The Effect of Volatile Anesthetics on Giant Neurons in the Lobula Plate in the Fly

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Movement sensitive giant neurons in the lobula plate of the fly (H_1-neurons, V-neurons) are affected by low concentrations of volatile anesthetics (halothane, N_2O): the spike frequency generated by motion in the preferred direction decreases, that in the opposite direction increases. This means that the response to the motion stimulus defined as the spike frequency modulation decreases. Higher concentrations of the anesthetics lead to an increasing spike frequency which is unaffected by the motion stimulus, until eventually no spikes are generated any longer. The results are in agreement with the assumption that the anesthetics increase the membrane permeability of these neurons.

It is generally assumed that volatile anesthetics produce their clinically useful effects within the central nervous system (CNS) by depressing transmission at synapses [1, 2]. A comparative study in insects has shown, however, that the most sensitive site in the CNS of these animals can neither be at synapses nor in the spike conducting axons. In agreement with the experimental results is the assumption that the transmission of graded signals in long dendrites and/or axonal arborisations of large neurons is the most sensitive. This was concluded first from experiments in which the all over motor activity in animals, different very clearly in size, was investigated [3]. It was confirmed by experiments in *Calliphora*, in which the hierarchy of failure of neuronal pathways of a known structure was investigated [4]. According to this view the type of giant neurons which has been found in the lobula plate of the fly [5] should be especially sensitive to volatile anesthetics. In order to confirm this interpretation directly we measured the activity of the so called H_1-neurons and V-neurons during the application of halothane and nitrous oxide.

Recordings of extracellular spikes were similar to those described previously [6, 7]: The animals were fixed with wax at the end of a plastic tube (diameter 1 cm), the head protuding and bent forward. The electrode was inserted into the lobula plate by a hole in the back of the headcapsule. The anesthetic vapors were applied from the back of the plastic tube, bypassed the animal and were sucked off by a ventilator driven tube (diameter 8 cm). This tube was fixed in such a position as not to prevent vision of stripepatterns arranged in front of the right and left eye, respectively. The neurons were specified according to the type of response and the position of the recording electrode [5].

The response of the H_1-neuron to moving stripe patterns can be affected and reduced by rather low concentrations of the anesthetics. 0.2–0.5 vol.% of halothane are sufficient to significantly reduce the modulation of the spikefrequency due to the motion stimulus: the spike frequency due to movement of the pattern in the preferred direction is reduced, and the one with the motion to the opposite direction is increased. The spontaneous activity which can be measured if the pattern is stationary, or if the animal is in the dark, is increased by the application of the anesthetic (Fig.). If the concentration of the anesthetic is further increased, the spontaneous activity of the neuron increases, the modulation of the spike frequency due to the motion stimulus is more and more reduced because the cell generates spikes of high frequency irrespective of the motion of the pattern, until eventually spikes are no longer generated and the cell becomes silent. Neurons sensitive to motion in the vertical directions (V-neurons) show a similar dependence from the anesthetics, several of those neurons have been more sensitive, however: whereas in the H_1-neurons in most cases 0.5 vol.% of halothane are needed to depress the modulation of the spike frequency, in these V-neurons 0.2 vol.% halothane or 80 vol.% N_2O have been sufficient. In some cases the first effect of low concentrations of halothane (0.2 vol.%) and that of 80 vol.% N_2O has been different from the scheme described above: the spike rate induced during the movement of the pattern in the preferred direction was reduced to zero, and also no spikes occurred during motion of the pattern in the opposite direction. If the halothane concentration was increased to 0.3 to 0.5 vol.% the cell started firing again, and behaved as described above and shown in the figure.

