An intracellular study of pretectal influence on the optic tectum of the frog, *Rana catesbeiana*

Hong-Jian KANG^{1,2}, Xiao-Hong LI^{1,3}

¹Kyushu Institute of Technology, Graduate School of Life Science and Systems Engineering, Department of Brain Science and Engineering, Fukuoka 808-0196, Japan

²Department of Neurosurgery, ³Department of Ear-Nose-Throat, the First Hospital of Zibo, Zibo 255200, China

Abstract: Objective A few investigations have been reported about pretectal suppressive influences on the optic tectum of frog, but characteristics of tectal activity to pretectal input are left unknown. We made intracellular recordings to demonstrate the unexpected complexity in synaptic mechanisms involved in the suppressive influences of pretectal stimulation on the tectal cells. **Methods** In the present study, we investigated the neuronal activity evoked by pretectal (Lpd/P) nuclei stimulation using intracellular recording technique. **Results** The pretectal stimulation mainly elicited two types of responses in the ipsilateral tectum: an excitatory postsynaptic potential (EPSP) followed by an inhibitory postsynaptic potential (IPSP) and a pure IPSP. The latter predominated in the tectal cells responding to pretectal stimulation. In a few cells, biphasic hyperpolarization appeared under stronger stimulus intensities. The spikes of tecto-pretectal projecting cells elicited by antidromical stimulation were recorded in the ipsilateral tectum, which revealed reciprocal connections between the tectum and particular pretectal nuclei. The synaptic natures underlying pretecto-tectal information transformation have also been demonstrated. EPSPs with short latencies were concluded to be monosynaptic. Most IPSPs were generated through polysynaptic paths, but monosynaptic IPSPs were also recorded in the tectum. Nearly 98% of impaled tectal cells (except for antidromically projecting cells) showed inhibitory responses to pretectal stimulation. **Conclusion** The results provide strong evidence that pretectal cells broadly inhibit tectal neurons as that has suggested by behavioral and extracellular recording studies.

Keywords: electric stimulation; optic tectum; *Rana catesbeiana*

1 Introduction

In anurans the optic tectum provides the main interface between afferent retinal messages and efferent motor commands^[1-6]. It not only receives retinal signals via direct projections through the optic nerve but also receives them indirectly through various visual pathways, for example, posterior thalamus nucleus, nucleus lentiformis mesencephali (NLM), posterodorsal and posteroventral tegmental nuclei, dorsal horn of the cervical spinal cord, nucleus isthmi and contralateral tectum^[7-11]. Among these non-optic afferents to the tectum, the thalamic pretectal

nucleus is assumed to be the source of tectal inhibition which influences the control of retinotectal excitatory processes^[12]. Earlier brain lesion studies^[13-15] provide evidence for such pretectotectal inhibitory influence. Lesions to the caudal dorsal thalamic pretectal region (Lpd/P) in toads lead to hyperactive prey-catching in response to any moving visual stimulus including very large objects that are normally avoided. This “TP-lesion-syndrome” was also observed in fire salamanders^[16]. Therefore, Ewert suggested that neurons in the anuran caudal thalamus normally exert an inhibitory influence on the optic tectum, which preserves realistic behavior toward visual objects, and indicated that the discrimination of moving visual objects for prey recognition depends on inhibitory connections from pretectum to optic tectum, with both structures obtaining retinal inputs^[1].

Previous single cell recording and field potential studies carried out in the anuran optic tectum and pretectum^[12,17-19]

Corresponding author: Hong-Jian KANG
Tel: 86-533-4252035
Fax: 86-533-4253326
E-mail: hongjian01@hotmail.com
Article ID: 1673-7067(2007)02-0113-06
CLC number: Q424
Document code: A
Received date: 2007-01-19

revealed some physiological properties of pretectotectal information transfer. However, all these electrophysiological studies were performed using extracellular recording techniques. Until now no available evidence existed about the synaptic mechanisms involved in such suppressive effect on the tectal cells or about the intervening neuronal circuits. Therefore we made intracellular recordings from the tectal cells following electric stimulation applied to the pretectal nuclei (Lpd/P), and demonstrated the unexpected complexity in synaptic mechanisms involved in the suppressive influences of pretectal stimulation on the tectal cells.

