SELECTIVITY OF VISUAL CORTICAL NEURONS
OF RABBITS TO MAGNITUDE OF MOVING STIMULI

A. Ya. Supin

Unit responses of the rabbit visual cortex were investigated in relation to size of visual stimuli moving in their receptive field. With an increase in size of the stimulus in a direction perpendicular to the direction of movement ("width" of the stimulus) an initial increase in the intensity of the unit response through spatial summation of excitatory effects is followed by a decrease through lateral inhibition. This inhibition is observed between zones of the receptive field which behave as activating when tested by a stimulus of small size. Each neuron has its own "preferred" size of stimuli evoking its maximal activation. No direct correlation is found between the "preferred" stimulus size and the size of the receptive field. With a change in stimulus size in the direction of movement ("length" of the stimulus) the responses to stimuli of optimal size may be potentiated through mutual facilitation of the effects evoked by the leading and trailing edges of the stimulus and weakened in response to stimuli of large size. The selective behavior of the neurons with respect to stimulus size is intensified in the case of coordinated changes in their length and width. It is postulated that the series of neurons responding to stimuli of different "preferred" dimensions may constitute a system classifying stimuli by their size.

INTRODUCTION

The central visual system contains neurons which not only respond selectively to particular properties and features of stimuli, but also classify stimuli with respect to these features. For example, neurons with "simple" reactive fields in the visual cortex of cats and monkeys [12, 13, 15] respond to presentation of lines in a certain direction, and each neuron has its own "preferred" direction of the lines. The complete set of neurons forms a system which classifies the elements of a picture depending on their orientation. Binocular neurons in the cat's visual cortex are another example: different neurons differ in the disparity of the receptive fields on the two retinas, and they can accordingly classify objects with respect to their distance away [9, 10, 17].

However, the qualitative characteristics of elements of the visual centers (their selectivity toward particular properties of the stimulus) differ in animals of different species. To detect the most common principles in the work of the sensory systems of the brain it is interesting to determine what features serve as the basis for identification and classification of stimuli by the visual system of different animals. This paper examines the possibility of stimulus classification based on size by visual cortical neurons of the rabbit, in which the organization of the receptive fields differs from that in the cat [2, 4, 11, 19].

Earlier observations [1, 3] confirmed that cortical unit responses in rabbits are dependent on the size of stationary photic stimuli. This problem is investigated specially below with respect to more adequate stimulation by moving objects.

METHOD

Experiments were carried out on unanesthetized curarized rabbits. The animals were scalp ed and trephined under local procaine anesthesia. The animals were fixed in a frame so that the greater part of the visual field remained open. The body temperature was kept at 36-37°C. The cornea was smeared with silicone oil to prevent it from drying.
The visual stimuli were rectangles of light of variable length and width applied to the screen of a cathode-ray tube. The illuminated rectangles were obtained by scanning with a beam of uniform brightness on a rectangular screen the width and length of which could be altered at will. Because of the high scanning frequency (1 kHz for frame and 100 kHz for line scanning) flashing was prevented. The illuminated rectangle could be moved in any direction at an assigned speed (usually 5-10 deg/sec). The refraction of the eye was corrected by means of a lens placed in front of the animal's eye.

Single unit activity in the visual cortex was recorded extracellularly by capillary microelectrodes. Post-stimulation histograms were constructed during the experiment by means of an analogue storage unit on magnetic tape.

RESULTS

Responses of 48 cortical units were analyzed on the basis of their firing pattern as cortical neurons and not as afferent fibers. Irrespective of the concrete size of the stimulus, its width will hereafter be taken as the measurement perpendicular to the direction of its movement and its length as the measurement in the direction of movement.

Effect of Width of Moving Stimulus on Response of Neurons Selective to Its Direction of Movement. Just as during exposure to stationary photic stimuli, the intensity of the response of many visual cortical neurons depended essentially on the size of the moving stimulus. The most characteristic type of behavior of a neuron was that in which, in response to an increase in stimulus width, its response initially increased and then decreased in intensity, sometimes disappearing completely. An example of the responses of such a neuron to testing with illuminated rectangles from 0.25 to 10° in width (stimuli of all sizes were oriented in the receptive field so that their centers followed the same path through the predetermined center of the receptive field) is shown in Fig. 1. A stimulus of a certain optimal width (about 2° in Fig. 1) thus evoked the most intensive activation of the neuron.

Many neurons showed a qualitatively similar relationship to that described above. However, the sizes of the stimuli corresponding to maximal responses differed considerably for these neurons: from 0.5 (optimal) to 10-12° (maximal). By plotting curves showing the responses of each neuron as a function of stimulus width a set of characteristic curves was obtained for virtually the whole range of stimulus sizes used (Fig. 2a).

Fig. 2. Responses of various visual cortical neurons as a function of stimulus width: a) for neurons selective to stimulus width; b) for unselective neurons. Abscissa, width of stimulus; ordinate, magnitude of response measured from peak of post-stimulus histogram in percent of its magnitude in response to stimulus of optimal size.