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Neurotransmitter and receptor in pigeon retinotectal transmission

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THE retina in birds projects to the contralateral tectum. Our previous study[1] and some other physiological, histochemical and neurochemical evidence[2, 3] have suggested that the retinotectal projection in birds might use glutamate as an excitatory transmitter. However, very little is known about its particular receptor type(s), because there are at least three major pharmacologically defined types of glutamate receptors: NMDA, AMPA/Kainate, and metabotropic glutamate receptors[4].

Many studies have shown that NMDA receptors and AMPA receptors are often colocalized on the same neurons, and thus these glutamatergic synapses work on a dual receptor system[5]. Furthermore, a neuron may receive two different synaptic inputs mediated separately by NMDA receptors and AMPA receptors[6]. Recently, we have indicated that a large part of the nucleus isthmi pars magnocellularis (Imc)-tectal fibers are glutamatergic, and mediated by NMDA receptors[7]. This study will show that retinotectal projection is also glutamatergic, but mediated by AMPA receptors.

1 Materials and method

The experiments were performed on 18 adult pigeons (Columba livia), weighing 280—400 g. The birds were anesthetized with urethane (20%, 1 mL/100 g b.w.) and fixed in a stereotaxic apparatus. The left optic tectum was exposed and the dura opened. In the experiments with electrical stimulation, eyelid, cornea, lens and vitreous humour of the contralateral eye were removed; otherwise, the eye was kept intact. In the former cases, a bipolar tungsten electrode was placed on the optic nerve. Rectangular pulses of 0.1—1.5 mA intensity and 50—300 μs duration were delivered to the optic nerve. In the latter cases, visual stimulus was a 5° black disc, which was moved at 20—40°/s. Extracellular recordings of action potentials were obtained from tectal neurons with the 2 mol/L NaCl-filled barrel (5—15 MΩ) of a five-barrelled micropipette (4 μm diameter). The other channels contained the following compounds to be ejected microiontophoretically with appropriate currents: L-glutamate (0.5 mol/L, pH 7.5), N-methyl-D-aspartate (NMDA, 50 mmol/L, pH 8.0), α-amino-3-hydroxy-5-methyl-4-isoxazole-propionate (AMPA, 10 mmol/L, pH 8.3), 3-rs-2-carboxy-piperazine-4-yl-propyl-1-phosphonate (CPP, 10 mmol/L, pH 7.8), or 6-cyano-7-nitro-quinoxaline-2, 3-dione (CNQX, 10 mmol/L, pH 8.3). The majority of neurons were sampled at a radial distance between 400 and 1 400 μm from the tectal surface, which corresponds to tectal layers Ⅱd-Ⅲ.

2 Results

A total of 57 tectal cells were examined. Among them 12 cells were tested for NMDA and AMPA, two glutamate agonists (fig. 1). All these tested cells were excited by iontophoretically applied AMPA (4—30 nA). The responses started rapidly (less than 4 s), and lasted for 1—4 s after stopping AMPA application. These 12 cells were also excited by NMDA. However, the responses had longer latency (5—20 s) and lasted for 10—20 s after stopping NMDA application. It is suggested that both AMPA receptors and NMDA receptors are colocalized on tectal cells recorded.

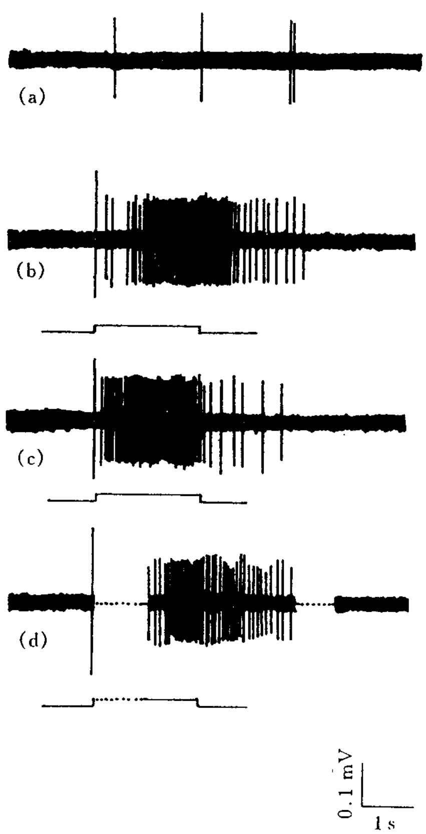

Fig. 1. Responses of a tectal cell to microiontophoretically applied glutamate ((b), 20 nA) and its agonists AMPA ((c), 20 nA) and NMDA ((d), 20 nA). (a), control. Interrupted baseline in (d) represents 10 s. Scales: 0.1 mV, 1 s.

