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Review Article

Relay Thalamic Nuclei

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Received Date: June 20, 2025 | Accepted Date: July 07, 2025 | Published Date: July 16, 2025

Citation: Bon E.I, Maksimovich N.Ye, Novak A.A, (2025), Relay Thalamic Nuclei, *Clinical Reviews and Case Reports*, *4*(4); **DOI:**10.31579/2835-7957/118

Abstract

During the development of neuronal activity of the thalamic nuclei, attention is drawn to the striking uniformity of the processes occurring in different relay nuclei during afferent stimulation. The main reason for the activation of relay nuclei is the specialization of inputs and high-precision transmission with the addition of an input signal as in non-anesthetized animals. Of particular interest is the fact of the reliability of the synaptic site, not counting the fact that the second-order afferents (lemniscal) are located exclusively on the dendrites of relay thalamocortical neurons, as is the case in n. VP[1] or in n. VL, where the axodendritic connections found between the afferents of the connecting legs and the relay neurons of this nucleus are similar. The afferent wave does not decay in the relay nucleus, which apparently contributes to the development of EPSP (excitatory postsynaptic potential) of the "all or none" type, as well as the appearance of partial or complete peaks already in the dendrites.

Keywords: thalamus; brain; neurons

Introduction

During the development of neuronal activity of the thalamic nuclei, attention is drawn to the striking uniformity of the processes occurring in different relay nuclei during afferent stimulation. The main reason for the activation of relay nuclei is the specialization of inputs and high-precision transmission with the addition of an input signal as in non-anesthetized animals. Of particular interest is the fact of the reliability of the synaptic site, not counting the fact that the second-order afferents (lemniscal) are located exclusively on the dendrites of relay thalamocortical neurons, as is the case in n. VP[1] or in n. VL, where the axodendritic connections found between the afferents of the connecting legs and the relay neurons of this nucleus are similar. The afferent wave does not decay in the relay nucleus, which apparently contributes to the development of EPSP (excitatory postsynaptic potential) of the "all or none" type, as well as the appearance of partial or complete peaks already in the dendrites [1]. In addition, the dendrites of the thalamocortical neurons determine the basic group, which unites 6-8 neurons. Afferents of different pathways (for example, the medial lemniscus in VBc) determine multiple synapses at once in a large number of dendrites of this group of neurons [2]. This principle of organization ensures synchronous activation of the entire group of neurons under the influence of the same afferent hall, which ensures the possibility of accurate signal transmission [1]. And such properties of neurons of relay nuclei as minimal adaptation to intracellular currents and the absence of significant differences in the thresholds of the membranes of the initial segment and soma[2] also ensure the preservation of linear connections with the “input-output” characteristic of the relay nucleus.

1. Sequence Of Processes Occurring In Relay Nuclei During Afferent Stimulation

The focal potential arising in the relay nuclei in response to afferent stimulation has a number of components. The first to appear is a short positive component, followed by a long negative wave with peak potentials. N. VP of the cuneate nucleus responds to stimulation of the median (M) and ulnar (U) nerves. In this case, the response in the cuneate nucleus arose 1 ms earlier than the initial positive wave in the thalamus, which can therefore be interpreted as the initial positive phase of the presynaptic potential created in the thalamus by the discharge of cells of the cuneate nucleus[3]. With a slow sweep, the initial negative wave is followed by a long positive oscillation, which ends with a negative wave with a transition to the next positive one. During intracellular recording in response to afferent stimulation, an EPSP of relatively short duration (up to 20-30 ms) occurs in most neurons of the relay nuclei, at the apex of which, as a rule, one or several peaks appear. Then, following the EPSP, longer IPSPs (inhibitory postsynaptic potential) develop (from tens to hundreds of milliseconds), which are replaced by a second wave of depolarization and sometimes accompanied by peaks. Such a picture of a sequential change of EPSP-IPSP is observed when studying neuronal responses in almost all nuclei of the thalamus [2], although in a number of cases, IPSPs did not develop following the EPSP, or the IPSPs were primary, i.e. without the preceding development of EPSPs.