2 Materials and methods

2.1 Animals Adult bullfrogs, *Rana catesbeiana*, of either sex, measuring 11–13 cm in length and 100–300 g body weight (b.w.) were obtained commercially and kept in laboratory tanks until use. The animals were fed on chicken liver twice a week. Before an experiment, in order to avoid possible stimulation of retinotectal fibers, the right optic nerve was ablated via the mouth, under the conventional anesthesia as described below. Experiments were carried out 10–14 d after surgery.

2.2 Preparations Experimental animals were anesthetized by subdermal injection of tricaine methanesulfonate (MS222, Sigma; 0.02 mg/g b.w.), immobilized by injection of succinylcholine (Succin, Yamanouchi; 0.02 mg/g b.w.), and then placed on a metal frame. After infiltration of the local anesthetic (Xylocaine, Fujisawa, Japan) the skin of the operative area on the bullfrog head was cut, the skull was opened, and the left optic tectum and ipsilateral diencephalon were exposed by careful removal of bone with a dental drill and by retracting the dura mater and the arachnoidea with fine forceps and scissors. The skin was kept moist with a thin wet gauze to facilitate cutaneous respiration. All experiments were carried out at room temperature (18–22 °C).

2.3 Stimulation For electric stimulation of pretectal nuclei, small bipolar tungsten stimulus electrodes were inserted into the left pretectal lateral posterodorsal (Lpd) and posterior (P) thalamic nucleus (Lpd/P region). The electrode tips were electrolytically sharpened, and were separated by 0.15–0.2 mm. For Lpd/P stimulation, both electrodes were aligned parallel to the sagittal brain axis, and the rectangular pulses of 100 μ s duration were delivered. After the intracellular recordings were made, DC current of 20 μ A was passed for 20–30 s through the stimulating electrode in

order to verify its position. The brain was removed and fixed in a mixture of 3% formaldehyde and 3% glutaraldehyde, and then immersed in 30% sucrose in phosphate buffer solution overnight. Frozen sections were cut at 60 μ m, mounted, stained with 0.27% cresyl violet, and finally dehydrated. Histological sections containing the stimulation sites were photographed with a microscope (Olympus BX50). The stimulating sites were determined by reconstruction based on the photomicrographs of serial sections.

2.4 Recording Intracellular recording micropipettes were filled with 2 mol/L potassium citrate solution. Before use, the tips of the electrodes were broken by lightly touching against the edge of a slide glass with a micromanipulator under a microscopic control. The tip diameter ranged from 0.5 μ m to 1.2 μ m and the resistance after breaking was between 20 M Ω and 40 M Ω .

The microelectrode was connected through a thin silver-silver chloride wire to a preamplifier (MEZ-7200, Nihonkoden), whose output was displayed on the screen of an oscilloscope (CS-4025, Kenwood) through a main amplifier (DPA-200, Dia Medical System) and stored on the magnetic tape of a data recorder (PC-108M, Sony). Recording depths were taken from readings of the micromanipulator (PC-5N, Narishige).

3 Results

A total of sixty-three tectal neurons were intracellularly recorded in response to electric stimulation of ipsilateral Lpd/P nuclei. The membrane potentials of the impaled neurons ranged from –30 mV to –66 mV. Of the 63 cells, 51 cells exhibited postsynaptic potentials and 12 cells showed exclusive action potentials.

Electrolytic lesions confirmed that the stimulating electrodes were localized in the pretectal (Lpd/P) region (Fig. 1).

3.1 Response patterns of tectal cells to electric stimulation of the pretectal Lpd/P region The pretectal stimulation evoked two main response patterns in the optic tectum (Fig. 2). One group (11 cells) was defined as EI type (Fig. 2A). It consisted of an excitatory postsynaptic potential (EPSP) followed by a longer-lasting inhibitory postsynaptic potential (IPSP), presumably due to two inputs mediated by different conduction velocities or by different circuits. In most of EI type responses, the initial EPSP was relatively small in amplitude and was rapidly overcome by the large, prolonged IPSP, which made the depolarizing phase very short and kept the membrane potential under

Fig. 1 Localization of the stimulating electrode tips was marked by electrolytic lesions within the thalamic pretectal nuclei (Lpd/P). Left: Histological transverse section through the caudal diencephalons region. Two lesions within the Lpd/P nuclei are shown by arrows. Right: Schematic reconstruction of localization of electric stimulation (see squares: centers of lesion). OT, optic tectum; Lpd, lateral postero-dorsal thalamic pretectal nucleus; P, lateral portion of the posterior thalamic pretectal nucleus. Scale bar, 500 μ m.

threshold. In some cases an increase in stimulus intensity caused the EPSP to increase until it generated an action potential. In one cell, two temporally separated EPSPs (EE type) were observed. The second EPSP gradually increased with increasing stimulus intensity until a spike was triggered (Fig. 2B).

