THE CONVERGENCE OF SOMATIC AND VISUAL AFFERENTS IN SENSORI-MOTOR CORTEX OF THE CAT

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The problem of convergence of visual and other sensory inputs on the same cortical neuron has been of great interest for many authors (Buser and Borenstein 1959, Buser et al. 1959, Bruner 1960, Buser and Imbert 1961, Dubner and Rutledge 1964, 1965, Dow and Dubner 1969). Such a multimodal convergence may subserve basic functions of a cortical neuron concerning its participation in the higher integrative activity. From this point of view the investigations of somatic and visual input convergence onto the cortical neurons were especially interesting.
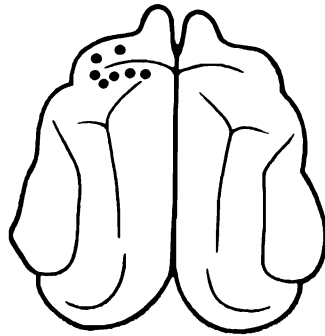

Fig. 1. Points in the pericruciate region of cat's cortex where from recordings were made.

The present paper describes some of our observations on polysensory neurons in sensori-motor cortex of the cat.

Twenty four cortical neurons were investigated in twelve cats. The animals were anesthetized by intravenous injection of Chloralose (60 mg/kg). A trepan hole was made in the anterior part of the skull

and the region of sulcus cruciatus was exposed. After the removal of the dura the hole was filled with soft agar. During the recording procedure Flaxedil (20 mg/hr) was given as a muscle relaxant. The pupils were dilated by instilling the cornea with 0.1% Atropine sulfate.

Single unit activity, as well as evoked cortical potentials were recorded by Tungsten microelectrodes covered by varnish with a bare tip diameter of $3-5\mu$. Recordings were made preferentially from the postcruciate gyrus (Fig. 1). Responses were amplified with an amplifier time constant 50 msec for evoked responses and 5 msec for spikes, and displayed on a Tektronix 502 oscilloscope, from which pictures were taken with a Grass kymograph camera. In some experiments the electrophysiological data were analysed by means of the ANOPS-1 average response analyser (Jankowski 1967).

Stimulating needle electrodes were inserted into fore- and hindpaws, and single electric shocks of 3–5 v, and 0.5 msec duration were applied with 0.5/sec frequency. Visual stimuli were 400 msec flashes delivered every 1/sec and diffusely illuminating a white concave screen in front of the animal's eyes and a light spot of 5° with the intensity of illumination 4.2 cd/m², moving on the same screen.
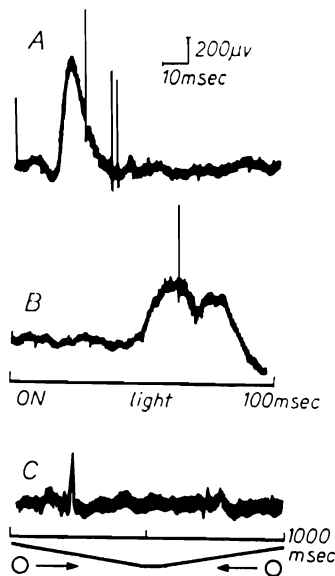

Fig. 2. Single unit spike discharges and evoked responses to somatic and visual stimulation recorded from same site. A: primary evoked potential and single unit spike responses to the stimulation of the contralateral hindpaw (0.5/sec, 0.5 msec duration of 3–5 v shocks). B: responses recorded from the same site to flashes of diffuse light with 1/sec frequency. C: evoked potentials (single) recorded from the same point to the horizontal movement of a 5° light spot (intensity of illumination 4.2 cd/m²).

