DYNAMICS OF NEURON ASSEMBLIES IN THE VISUAL CORTEX OF RATS DURING EVOKED PAROXYSMAL DISCHARGES

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Several roles of neurons in epileptiform activity have been distinguished. During paroxysmal discharges considerable changes take place in interneuronal relationships. The relationship between excitatory and inhibitory responses to a photic stimulus is altered. Two possible forms of interaction between neurons during epileptiform activity are examined: strictly fixed and stochastic.

Some of the results [2, 5-7] obtained by the study of neuron assemblies in states of increased cortical excitability suggest that more rigidly fixed forms of interaction are the decisive elements of functional organization at this time. The parameters of the neuronal assemblies are altered under these conditions. To determine the character of their dynamics and the principles governing them, the writer investigated the relationships between unit activity, using a specific stimulus for that particular cortical region, during normal brain function and also during epileptiform fits.

EXPERIMENTAL METHOD

Albino rats were immobilized with D-tubocurarine. Unit activity was recorded extracellularly in the visual cortex simultaneously by two or three microelectrodes. The distance between the microelectrodes was 100-250-500 μ. The ECoG was recorded concurrently. Flashes were used as the adequate stimulus. To evoke epileptiform activity, series of square pulses (20 V, 0.1 msec, 10/sec) were applied from a type GÉFI-3-BU stimulator. Bipolar stimulating electrodes were located around the edges of a hole cut in the cranial bones for insertation of the microelectrodes. The distance between the stimulating electrodes was 3 mm. Recordings were made on a type 4-EEG electroencephalograph with trigger attachment for converting spikes into pulses of current for pen recording.

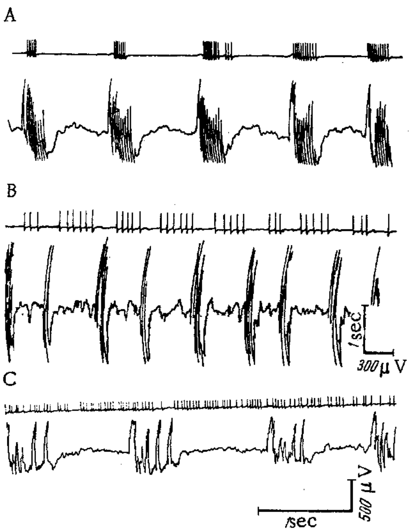

Fig. 1. Types of role of visual cortical neuron in epileptiform activity: A) type 1; B) type 2; C) type 3. From top to bottom: unit activity and ECoG.

EXPERIMENTAL RESULTS AND DISCUSSION

The generalized epileptiform fit was characterized by the appearance of typical high-voltage spike discharges on the ECoG. Three types of role of the neurons in paroxysmal activity were distinguished. Type 1 consisted of neurons responding by increased activity during the epileptiform spikes on the ECoG, and ceasing to discharge during the intervals between the spikes. Neurons of the second (inhibitory) type were characterized by the opposite relationship: inhibition

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TABLE 1. Changes in Types of Unit Responses in the Visual Cortex to Photic Stimulation during Epileptiform Activity

Response to light		Percentage of neurons with given type of response
normal	epileptiform activity	
N	N	86.6
N	I	4.8
N	A	8.6
A	A	57.7
A	I	0
A	N	42.3
I	I	23.6
I	A	7.2
I	N	69.2

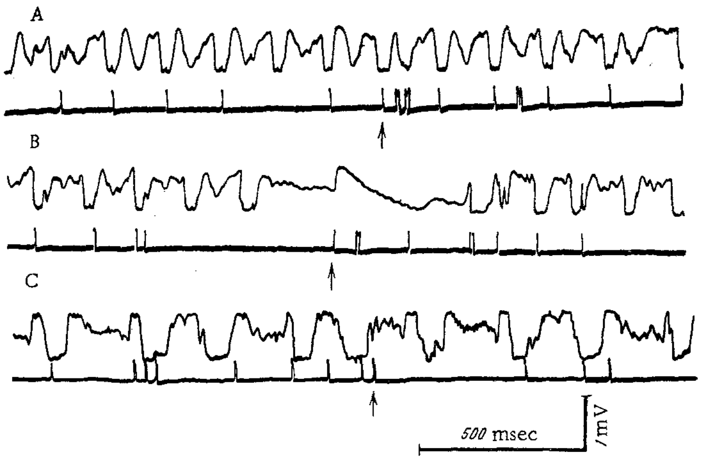

Fig. 2. Evoked activity during epileptiform fit: A) activation in response to photic stimulation during epileptiform spikes; B) activation in response to photic stimulation during a period of "silence"; C) inhibition in response to photic stimulation during epileptiform activity. Arrow marks stimulation. From top to bottom: ECoG and unit activity.