The second tectal cell response pattern (34 cells) was characterized by a long-lasting (ca. 80 ms) IPSP (I type; Fig. 2C). In five cells, when the stimulus intensity was raised, this IPSP became shortened and was followed by another a similar IPSP. This response type was called as II type (Fig. 2D).

Other than two main response types of excitatory or inhibitory synaptic potentials, twelve cells responded only with action potentials without any graded response were also recorded in the optic tectum (Fig. 2E).

3.2 Latency of postsynaptic responses The latency of the initial EPSP or IPSP was determined at the diverging point between the intracellular and extracellular traces. Figure 3 gives the distribution of the latencies of both the EPSPs and IPSPs recorded in the optic tectum. The EPSP (EI, EE) latency had a unimodal distribution ranging from 1.3 ms to

Fig. 2 Intracellular recordings of responses elicited by pretectal (Lpd/P) stimulation. Superimposed traces from 5 different tectal cells. A: a neuron showing an EPSP followed by a longer-lasting IPSP (EI type); B: response with two temporally separated EPSPs and spikes (EE type); C: a neuron responding with a pure IPSP (I type); D: a neuron showing an initial IPSP followed by a subsequent IPSP with the electric stimulation raised (II type); E: an example of antidromic spike from an association tectal efferent cell. Lower traces under each postsynaptic potential indicate field potentials recorded immediately after loss of the cell. The arrow in A indicates the onset of the electric stimulation. Time scale applies to all records. Voltage scale of 5 mV is for A–D and that of 20 mV for E.

3.8 ms (Fig. 3 top). The latencies of the IPSPs, ranging from 1.5 ms to 9.3 ms, showed a bimodal distribution with one peak between 1.5 ms and 3.3 ms, and the other between 4.2 ms and 9.3 ms (Fig. 3 bottom), respectively. It is of particular interest to note that the IPSP–IPSP sequence (II type) was found to be in the shorter latency group, presumably receiving a direct independent inhibitory input from the ipsilateral pretectal cells.

3.3 Antidromic spike responses Figure 4 illustrates the latency distribution of 12 cells in the optic tectum which showed only spikes of 50–70 mV in amplitude. The latencies are distributed between 0.6 and 1.9 ms [mean $\pm$ SD, (0.9 $\pm$ 0.29) ms]. Considering the synaptic delay time of about 1.0 ms^[20], we conclude that these responses were antidromically elicited spikes (Fig. 2E).

Fig. 3 Latency histograms of postsynaptic potentials in tectal cells in response to electric stimulation of ipsilateral Lpd/P regions. Upward histograms show EPSP latencies and downward histograms show IPSP latencies. Light histogram: latency of EPSP-IPSP sequence (EI type). Dark histogram: IPSP (I type) latency. Vertical hatched histogram: EPSP-EPSP (EE type) latency. Horizontal hatched histogram: IPSP-IPSP (II type) latency.

Fig. 4 Frequency histograms of the synaptic delay time obtained from spikes of tecto-pretectal projecting cells elicited by antidromical stimulation in the ipsilateral tectum.

4 Discussion

The present study demonstrates the physiological evidence for synaptic connection between the pretectal thalamus and the optic tectum in frogs. It provides helpful cues to formulate the neuronal circuitry in the two important brain structures related to visual information processing. In our results nearly 98% of intracellularly impaled tectal cells, except for the antidromically innervated cells, received inhibitory inputs from the pretectal nuclei. Thus, the present investigation gives confirmation to previous observation^[1], indicating that the pretectal thalamus

elicits inhibitory effects on the tectal neurons of frogs. More importantly, the present results demonstrate that the postsynaptic nature of the inhibitory events in the tectal cells is directly or indirectly driven by the pretectal afferents.