Primary cortical responses to hindlimb and forelimb stimulation were recorded. The latency of responses to hindlimb stimulation was nearly 14–16 msec and for forelimb 12–14 msec. Visually evoked responses were recorded from the same cortical point. The latencies of visually evoked potentials were always much longer in comparison with somatic primary responses and ranged between 40–60 msec. Although the number of investigated units is too small to make possible a generalization of these measurements, the fact is that no shorter latencies were observed. The
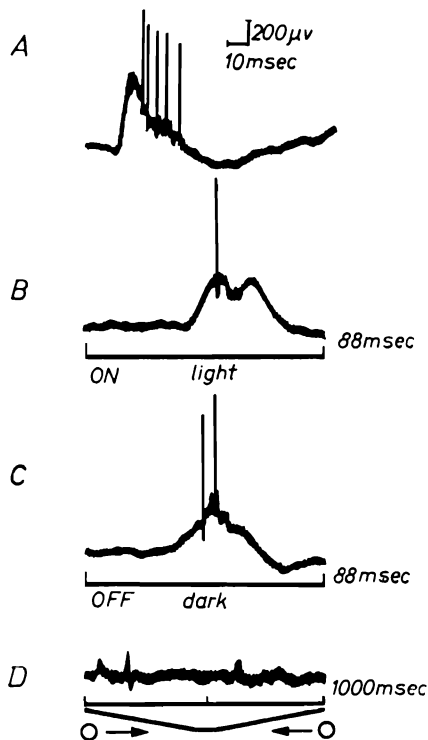

Fig. 3. Responses of a cortical neuron to somatic and visual stimulation (not averaged). A: Primary evoked response and unit discharges to the stimulation of the contralateral forepaw. B, C: spike responses of the same cell to flashing light: B, to light "on", C, to light "off". D: evoked potentials recorded from the same point to the movement of 5° light spot.

duration of the positive phase of the visually evoked responses was always longer (nearly 30 msec), that of somatic responses which had 15–20 msec duration. Visual responses had usually a smaller amplitude than the somatic ones (Fig. 2). Thus, the primary responses to somatic stimulation seem to be more synchronous then the visual responses.

It was interesting to observe the presence of quite distinguishable

evoked potentials to moving visual stimuli recorded from the same site where two former responses were obtained (Fig. 2, 3 and 4). This fact suggests the existence of many movement-sensitive cells in the recording point. Such cells situated in the vicinity of the pyramidal neurons, may have very important functions related to the visually guided behavior of the animal.

The first problem, which we wanted to solve in this case was whether the same neuron pools are involved in the responses from different mo-
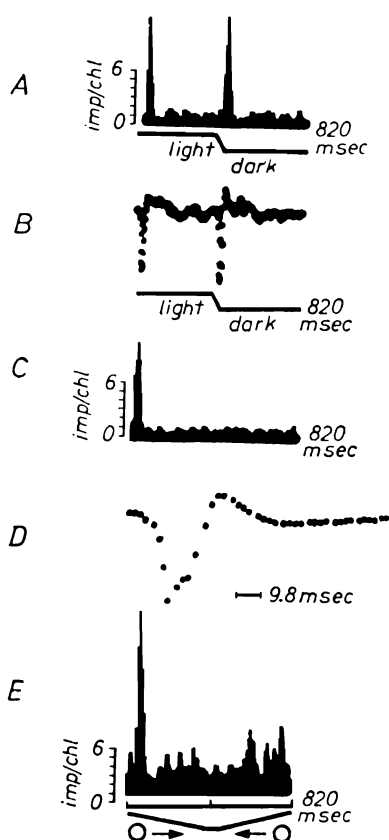

Fig. 4. Visual and somatic averaged evoked potentials, as well as unitary responses from the postcruciate gyrus of the cat cortex. A: PST histogram of a neuron which responds to flashing light by "on–off" discharges (32 repetitions of stimuli). B: averaged evoked responses to the flash. The "on–off" reaction are clearly seen (64 repetitions of stimuli). C: PST histogram of the same cell as in A to the electric stimulation of contralateral forepaw (30 repetitions of stimuli). D: averaged evoked potential to the contralateral forepaw stimulation (48 repetitions of stimuli). E: PST histogram of the same neuron as in A and C to the movement of a 5° light spot. A direction-sensitive type of response is clearly seen. imp/chl, impulses per channel. Bin width = 1.6 msec,

dality stimulations, or whether each modality had its own groups of neurons. For this purpose single unit recordings were made. In the course of the electrode track through the motorsensory cortex one could find many neurons which responded easily to limb stimulation. The neurons, which respond to visual stimulation constituted nearly a half of the neurons in the track. We chose only 24 neurons, which were clearly bimodal and had clear-cut responses to somatic as well as to visual stimuli.