Several facts were very important for explaining the mechanisms of the described sequence. First, it was established that the EPSP (excitatory postsynaptic potential) and IPSP in response to an afferent wave arise synchronously in a large number of neurons of the relay nucleus of the thalamus. Second, it turned out that the EPSP-IPSP sequence in thalamic neurons in response to afferent stimuli is preserved after extirpation of the projection area of this nucleus in the cerebral cortex [4]. On this basis, it

was concluded that postsynaptic reactions of the EPSP-IPSP type with subsequent repeated depolarization and generation of peak potentials are associated with some intrathalamic mechanism, and not with reverberating thalamocortical circuits. Therefore, it was assumed that in the relay nuclei or in the immediate vicinity of them, in addition to the relay neurons, there are also interneurons that perform inhibition by a recurrent mechanism. It was postulated that the interneuron is activated by collaterals from the axons of many thalamocortical neurons and itself gives off many inhibitory endings to the relay thalamocortical neurons. Such a scheme explains not only the possibility of a sequence of EPSP-IPSP processes arising in response to an afferent wave, but also the possibility of the occurrence of initial IPSPs, which are more common in the neurons of the relay nuclei than the EPSP-IPSP sequence [2].

The assumption of the existence of the described mechanism is also based on other facts. First of all, the latent periods of peak potentials of the relay nuclei of the thalamus and the subsequent IPSPs correspond to the time that was assumed for the existence of a recurrent inhibitory chain [4]. The comparatively short latent period of IPSPs evoked in the cells of the n. VL by stimulation of the brachium conjunctivum is consistent with the hypothesis of recurrent inhibition [3]. This is also supported by the possibility of the assignment of powerful IPSPs from neurons of the relay nuclei of the thalamus during cortical stimulation [4]. The described sequence of EPSP-IPSP is in accordance with the excitability cycles of neurons of the relay thalamic nuclei after the conditioning stimulation [5]. At the beginning of the cycle there is a phase of facilitation of conduction through the nucleus, which corresponds in time to the development of EPSP in neurons, then there is a phase of suppression of conduction, which corresponds in time to the emergence of IPSP. In recent years, an increasing number of facts have appeared indicating the important role of not only recurrent, but also progressive inhibition in the activity of relay thalamocortical neurons [5]. It has been established that in VBc IPSP of relay neurons upon stimulation of fibers of the medial loop are disynaptic, since they occur 0.5-1.3 ms (on average 0.8 ms) later than EPSP, and, therefore, can only be the result of progressive inhibition [4], as well as n. GM [2]. Thus, translational and reciprocal inhibition are mandatory mechanisms for controlling the conduction of excitation through relay nuclei. The activity of interneurons was first studied in 1964. A small number of cells (about 10%) were found in VBc that were characterized by high-frequency discharge during afferent stimulation and stimulation of the somatosensory cortex. High-frequency discharge, gradually increasing with increasing stimulus strength, arose at the time of IPSP development in the relay thalamocortical neurons of VBc. The latent period during cortical stimulation in these neurons was about 1.1 ms, i.e., it was long for antidromic activation and more consistent with monosynaptic excitation through the collaterals of the axons of thalamocortical neurons. These neurons had a longer latent period of excitation during afferent stimulation compared to relay thalamocortical neurons and presumably small sizes, since it was difficult to perform intracellular recording in them [5]. The first are located inside the nucleus and are not activated, or are activated polysynaptically from the cerebral cortex, and the second, localized on the periphery of the nucleus (perigeniculate interneurons), are excited monosynaptically upon cortical stimulation. On this basis, it can be concluded that the first group of interneurons belongs to the system of translational inhibition, and the second to the system of recurrent inhibition of relay neurons n. GL. In addition to the relay thalamocortical neurons and inhibitory interneurons, another group of cells was found in n. VP, which, according to its functional properties, is difficult to classify as relay or inhibitory neurons [6]. These neurons had rhythmic activity under barbiturate anesthesia (frequency - 10-12 imp/s). During stimulation of the cutaneous nerve, inhibition of background impulses was observed, lasting 90-120 ms. When exiting the inhibitory pause, neurons of this type generated several high-frequency discharges. The functional role of these neurons is discussed in connection with the consideration of the nature of the second wave of depolarization (postinhibitory recoil), which replaces the IPSP in relay thalamocortical cells. Previously, it was suggested that there are special interneurons and pathways that generate EPSPs after IPSPs, providing rhythmic activity [5]. This is precisely the function that is given to the cells with rhythmic activity that they found in n.VP. These neurons exit the inhibition phase and generate a high-frequency discharge before the secondary discharges of relay neurons occur. And it can be assumed that neurons with rhythmic activity, being synaptically connected with relay cells, are excitatory interneurons. In this case, the activity of excitatory interneurons is probably phased by the same inhibitory mechanism as relay neurons [6]. The processes described in this section, developing in the neurons of the relay nuclei of the thalamus, are apparently inherent in all nuclei that contain relay thalamocortical neurons. Therefore, their sequence reflects the work of the thalamocortical switching mechanism rather than only the activity of the relay nuclei of the thalamus.

