MECHANISM OF THE "ENHANCING" RESPONSE IN THE RABBIT VISUAL CORTEX

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Mechanisms of the "enhancing" evoked potential arising in the visual cortex in response to repeated stimulation at intervals of 100-150 msec were investigated on unanesthetized rabbits. Such intervals correspond to the phase of postinhibitory activation caused by the first (conditioning) stimulus. It is shown that the enhancing response lasts slightly longer than the primary response to a single stimulus and develops upon stimulation of the optic nerve and subcortical white substance under the point of derivation. The enhancing response is accompanied by a high-amplitude excitatory postsynaptic potential in cortical neurons and by a burst of impulse activity. Hence it can be concluded that it is generated by excitatory synapses of cortical neurons. Characteristic features of the enhancing response are the relation between the duration of the response and its amplitude (the response is shorter, the higher its amplitude) and the weak effect of the intensity of the stimulus on the amplitude of the response. An analysis of the possible mechanisms of enhancement of the response when the stimulus evoking it coincides with the phase of postinhibitory activation leads to the suggestion that this response is generated by a recurrent excitatory intracortical system. This suggestion makes it possible to explain the ability of the response to be enhanced in the presence of postinhibitory activity and some other properties of it.

INTRODUCTION

It is known [1, 13, 15] that a slow surface-negative wave with a duration of 150-200 msec arises in the rabbit cerebral cortex in response to a single afferent or direct stimulus, in addition to the initial evoked potential (primary with afferent stimulation or "dendritic" with direct stimulation). This wave is accompanied by the appearance of an inhibitory postsynaptic potential [6, 11] and inhibition of the impulse activity of cortical neurons [3, 5, 8]; therefore, we can consider that it is a reflection of the activity of inhibitory synapses of the cortex. At the end of the inhibitory interval a phase of postinhibitory activation develops—an increase of the frequency of neuronal discharges in comparison with the background [3, 5, 8]; at this time a specific evoked potential is observed in the electrocorticogram, which has previously been described as an "extrapotential" [4] or secondary response of the rabbit visual cortex [2, 12].

If paired afferent stimuli are applied with an interval such that the second stimulus falls on the decay of the slow negative wave (hence at the phase of postinhibitory activation or immediately before it) evoked by the first stimulus, we can observe in response to the second stimulus an evoked potential of greater amplitude in comparison with the amplitude of the primary response to a single stimulus [1, 14]. We demonstrated [7] that this phenomenon is related with a change of amplitude of the primary response and with the occurrence of a new evoked potential slightly longer than the primary potential. This evoked potential was designated as the "enhancing" response. Some of its properties were examined earlier [7, 8, 9]. In the present work we attempted to analyze in greater detail the nature of this phenomenon and to establish its possible synaptic mechanisms.

METHOD

The experiments were carried out on 50 unanesthetized rabbits gently restrained during the experiments. The stimulating and recording electrodes were attached directly on the dorsal surface of the skull,
which was exposed in a preliminary operation. For placing the microelectrodes we used a hydraulic micro-
manipulator, the actuating part of which was also mounted on the skull.

Silver extradural electrodes were used for recording the total potentials of the cortical surface. The
impulse activity of single elements was recorded by means of tungsten needles or, with intracellular record-
ing, by capillary microelectrodes with a resistance of 50–80 MΩ filled with 1.5 M potassium citrate. For
stimulation of the optic nerve and subcortical white substance we used bipolar electrodes with a spacing be-
tween poles of about 0.5 mm vertically.

The potentials were delivered to an ac amplifier (when recording slow potentials the time constant
was 1 sec and when recording fast evoked potentials and impulse activity, 40 and 0.5 msec) and in the case
of intracellular recording, to a dc amplifier. The input impedance of the microelectrode lead was not less
than $10^9 \Omega$. The amplified potentials were photographed from the screen of a cathode-ray oscillograph.

RESULTS

Characteristics of the Enhancing Response upon Stimulation of the Optic Nerve and Subcortical White
Substance. In the case of paired stimuli of the optic nerve the enhancing evoked potential arises in response
to the repeated stimulus at an interval equal to 100–150 msec (maximum at 120–140 msec). The response
has the form of a monophasic surface-positive (sometimes biphasic positive-negative) oscillation. As we
see from Fig. 1B, the positive phase of the enhancing response reaches its peak in about 10–12 msec, i.e.,
later than the positive phase of the primary response to a single stimulus (6–7 msec).