The majority of cells responded intensely to somatic stimulation and, as a rule weakly to visual stimulation (Fig. 2AB). Some cells responded only to the onset of the flash (Fig. 2B), whereas others displayed "on–off" discharges (Fig. 3BC). Only a few cells reacted to the movement of a 5° light-spot. A post-stimulus time histogram of such a neuron is represented in Fig. 4E. This unit responded "on–off" to the flashing light (Fig. 4A), and also to the contralateral hindlimb stimulation (Fig. 4C). The evoked potentials (averaged) to flash and hindlimb stimulation (Fig. 4BD) were well defined, which indicates that there were many cells of the same type near the tip of the recording electrode. One of the most interesting features of these bimodal neurons was their ability to respond in a direction-sensitive way to a moving stimulus. Figure 4E demonstrates the response of a neuron to the movement of a light spot in the horizontal
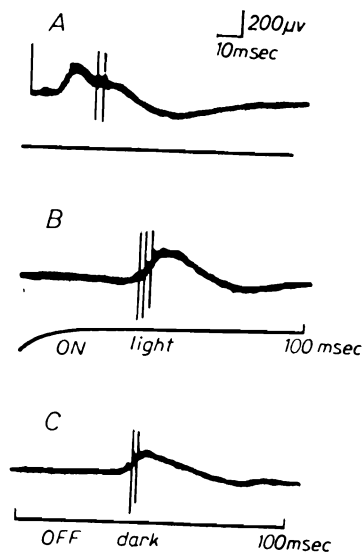

Fig. 5. Single evoked potentials and unit spike discharges to the contralateral fore-paw stimulation (A) and flashes of diffuse light (B and C). Note the localization of spike discharges in the course of the decaying slope of somatic response wave and during the rising phase of visual responses.

plane. It can be seen that responses to movements in different directions were clearly different.

In general majority of neurons generated spikes in the course of the decaying slope of the somatic evoked potential wave (the time constant of the preamplifier was 50 msec). Only cell out of 24 discharged spikes during the rising phase of the somatic evoked potential wave. Neurons which discharged spikes in the course of the decaying slope of somatic evoked potentials, always had discharges in the course of the rising phase of visually evoked responses (Fig. 5). So the latency of responses of such a bimodal neuron to somatic stimulation was always longer, than the latency of summated evoked potential, whereas in the case of visual stimulation they were more or less the same for the neuron response as for the summated evoked potential. This fact suggested the possibility of different types of convergence of somatic and visual afferents onto the cortical neurons. Summing up one can conclude that the pericruciate cortical area in cat, especially its posterior part, seems to play an important part in the final processing of information in visually guided behavior.

REFERENCES

BRUNER, J. 1960. Résponses visuelles et acoustiques au niveau de la face médiane antérieure du cortex chez le Chat sous chloralose. J. Physiol. (Paris) 52: 36.

BUSER, P. and BORENSTEIN, P. 1959. Résponses somesthétiques, visuelles et auditifs recueillies au niveau du cortex "associatif" suprasylvien chez le chat curarisé non anesthésé. Electroenceph. Clin. Neurophysiol. 11: 285–304.

BUSER, P., BORENSTEIN, P. and BRUNER, J. 1959. Ètude des systémes "associatifs" visuels et auditifs chez le chat anesthésié au chloralose. Electroenceph. Clin. Neurophysiol. 11: 305–324.

BUSER, P. and IMBERT, M. 1961. Sensory projection to the motor cortex in cats: a microelectrode study. In W. A. Rosenblith (ed.), Sensory communication. Technology-Press and Wiley, Cambridge, p. 607–626.

DOW, B. M. and DUBNER, R. 1969. Visual receptive fields and responses to movement in an association area of cat cerebral cortex. J. Neurophysiol. 32: 773–784.

DUBNER, R. and RUTLEDGE, L. T. 1964. Recording and analysis of converging input upon neurons in cat association cortex. J. Neurophysiol. 27: 620–634.

DUBNER, R. and RUTLEDGE, L. T. 1965. Intracellular recording of the convergence of input upon neurons in cat association cortex. Exp. Neurol. 12: 349–369.

JANKOWSKI, T. 1967. ANOPS, organization and construction (in Polish). Przegl. Telekom. 5: 141–144.