2. organization of receptive fields of the neurons of the external geniculate body

The main nucleus for visual afferents is the dorsal part of the nucleus (n. GLd). In response to afferent stimulation (a flash of light) in n. GLd a focal reaction occurs, which has a number of components (up to five). The first components are two fast oscillations associated with two groups of fibers of the optic tract, which have different conduction velocities. It is believed that the first component is caused by a presynaptic wave traveling along the fibers of the optic nerve, and the second - by a synchronous discharge of neurons n. GLd. The third slow component reflects the summation of EPSP on neurons n. GLd, arising in response to an afferent volley in the fibers of the optic tract. Subsequent components arise from feedback activity with the visual cortex, recurrent axon collaterals, and possibly other sources [6]. Electrical stimulation of the optic tract induces EPSPs in neurons of the n. GL that have a minimum duration close to the duration of elementary EPSPs, i.e., on the order of several ms [7]. The latent period of EPSPs is also very short, about 1.5 ms, indicating its monosynaptic nature. EPSPs have a steep leading edge and cause synchronous peak potentials with a latent period of 1.6–1.7 ms in a large number of neurons. Reactions with a longer latent period are also possible due to the presence of fiber groups with different conduction velocities in the optic tract. Light stimulation of the retina results in a significantly greater dispersion of afferent impulses entering the n. GL via the optic fibers than stimulation of the optic tract.

Following the EPSP, a prolonged IPSP is observed (it occurs in neurons with a somewhat longer latent period than the EPSP), which is noted when the retina is stimulated by light, and especially well - with electrical stimulation of the optic tract [6]. Of great importance for understanding the activity of n. GL is the study of the receptive fields of its neurons. The predominant form of receptive fields are concentric, which are described in carnivores and primates. Each cell of n. GL is activated from a round area of the retina and has an "on" or "off" center with a periphery of the opposite sign [7]. According to the nature of the receptive fields, neurons n, GL are divided into X-, Y- and W-cells [8]. The criteria for distinguishing X- and Y-cells are: short (Y) or long (X) latent period, large (Y) or small (X) receptive field center, phasic (Y) or tonic (X) responses. W-cells were characterized by large and heterogeneous receptive fields. The concentric receptive field of n.GL neurons consists of two zones, stimulation of which causes reactions of the opposite type: the central zone with a visual field diameter of 1-5° in a cat and the peripheral ring zone. Excitation of neurons upon stimulation of the center of the receptive field causes depolarization of the neuron, which is the result of the summation of elementary EPSPs. Elementary EPSPs are caused by afferent impulses coming to the n.GL neurons along a single fiber of the optic nerve [9]. The same applies to the occurrence of IPSPs. The neurons of the n. GL can be classified in the same way as the retinal ganglion cells [8], but there are differences between the neurons of the n. GL and the retinal ganglion cells, the most significant of which is the significantly more pronounced ability