4.1 Pretecto-tectal information transfer The electric stimulation of pretectal nuclei (Lpd/P) mainly evoked two types of responses in the ipsilateral tectum, an EPSP-IPSP sequence and a pure IPSP. It is notable that the duration and the amplitude of IPSPs in the EPSP-IPSP sequence are much bigger than those of EPSPs in many of the recorded cells, and EPSPs are interrupted by an IPSP shortly after their onset. In interpreting the EPSP-IPSP sequences (Fig. 2A), we have considered at least two possibilities involved in the neural information processing. One possibility is that the pretectal stimulation activated two different types of nerve fibers, excitatory and inhibitory. The two inputs arrive directly at the target cell of the optic tectum at different conduction velocities where a combination of excitatory and inhibitory inputs occurs. Another possibility is that the tectal cells receive primarily an excitatory input and secondarily an inhibitory input through tectal interneurons.

The pure IPSP with a shorter latency is presumed to be the direct input from ipsilateral pretectal cells. Previous immunocytochemical studies^[21] have revealed that the pretectal Lpd/P nuclei contain neuropeptide Y (NPY)-like immunoreactivity cells whose fibers distribute in the superficial layers of the ipsilateral tectum (except lamina A), where they partially overlap retinal recipient laminae^[22,23]. Because it is known that NPY can reduce the excitatory input, as observed in the rat hippocampus^[24], it is likely that the inhibitory inputs from pretectal cells are attributable to NPY-like immunoreactivity. These neurons may play an inhibitory role in control of visual information flow in the optic tectum of frogs. The retinal excitatory impulses arriving to the tectum are partly arrested by the pretectal inhibitory pulses, which checks unlimited spread of the excitation state as demonstrated by Székely and Lázár^[25]. Therefore, it is progressively clear that the optic nerve and Lpd/P mediated inputs interact in superficial tectal layers.

All of the IPSPs that we observed could be used to explain the disinhibition in the optic tectum caused by mechanical, electrolytical, or axon sparing chemical lesions applied to the pretectal region (Lpd/P)^[1,18]. As described by Székely and Lázár^[25], a focal excitatory state could extend over the whole tectum if it was not for inhibition. The pretectal cell, which is one of the assumed sources of tectal

inhibition, keeps the state of excitation within limited boundaries. In our study, nearly 98% of impaled tectal cells (except for antidromically innervated cells) gave inhibitory responses to pretectal (Lpd/P) stimulation. We conclude that the pretectal cells exert a strong inhibitory effect on the tectum, in agreement with previous behavioral studies^[1].

4.2 Response properties of postsynaptic connections The intracellular recordings allowed insight into the pretectal-tectal synaptic connectivity. Based upon the latency distribution (Fig. 3), and synaptic delay of about 1.0 ms^[20], we infer that the majority of EPSPs are produced monosynaptically through axons of pretecto-tectal projecting cells. The latencies of IPSPs consisted of two distribution groups. Many IPSPs in the short latency group should be monosynaptic, as the range of latencies is similar to that of the short latency EPSPs. Whereas the IPSPs in the long latency group probably represent disynaptic or polysynaptic pathways. The differences in delay time in the monosynaptic responses may result from the axons of pretectal cells having a variety of conduction velocities^[26,27] and/or conduction distance between the sites of stimulation and recording.

The IPSPs in the long latency group probably represent disynaptic or polysynaptic pathways. In addition to intratectal polysynaptic inhibitory circuits, extratectal circuit may be considered. The nucleus isthmi is a possible candidate for an extratectal path. According to previous studies^[28], the nucleus isthmi receives a direct projection from the ipsilateral optic tectum and projects back bilaterally. It gives a strong inhibitory effect on the ipsilateral tectal cells^[29]. Considering the delay time of 4–5 ms from the nucleus isthmi to the ipsilateral tectum^[29] and the monosynaptic delay from the pretectal nucleus to the ipsilateral tectum assumed in the present study, our data seem not to support the hypothesis that nucleus isthmi is involved in the transmission of the ipsilateral induced IPSPs.

4.3 Tecto-pretectal interaction In the present context, we recorded some antidromically innervated tectal cells in the tectum. According to the previous studies on tecto-thalamic projections^[30], we postulate that these cells were tecto-pretectal projecting cells, sending their axons into the ipsilateral pretectal (Lpd/P) regions. They were activated antidromically by the electric stimulation applied to the pretectal Lpd/P region. Neuroanatomical and some physiological characteristics of the tecto-thalamic projection have been

described by others^[1,21,31–33]. Our data provide further physiological proof for the existence of reciprocal connections between the tectum and particular pretectal nuclei as suggested by Székely and Lázár^[25].