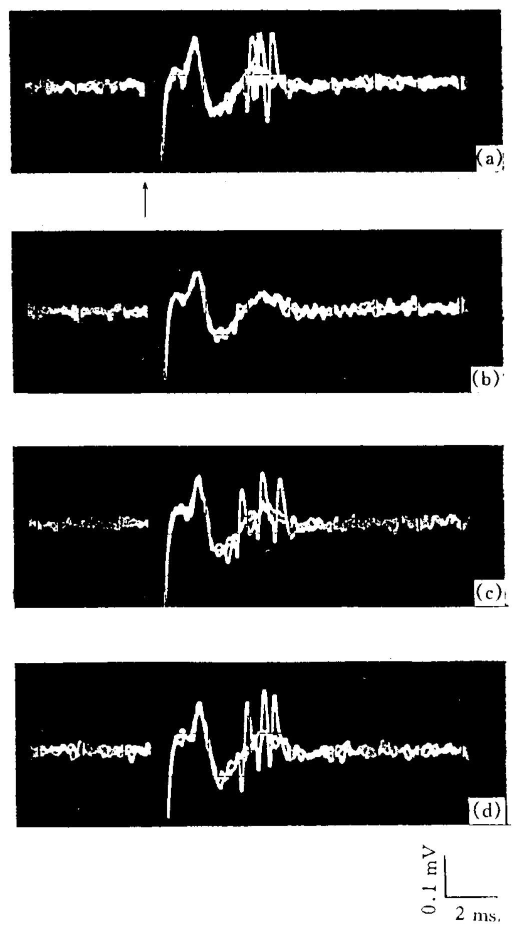

Fig. 2. Responses of a tectal cell to electrical stimulation of the optic nerve (a) and effects of glutamate antagonists (CNQX ((b), 40 nA) and CPP ((d), 200 nA) on the evoked potentials. (c), recovery 1 min after CNQX. Note that action potentials rode on the field potentials. Three superimposed sweeps. Arrow points to electrical stimulation artifact. Scales: 0.1 mV, 2 ms.

Other 34 tectal cells responding to electrical stimulation of the contralateral optic nerve were recorded and examined for CNQX (AMPA antagonist) and CPP (NMDA antagonist) (fig. 2). Following single pulse electrical stimulation the average latency to the first spike was 7 ms. The induced responses in all 34 cells were either abolished or significantly reduced by iontophoretically applied CNQX (40—100 nA). This suppression effect had latency of 30—60 s and lasted for 60—180 s after stopping application. However, CPP produced no effects on 33 cells, with exception of 1 cell, which was depressed by CPP.

The remaining 11 tectal cells responding to a visual stimulus moving through their receptive fields were examined for glutamate, CNQX and CPP. Ten of 11 visual cells were also excited by glutamate (10—20 nA). Their visual responses were blocked by CNQX (40—150 nA), but not by CPP (100—200 nA). Antagonist suppression had longer latency (40 s—3 min), and recovered in 2—4 min after stopping CNQX ejection. Another cell was excited by the moving target, but not sensitive to glutamate. Therefore, its visual responses were not affected by either of CNQX and CPP.

Taken together, electrical and visual stimulation experiments indicate that retinotectal fibers in pigeons release glutamate as a transmitter, which plays its role through AMPA receptors on postsynaptic tectal cells.

3 Discussion

Retinotectal transmission is an important step towards central visual information processing. This paper confirms the previous result that the optic nerve in pigeons may use glutamate as transmitter[1]. The more important finding here is that this excitatory amino acid is a fast-acting ligand to AMPA receptors or non-NMDA receptors on tectal cells postsynaptic to optic fibers in pigeons. Similarly, the amphibian retinotectal transmission might also be mediated by glutamate and non-NMDA receptors[8].

Many studies have shown that NMDA receptors and non-NMDA receptors are often colocalized on the same neurons. The synaptically released glutamate can cause activation of both NMDA and non-NMDA receptors, resulting in a dual synaptic response[5]. It is interesting to note that neurons of the zebra finch song control nucleus, the robust nucleus of the archistriatum, receive two separate inputs from the lateral magnocellular nucleus of the anterior neostriatum and the caudal nucleus of the ventral hyperstriatum, with the first inputs being mediated mostly by NMDA receptors and the second by non-NMDA receptors[6]. Recently, we have found that a part of Imc-tectal fibers use glutamate and NMDA receptors to activate their postsynaptic tectal cells[7]. Therefore, there may be a possibility that tectal cells in birds receive retinal excitation via non-NMDA receptors and isthmic excitation via NMDA receptors. Cooperative interaction of the two glutamate receptor subtypes may occur on tectal cells. This suggestion needs to be further studied.

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