of the periphery of the receptor field of the neurons of the n. GL to suppress the effect of the center. This means that the cells must be more specialized than the ganglion cells of the retina with respect to the reaction to the period of illumination of the retina, and not to the illumination itself. It is believed that the function of the neurons of the n. GL is to enhance the difference in the reaction to a small light spot and to diffuse illumination of the retina. In addition to this main type of receptive field (type I), the system of which in the n. GL apparently gives a point description of the object with a sufficient degree of illumination, there are receptive fields of two more types [8]. Type II fields presumably convey information about illumination, since the neurons of this receptor field increase the intensity of the response depending on the illumination of the retina. The system of type III fields, in which the response does not depend on contrast, can provide a description of the size of the image invariant to illumination. There are several structural schemes of the receptive field of n. GL [9]. It is assumed that each neuron of n. GL receives excitation from only one ganglion cell and that mutual recurrent inhibition of neurons of n. GL is carried out by interneurons. In this case, the periphery of the on-receptor field of n. GL is formed only by the off-fields of the retina, and the off-fields of n. GL are formed only by the on-fields of the retina, which carry out inhibition of neurons of n. GL through interneurons. The inhibitory periphery of the on-field of n. GL is formed by both the on- and off-central fields of the retina, and each neuron of n. GL can inhibit neighboring neurons of any type through interneurons. Based on this scheme, the phenomena observed in the neurons of the n. GL when stimulating the retina with a small spot of light, when changing the diameter of the spot, when simultaneously turning on two spots, and so on, become explainable [9]. The idea of a possible transition of receptive fields of type I to type II and III or, conversely, due to the depth of feedback through interneurons has been little developed, but is very promising for understanding the activity of the n. GL. A special place in the visual system belongs to the ventral section of n. GL — a nucleus with a subcortical connection (pregeniculate nucleus in primates). Neurons of n. GLv respond to retinal stimulation with light, and all neurons have contralateral receptive fields and only 15% have binocular ones, and the reaction to ipsilateral stimulation depends on the contralateral retina [10]. By the nature of the receptive fields, neurons of n. GLv are divided into several groups [7]. The first group (constitutes about 40% of all elements of n. GLv) has concentric or regular receptive fields, the angular dimensions of which are 4-60° in diameter. Neurons of the second group (about 20% of all elements) have receptive fields of 3° or less in diameter, and a very high expression of the response. In the third group (about 10% of all elements), neurons have widespread receptive fields that cover the entire contralateral visual field or square. The fourth group (about 7%) consists of neurons similar to the first group, but having opponent color properties in on- and off-effects. Their receptive fields are usually irregular in shape. The fifth group of neurons (about 23%) consisted of neurons that were inactive in response to visual stimuli.

There is evidence that neurons of the GLv respond to vestibular stimuli [7]. In addition, their activity can be triggered by saccadic eye movements [8]. These data indicate that the GLv is involved in the control of eye movements and, perhaps, therefore receives extensive visual afferentation.

3. Organization Of Receptive Fields Of The Internal Geniculate Body Neurons

The small-celled division of n. SM is a relay structure of the auditory sensory system. Neurons of n. GM in response to a sound click, as a rule, generated several peak potentials. According to the duration of the latent period, three groups of responses were distinguished with a latent period of 4-1, 12-32 ms and late responses with a latent period of 50-250 ms [10]. The responses of the first group had a stable latent period, changing little with an increase in the intensity of the click. The responses of the second group were characterized by a dependence on the strength of the stimulus. In intracellular recording, the response to the click was observed as a sequence of EPSP-spike-IPSP or primary IPSP.

