaptic responses of pyramidal and internuncial motor cortex neurons to electrocutaneous stimulation of the sole of a contralateral forepaw. *A*, histogram of the latencies of EPSP's of internuncial neurons (*I*), pyramidal cells (Groups I and II) (*II*) to single stimuli. Abscissa, latencies in msec; ordinate, number of cells. B, samples of postsynaptic responses of interneurons (*1, 2*) and two PT neurons (*3, 4*). At the beginning of the beam before the stimulus artifact is the calibrating impulse, 10 mv, in this Figure and others; time, 20 msec.

excitatory-inhibitory reaction in the form of EPSP (very often it reached the threshold of a discharge generation) which was followed by an IPSP lasting 150–200 msec was observed in 55% of the pyramidal neurons (Fig. 1*B3,4* and Fig. 3). This type of response was often observed in neurons of different cortical areas during sensory activation (1, 2, 16,

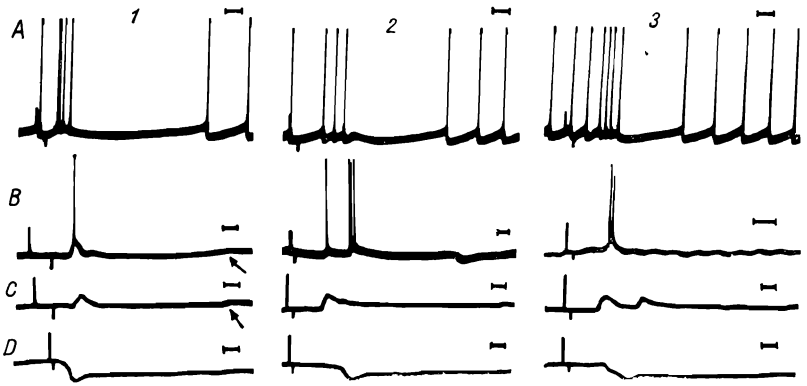

Fig. 2. Variations of responses of motor cortex neurons to electrocutaneous (*1*), light (*2*) and sound (*3*) stimulations. *A–D* represents the different neurons. Records *A1-3*, *C2,3* and *D1-3* are the samples of responses of single units. Arrows show the time of the repolarization of the neuron membrane.

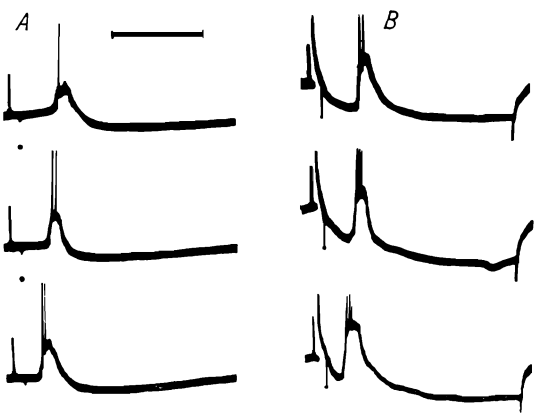

Fig. 3. *A*, the responses of a PT neuron to light, sound and electrocutaneous stimulation (from above downward); *B*, effects of the interaction of the same synaptic responses with the injection of hyperpolarizing current (14 na). The spikes in all oscillograms are cut. Time, 100 msec.

17) and electrical stimulation of the thalamic nuclei (8, 12). Our data show that this type of response is observed in all three groups of motor cortex neurons, although it is the most distinct in PT neurons (Fig. 1*B1*

and Fig. 3*A*). Many cells showed an excitatory response which was not followed by a visible IPSP. However, the break in the background firing following the excitation (Fig. 2*A1–3*) as well as the repolarization oscillations of a membrane potential (Fig. 2*B1,C1*) show a mixed nature of postsynaptic responses in some cases, where the summation of de- and hyperpolarizing effects results in masking the latter.

When all kinds of sensory stimuli were applied, single two-component excitations could be observed (Fig. 2*B2,C2*). Such reactions had been earlier observed (16). The late secondary excitations could be the result of the chloralose anesthesia (9). We failed to confirm the previous observations (16, 17) that high percentage of primary IPSP's occurs in motor neurons during sensory stimulation. The nine primary IPSP's we observed (Fig. 2*D*), took place only in cells having evident signs of damage.

The latencies of the initial EPSP's of the pyramidal cells were 9–20 msec to skin stimulation, 14–32 msec to clicks and 18–30 msec to flashes. The difference in the latencies of effects of different modalities is likely to be due to a great number of synaptic relays in relevant nerve circuits.

Intracellular injection of hyperpolarizing current revealed distinct interaction between the current pulses and responses of the pyramidal cells to the stimulation of all modalities (Fig. 3*B*), which suggests that the localization of at least some synaptic terminals causing these PSP's are localized in proximity to the site of the microelectrode tip — most probably at the dendritic parts, proximal to the soma (16). Similar responses of PT neuron to the stimulation of different modalities and changes in responses due to artificial membrane polarization supports the view of Thompson and coworkers (15) that the heterosensory information is transferred from the subcortical association system (probably from relevant thalamic nuclei) to the functional neuron ensembles in the cortical areas through a single pathway.

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A. S. BATUEV, D. N. LENKOV and A. A. PIROGOV, Biophysics Department, Leningrad State University, 7/9 University Embankment, Leningrad, USSR.