We have shown that halothane in photoreceptors leads to a depolarisation by 10–20 mV, combined with a significant increase of the membrane perme-

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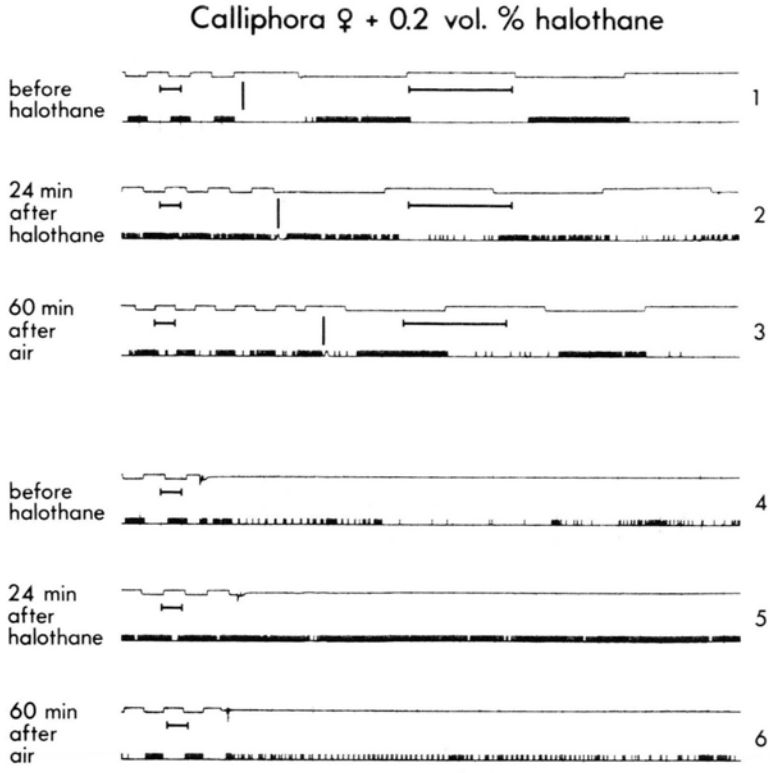

Activity of a H_1-neuron of *Calliphora* before and during application of 0.2 vol.% halothane and as a control after application of pure air. The upper track in each pair no. 1 to 6 shows the monitor of the movement of a stripe pattern (spatial wavelength 12°, extension of the moving pattern $70 \times 70°$, temporal frequency 1.7 s^{-1}, mean luminance 500 cd/m^2, line in the upper position: movement of the stripes from front to back), the lower track shows unit impulses, triggered by the spikes from the neuron. Records 1–3 show activity of the neuron to movement of the stripe pattern on two different time scales (calibration bar 1 s). Records 4–6 show from the same neuron first activity to moving stripes followed by the activity if the movement was stopped.

ability probably primarily to ions with a negative equilibrium potential [8]. If halothane has similar effects in the giant neurons of the lobula plate it would produce the effects we can see in the experiments: the depolarisation should lead to an increase of the spontaneous spike frequency. In addition the increased membrane permeability should reduce the signals integrated *via* the dendrites at the pacemaker of the neuron, either by reducing the length constant of the dendrites and/or by stabilising the membrane potential at negative values. Other interpretations which take a modification of the interaction between different neurons into account are also possible. The results confirm the conclusion drawn from other types of experiments [3, 4] that the giant neurons in the lobula plate should represent a type of neuron in the CNS especially sensitive to anesthetic action.

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[1] M. G. Larrabee and J. M. Posternak, J. Neurophysiol. **15,** 91 (1952).
[2] C. D. Richards, J. Physiol. **233,** 439 (1973).
[3] K. Kirschfeld and V. Baier-Rogowski, Biol. Cybern., in press (1986a).
[4] K. Kirschfeld and V. Baier-Rogowski, Biol. Cybern., in press (1986b).
[5] Review: K. Hausen, in: Photoreception and Vision in Invertebrates (M. A. Ali, ed.), NATO ASI Series, Series A: Life Sciences, **Vol. 74,** pp. 523–559, Plenum Press, New York, London 1984.
[6] K. Hausen, Biol. Cybern. **45,** 143–156 (1982).
[7] R. R. de Ruyter van Steveninck, W. H. Zaagman and H. A. K. Mastebroek, Biol. Cybern. **54,** 223–236 (1986).
[8] K. Kirschfeld, Naturwissenschaften, in press (1986).