For solving the questions about the neural organization of n. GM, the data obtained in the study of the reactions of neurons to stimulation of the handles of the posterior colliculus are of great importance [10]. In this case, the afferent volley enters n. GM without additional switching, which excludes the influence of the underlying parts of the auditory system on the reaction of n. GM neurons. These responses resembled reactions to a sound click, but had a shorter latent period: the main group (74%) of neurons responded with a latent period of 0.6-3.0 ms. The possibility of antidromic excitation of n. GM neurons upon stimulation of the handle of the posterior colliculus [10] indicates the existence of descending connections of n. GM neurons, the role of which may be associated with the control of processes occurring at the prethalamic levels in the auditory system. In intracellular recording of neurons n. GM, 24.2% of neurons generated a sequence of EPSP-IPSP in response to stimulation of the knob of the posterior colliculus, and primary IPSPs were observed in 42.8% [10]. About 25% of IPSPs arose with a latent period of 0.6-1.0 ms, i.e. they were monosynaptic (therefore, inhibitory neurons are located in the posterior colliculus). In addition to monosynaptic IPSPs, disynaptic ones were also observed (latent period 1.1-2.5 ms). In this case, the influence from the posterior colliculus excites the inhibitory interneuron, which is located in n. GM. In this case, inhibition can be both progressive and recurrent. When studying neurons of the n. GM under the action of pure tones, frequency-threshold curves of the most varied types were obtained: narrow, wide, closed, with several sensitivity maxima [11]. Tonotopic organization is inherent in neurons of the ventral section of n. GM. Moreover, the tonotopic organization is most clearly determined in the lateral part of the ventral section, where low-frequency elements are located laterally, and high-frequency ones are localized medially [11]. In the oval part, the tonotopic organization is not determined, which can be explained by the anatomical arrangement of cells in this section of the nucleus (the course of layers with the formation of a whorl), which complicates the identification of the tonotopic organization. For neurons of n. GM (ventral part), another characteristic feature is observed: low-frequency elements have, as a rule, a wide frequency-threshold curve, and high-frequency ones - a narrow one. The frequency-threshold curves of the neurons of the n. GM are wider than in the fibers of the cochlear nerve or the cells of the inferior colliculus [11]. About 2/3 of the neurons in n. GM respond to binaural stimuli [12]. Most neurons are excited by stimulation through both cochleas, or react with a mixed reaction: stimulation of one cochlea excites, and stimulation of the other inhibits the activity of the neuron. Most often, neurons respond to binaural stimulation. Finally, of greatest interest, from the point of view of sound source localization, are neurons sensitive to the time delay or difference in its intensity between stimulation of both cochleas [12]. Neurons sensitive to the time delay between stimulation of the right and left cochlea had low-frequency frequency-threshold curves (the optimum is 0.4-0.8 kHz). About 1/5 of the neurons in n. GM respond to the movement of the sound source [12]. It is characteristic that most of these neurons respond to a certain range of sound movement. The large-celled part of the nucleus (n. GMmc) has been studied much less than the small-celled one. Its description will be given together with other nuclei of the posterior group.

4. Organization Of Receptive Fields Of Neurons Of The Ventrobasal Complex

As indicated above, afferent impulses coming from the spinocortical and spinocervicothalamic tracts, including the corresponding bulbothalamic components, are switched to the cerebral cortex through various parts of n. VP. In addition, the medial part of n. VP (n. VPMi) is a system for switching taste sensitivity. The representation in the nucleus of tactile sensitivity of the skin in rats, rabbits, raccoons, cats and monkeys has been studied in detail [13]. The somatotopic nature of the organization of the representation of tactile receptors in n. VP has been established. By