References:

- [1] Ewert JP. Tectal mechanisms that underlie prey-catching and avoidance behaviors in toads. In: H. Vanegas (ed.), *Comparative Neurology of the Optic Tectum*. New York: Plenum Press, 1984, 247–416.
- [2] Ewert JP, TW Beneke, Schürg-Pfeiffer E, Schwippert WW, Weerasuriya A. Sensorimotor processes that underlie feeding behavior in tetrapods. In: Bels VL, Chardon M, Vandevallé P (eds.), *Advances in comparative and environmental physiology*. Vol. 18: *Biomechanics of feeding in vertebrates*. New York: Springer-Verlag, 1994, 119–161.
- [3] Heiden an der U, Roth G. Retina and optic tectum in amphibians: a mathematical model and simulation studies. In: Ewert JP, Arbib MA (eds.), *Visuomotor coordination: amphibians, comparisons, models, and robots*. New York: Plenum Press, 1989, 243–267.
- [4] Hughes TE. A light- and electron-microscopic investigation of the optic tectum of the frog, *Rana pipiens*, I: The retinal axons. *Vis Neurosci* 1990, 4: 499–518.
- [5] Hughes TE. A light- and electron-microscopic investigation of the optic tectum of the frog, *Rana pipiens*, II: The neurons that give rise to the crossed tecto-bulbar pathway, *Vis Neurosci* 1990, 4: 519–531.
- [6] Satou M, Ewert JP. The antidromic activation of tectal neurons by electrical stimuli applied to the caudal medulla oblongata in the toad, *Bufo bufo* L. *J Comp Physiol* 1985, 157: 739–748.
- [7] Gruberg ER, Udin SB. Topographic projections between the nucleus isthmi and the tectum of the frog *Rana pipiens*. *J Comp Neurol* 1978, 179: 487–500.
- [8] Lázár G. Organization of the frog visual system. In: Lissak K (ed.), *Recent Developments of Neurobiology in Hungary*. Budapest: Akadémiai Kiado, 1979, 9–50.
- [9] Roth G, Grunwald W, Dicke U. Morphology, axonal projection pattern, and responses to optic nerve stimulation of thalamic neurons in the fire-bellied toad *Bombina orientalis*. *J Comp Neurol* 2003, 461: 91–110.
- [10] Trachtenberg MC, Ingle DJ. Thalamo-tectal projections in the frog. *Brain Res* 1974, 79: 419–430.
- [11] Wilczynski W, Northcutt RG. Afferent to the optic tectum of the leopard frog: an HRP study. *J Comp Neurol* 1977, 173: 219–230.
- [12] Ewert JP. Single unit response of the toad (*Bufo americanus*) caudal thalamus to visual objects. *Z Vergl Physiol* 1971, 74: 81–102.
- [13] Ewert JP. Neural mechanisms of prey-catching and avoidance behavior in the toad (*Bufo bufo* L.). *Brain Behav Evol* 1970,