of activity during spike discharges and restoration of activity during periods of "silence" on the ECoG. The neurons on the third (mixed) type showed no visible correlation of their activity with the dynamics of the ECoG, although changes in their activity by comparison with the background level were clearly visible (Fig. 1). Most neurons in the visual cortex were of type 1 (57.5%). The number of neurons of types 2 and 3 was 17.2 and 25.2% respectively. In more than 90% of cases the unit activity showed characteristic changes during the epileptiform fit.

If photic stimulation was applied during an epileptiform fit, in 23% of cases it evoked changes in unit activity consisting of either an increase in amplitude or decrease in frequency of the activity. As a rule the response was independent of the time of stimulation, whether during the epileptiform spikes or during periods of "silence" on the ECoG (Fig. 2). The ratio between the number of excitatory and inhibitory responses of the neurons to the photic stimulus was changed. Whereas under normal conditions the number of nonresponding neurons (type N) was 64.5%, the number of activated neurons (type A) 14.0%, and the number of inhibitory neurons (type I) 21.5%, during the paroxysmal discharges the numbers were 77, 15.6, and 7.4% respectively. The changes in the types of response of different groups of neurons are shown in Table 1. Most responses to photic stimulation during epileptiform activity were obtained from neurons not exhibiting a very high firing rate during the paroxysmal discharges. The characteristic features of the ECoG during epileptiform activity in the present experiments were in general agreement with those obtained by other investigators [4, 5, 8-10, 12, 13, 16]. It is interesting to analyze the results obtained by photic stimulation of the animal during paroxysmal discharges. The results of the present experiment show that during an epileptiform fit afferent stimuli reach the cortex and evoke an increased strength or reduced frequency of activity analogous to the normal adequate response to light. However, despite the relative increase in the number of spontaneously active neurons in the cortex during the epileptiform fit [13-15], the number of cells responding to peripheral stimuli is reduced [15]. The reception of afferent stimuli is more difficult during this period and they are less effective. Most neurons cannot discharge at frequencies exceeding 500-1000/sec [4, 9, 12]. A further increase in the firing rate during the action of exciting afferent stimuli is impossible for these neurons, just as inhibitory effects cannot suppress activity from the focus of excitation. Practically all spontaneously active cortical neurons are involved in the epileptoid process [5, 11]. However, the degree of involvement of neurons, even if located very close together, in paroxysmal activity varies very considerably. Accordingly, two categories of neurons can be distinguished. The first category contains neurons whose activity is definitely correlated with the ECoG and which exhibit a high firing rate during paroxysmal discharges. These neurons constitute the majority (mainly neurons of types 1 and 2),and more rigidly fixed forms of interaction play a decisive role in their organization. The second category consists of neurons not exhibiting a high firing rate during epileptiform activity and remaining capable of conducting afferent stimuli (some neurons of types 1 and 2, and neurons of type 3). These neurons preserve the basic features of functional organization possessed by the cortex under normal conditions, and they may play a special role in the compensatory mechanisms of the brain structures. The function of this group of neurons is based on the stochastic principle of organization of its elements [1]. The increase in excitability of the cortical neurons during epileptiform activity [8, 13, 16] may contribute to the spreading of the excitatory nucleus of the neuronal assembly [3, 7] on account of a reduction in size of the inhibitory zones, corresponding to a certain increase in the number of neurons of type A and a decrease in the number of neurons of type I in the present experiments. Changes in the form of the responses to light (Table 1) also reflect adaptive changes in the cortex during paroxysmal states.

The fact will be noted that the ratio between the numbers of excited and inhibited neurons during photic stimulation at a time of epileptiform activity was 2:1. This is further confirmation of the hypothesis [2, 5] that this ratio reflects one of the general principles of the dynamic structure of the activity of cortical mechanism.

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