studying neuronal activity and partial transections of the spinal cord, it has been shown that in addition to tactile sensitivity, neurons of this same nucleus are influenced by receptors of muscles, ligaments, joints, fascia, and periosteum [12]. The overwhelming majority (98%) of neurons in n. VP are capable of responding to adequate tactile stimuli caused by light touch to the skin, mechanical irritation of the fascial beds and periosteum, and angular displacement of joints [11]. Neurons in n. VP are excited by the local receptive field of the contralateral half of the body. Very often, the projection field in which neurons in n. VR were activated by stimulation of a local area of skin (or other receptors), surrounded by an area where neurons are inhibited. Fields with an inhibitory effect on stimulation of joint receptors were found near the field in which neuron excitation occurs in response to stimulation of skin receptors [11]. In n. VPLc, neurons were found that were activated by painful stimuli of the skin, and in n. VPLo, by painful stimuli from deep peripheral structures: muscles, joints, fascia [12]. It is noteworthy that some of the neurons in n. VP, activated by adequate stimuli, were also excited by stimuli of other sensory modalities (sound, light). However, the nature of the responses to stimuli of other modalities was noticeably different from the responses to adequate somatosensory stimuli by a long latent period and instability (a "non-specific" type of response). This served as the reason for the separation of "lemniscal" and "extralemniscal" neurons depending on which tracts provide afferent supply to these elements. "Lemniscal" neurons responded to electrical stimulation of the posterior columns of the spinal cord and were characterized by the following properties: a short latent period of antidromic responses (up to 2 ms) with stimulation of the SI area, a stable reaction with a latent period of 4-20 ms with stimulation of the peripheral receptor field [13]. Neurons excited through lemniscal projections responded to light stimulation of the skin surface or deep tissues from local receptive fields of only the contralateral half of the body and only one sensory modality. These are the so-called modality-place-specific neurons or s-neurons in the Harris classification [11]. The cells of the ventrolateral system (i.e., the spinothalamic) are excited by stimulation of large and variable-sized receptive fields, often bilateral, sometimes of high intensity (even damaging). These cells can respond to stimuli of different modalities (modality-place-specific neurons or m-neurons in the Harris classification [11]. When studying the properties of neurons n. VPL, it is found that 60% of them have small receptive fields (2/3 respond to hair movement). About 30% of neurons have widespread receptive fields [13]. When stimulating the posterior funiculi and peripheral stimuli under cold block of the posterior funiculi, two types of responses are also found [13]. Lemniscal deafferentation caused a complete disappearance of responses in 80% of neurons n. VP, which apparently belong to the elements with a "specific" type of response. In the remaining neurons with a "non-specific" type of response, this effect led to an increase in the intensity of the response (according to the number of peaks in the phasic reaction) and an expansion of the size of the receptive field of the neuron. Representation in n. VP of various receptors and body parts has different localization. In particular, n. VPL contains representation of nerves of the skin, muscles, joints of the trunk, tail and hind limbs, whereas n. VPM contains representation of the same types of sensitivity of the forelimbs, head, face (muzzle), mouth and tongue [10], as well as taste sensitivity, passing as part of the chorda tympani and glossopharyngeal nerves [10]. With regard to the somatotopic organization of n. VP, it should be noted that despite the correctness of the conclusions regarding the continuity of the projection in the thalamus of the body and limbs, it turned out that they overlap each other. A second zone of somatosensory representation in n. VP, located in the caudolateral parts of n. VPM [11], was also discovered. The second zone also has a pronounced overlap of projections of receptors of various body parts. Of particular interest is the area of representation of the visceral nerves. The projections of the splanchnic nerve are localized in n. VPL on the border with n. VPM in the area of projections of the thoracic region of the body [12]. The projections of the pelvic nerve are in the area of the lumbar region of the body [12]. As for the vagus nerve, its projection is in n. VPM, overlapped by the area of representation of the muzzle and forelimbs [11]. Thus, in n. VR mainly represents the receptive fields of the spinocortical tract (various types of cutaneous, articular, visceral receptors), the spinocervicothalamic tract (tactile, cutaneous and pain, various types of muscle receptors) and the spinothalamic tract (pressure, temperature and pain receptors), as well as their analogues passing through the trigeminal nerve system.