- 3: 36-56.
- [14] Ingle D. Disinhibition of tectal neurons by pretectal lesions in the frog. *Science* 1973, 180: 422-424.
- [15] Kondrashev SL, Dimentman AM. Role of dorsal thalamus in the organization of visually-mediated behavior in amphibians. In: OY Orlov (ed.), *Mechanisms of vision of animals*. Moscow: Nauka, 1978.
- [16] Finkenstädt T, Ewert JP. Visual pattern discrimination through interactions of neural networks: a combined electrical brain stimulation, brain lesion, and extracellular recording study in *Salamandra salamandra*. *J Comp Physiol* 1983, 153: 99-110.
- [17] Buxbaum-Conradi H, Ewert JP. Pretecto-tectal influences I. What the toad's pretectum tells its tectum: an antidromic stimulation/recording study. *J Comp Physiol* 1995, 176: 169-180.
- [18] Ewert JP, Schurg-Pfeiffer E, Schwippert WW. Influence of pretectal lesions on tectal responses to visual stimulation in anurans: field potential, single neuron and behavior analyses. *Acta Biol Hung* 1996, 47: 89-111.
- [19] Schwippert WW, Beneke TW, Ewert JP. Pretecto-tectal influences II. How retinal and pretectal inputs to the toad's superficial tectum interact: a study of electrically evoked field potentials. *J Comp Physiol (A)* 1995, 176: 181-192.
- [20] Matsumoto N, Bando T. Excitatory synaptic potentials and morphological classification of tectal neurons of the frog. *Brain Res* 1980, 192: 39-48.
- [21] Lázár G, Toth P, Csank G., Kicliter E. Morphology and location of tectal projection neurons in frogs: a study with HRP and cobalt filling. *J Comp Neurol* 1983, 215: 108-120.
- [22] Danger JM, Guy J, Benyamina M, Jegou S, Leboulenger F, Cote J, *et al.* Localization and identification of neuropeptide Y (NPY)-like immunoreactivity in the frog brain. *Peptides* 1985, 6: 1225-1236.
- [23] Lázár G, Maderdrut JL, Trasti SL, Liposits Z, Toth P, Kozicz T, *et al.* Distribution of Proneuropeptide Y-derived peptides in the brain of *Rana esculenta* and *Xenopus laevis*. *J Comp Neurol* 1993, 327: 551-571.
- [24] Colmers WF, Klapstein GJ, Fournier A, St-Pierre S, Treherne KA. Presynaptic inhibition by neuropeptide-Y in rat hippocampal slice *in vitro* is mediated by a Y_2 receptor. *Br J Pharmacol* 1991, 120: 41-44.
- [25] Székely G, Lázár G. Cellular and synaptic architecture of the optic tectum. In: Llinas R, Precht W (eds.), *Frog neurobiology: A Handbook*. New York: Springer-Verlag, 1976, 407-437.
- [26] Grüsser OJ, Grüsser-Cornehls U. Neurophysiology of the anuran visual system. In: Llinas R, Precht W (eds.), *Frog neurobiology*. New York: Springer-Verlag, 1976, 298-385.
- [27] Steinbach JH, Stevens CF. Neuromuscular transmission. In: Llinas R, Precht W (eds.), *Frog neurobiology: A Handbook*. New York: Springer-Verlag, 1976, 33-92.
- [28] Gruberg ER. Nucleus isthmi and optic tectum in frogs. In: Ewert JP, MA Arbib (eds.), *Visuomotor coordination: amphibians, comparisons, models, and robots*. New York: Plenum Press, 1989, 341-356.
- [29] Wang SR, Matsumoto N. Postsynaptic potentials and morphology of tectal cells responding to electrical stimulation of the bullfrog nucleus isthmi. *Vis Neurosci* 1990, 5: 479-488.
- [30] Lázár G. Structure and connections of the frog optic tectum. In: Vanegas H (ed.), *Comparative neurology of the frog optic tectum*. New York: Plenum Press, 1984, 185-210.
- [31] Antal M, Matsumoto N, Székely G. Tectal neurons of the frog: intracellular recording and labeling with cobalt electrodes. *J Comp Neurol* 1986, 246: 238-253.
- [32] Bieger D, Neuman RS. Selective accumulation of hydroxytryptamines by frog's tectal neurons. *Neuroscience* 1984, 12: 1167-1177.
- [33] Brown WT, Ingle D. Receptive field changes produced in frog thalamic units by lesions of the optic tectum. *Brain Res* 1973, 59: 405-409.

青蛙前视盖与视顶盖间神经传导的细胞内电生理研究

康宏建^{1,2}, 李晓红^{1,3}

¹ 日本九州工业大学生命体大学院脑研究中心, 福岡县 808-0196, 日本; ² 淄博市第一医院神经外科, 淄博 255200;

³ 淄博市第一医院耳鼻喉科, 淄博 255200

摘要: 目的 已有许多研究报告了青蛙的前视盖对视顶盖起抑制作用, 但关于此神经活动的特性尚不清楚。本研究探讨了这种复杂的神经活动的机理。方法 用细胞内记录方法, 通过电刺激前视盖的神经细胞核来记录视顶盖细胞的神经活动。结果 前视盖的电刺激在同侧视顶盖主要唤起了两种神经反应: 一种是兴奋性(excitatory postsynaptic potential, EPSP)和抑制性突触后电位(an inhibitory postsynaptic potential, IPSP)同时出现, 另一种是单纯的IPSP, 后者在本记录中占主导地位。另外我们也记录到了某些投射到前视盖的视盖投射细胞的神经电位。它揭示了视顶盖和前视盖之间存在着交叉性的相互作用。短潜时的EPSP可能是通过单突触进行传导的, 而大多数的IPSP是通过多突触方式进行神经信息传递的。几乎98%被记录的视盖细胞对前视盖的刺激显示出了抑制性反应。结论 前视盖的神经细胞对视顶盖的神经活动发挥了强烈的抑制性作用。

关键词: 电刺激; 视顶盖; 牛蛙