5. Organization Of Afferent Input of The Complex Of The Ventral Lateral And Anterior Nuclei

Among the non-sensory switching nuclei, n. VL and n. VA occupy a central place. Despite the main function of the VL-VA complex, which consists in switching cerebellar and pallidal afferents to the cerebral cortex, the neurons of these structures also respond to peripheral stimuli. Neurons of n. VA react to various stimuli: skin of the extremities, light, sound stimuli [13]. With regard to neurons of n. VA, the greatest activity is caused by irritation of the forepaw, but the number of neurons responding to this irritation is less than 30% [13]. It has been shown that 47% of the responsive neurons of n. VA do not have a somatotopically organized input, and 22% respond to stimulation of various afferent systems. According to these characteristics, n. VA is similar to other nuclei of the nonspecific system of the thalamus, and above all n. R [13]. Neurons of n. VL are also activated by various peripheral stimuli [13]. Afferent proprioceptive impulses coming from receptors of muscle spindles, joints, tendons, as well as skin, vestibular, visual and auditory afferent systems, cause reactions of neurons of n. VL. Somatic afferent effects are the most effective [13]. In addition to studying the reactions of VL-VA neurons to peripheral stimuli, the responses of these structures to stimulation of a number of tracts have been studied in particular detail. In particular, n. VA neurons are activated by pallidal afferents: this communication system ensures the switching of signals coming from the caudate nucleus through the globus pallidus to the cerebral cortex. In this respect, n. VA resembles n. VL. In addition, n. VA neurons are excited by thalamic influences passing through the associative intrathalamic pathway, originating in the parafascicular complex. Close functional relationships have been established between the relay sensory nuclei (n. GL, n. GM, n. VP) and n. VA [12]. Some of the neurons of n. VA are activated antidromically by stimulation of n. VP and n. GL, which indicates the existence of direct connections of the VA neurons with the relay nuclei (mainly with n. VP). Neurons of n. VL are activated by two projections: fibers of the connecting legs and the lenticular loop. Intracellular recording from relay cells of n. VL showed that neurons monosynaptically activated by stimulation of the connecting legs can also be monosynaptically excited by stimulation of the ansa lenticularis, which carries striatal afferent pathways to the thalamus [14]. However, if upon stimulation of the connecting legs, monosynaptic EPSPs in the relay neurons of n. VL are usually accompanied by IPSPs, then stimulation of the ansa lenticularis does not cause IPSPs in the same cells. It follows that the IPSPs that arise upon stimulation of the connecting legs are not the result of recurrent inhibition, but only of translational (afferent) inhibition, and, consequently, a special inhibitory pathway runs from the connecting legs to the neurons of n. VL.

With some of the interneurons n. VL the two above-mentioned inputs can be connected polysynaptically. In this case, as a rule, a reciprocal influence is observed: one of the inputs causes an excitatory effect, and the second – an inhibitory effect. On some of the interneurons, a convergence of lenticular impulses and influences coming from non-specific nuclei of the thalamus is observed. The neurons of n. VL are organized into special groups relative to the inputs, which in turn limit certain synaptic territories within these groups. Moreover, cerebellar influences are limited both on relay neurons and on interneurons of n. VL, and pallidal influences are distributed over virtually all elements of the interneuronal network of n. VL. Consequently, the processes occurring in neurons of n. VL as a result of interaction occurring in interneuronal groups associated with inputs from the cerebellum, basal nuclei, and nonspecific nuclei of the thalamus are necessary for programming afferent messages from n. VL-VA to the

motor cortex. There is a suggestion that the conduction of cerebellothalamic influences through n. VL is controlled by neurons of n. R [14]. This suggestion is based on the different nature of the reactions of neurons of n. VL upon stimulation of the nuclei of the cerebellum and n.R. If in response to the first of these stimuli single peaks predominate, then with the second, a frequent form of reaction was a high-frequency discharge characteristic of inhibitory interneurons. It is possible that n. R has an inhibitory effect on neurons of n. VL.

6. Organization Of Afferent Inputs Of The Anterior Thalamus Nuclei

The anterior group of thalamic nuclei (n. AV, n. AD, n. AM) belongs to the category of non-sensory relay nuclei. The relay function of the anterior nuclei consists of switching impulses from the mammillary bodies, from where they go as part of the mammillothalamic tract (MTt) to the limbic cortex: n. AV projects to fields 23 and 24, n. AD to field 27, and n. AM to fields 24 and 32 [16]. The largest of the anterior nuclei and the one that develops progressively in phylogenesis is n. AV. The anterior nuclei of the thalamus consist of relay-type cells with disc-shaped dendritic fields and long axons extending beyond the nuclei [14]. Part of n. AM has clusters of reticular-type neurons, so this nucleus is classified as nonspecific [14]. All nuclei contain a certain number of interneurons (Golgi II cells), but n. AD has fewer of them than other nuclei [15]. The projections of the mammillary bodies to the anterior nuclei are differentiated. Three types are distinguished among the MM fibers. Two types are axons of the cells of the medial mammillary nucleus, projecting onto n. AV and n. AM, and the third type is of the lateral mammillary nucleus, projecting onto n. AD. In addition to this main afferent system, the anterior nuclei receive fibers from the CA1 field of the hippocampus (mainly n.AV), septum (except n. AV), non-specific nuclei of the thalamus and other sources [14].

The anterior group of nuclei is part of Peipets' limbic circle: hippocampus—mamillary bodies—anterior nuclei of the thalamus—limbic cortex and again the hippocampus [17]. It was assumed that this circle is of great importance for providing various emotional reactions. However, recent work makes it possible to consider in a different way the interrelations of the structures of the limbic system and the role of the anterior nuclei of the thalamus in the processes developing in its formations. First of all, it should be noted that upon stimulation of the CA1 field of the hippocampus, connected with the mamillary bodies by the postcommissural fornix system, neural and focal responses arise in the medial mamillary bodies with a latent period of 8-14 ms and the anterior nuclei of the thalamus with a latent period of 18-26 ms [15]. Responses arise at a stimulation frequency of 14-16 Hz both in the mamillary bodies and in n. VA. At the same time, in n. AM responses are suppressed already at a frequency of 8-9 Hz [11]. Consequently, n. AV is part of the system: field CA1 of the hippocampus—medial mamillary nucleus—n. AV, in which responses are reproduced at frequencies optimal for the hippocampus [15]. It is very significant that the mesencephalic reticular formation does not influence the responses of the anterior thalamic nuclei evoked by stimulation of the hippocampus. Thus, the influences coming from the hippocampus through the mammillary bodies to the anterior thalamic nuclei are very strong and therefore independent of the influence of non-specific structures. The neuronal activity of the anterior nuclei of the thalamus (especially the main one n. AV) has been analyzed in detail in a number of studies [15]. It has been established that the neurons of n. AV have a relatively high level of background activity. In reactions to afferent influences, phasic reactions predominate and tonic reactions are observed only occasionally. Among the neurons of n. AV, both polysensory and monosensory elements are encountered.

A very important observation is the selectivity of the reactions of monosensory neurons to stimuli even within a single modality [15]. For example, neurons that respond to sounds do not respond across the entire band of the sound spectrum, but select a relatively narrow frequency range, not responding to other frequencies. Moreover, individual neurons of the n. AV respond better to natural sounds (speech, complex sound complexes) than to pure tones. Another property of neurons concerns the nature of their reactions to repeated stimuli. The formation of reactions occurs, as a rule, by the fourth to seventh application of the stimulus. Suspense also occurs, and, apparently, this is associated with a slow restructuring of the response rhythm from one stimulation frequency to another. A special type of reaction in background-active neurons is background suppression and the appearance of phasic reactions, so that the neurons acquire the appearance of a responding cell without background activity.

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