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Original Article

The Biophysical Modelling of the Kinaesthetic Receptors

Janos Vincze, Gabriella Vincze-Tiszay

Health Human International Environment Foundation, Budapest, Hungary

Corresponding Author: Janos Vincze

ABSTRACT

The receiver or the analyser's peripheral segment, the afferent pathway which takes the excitation to the cerebral cortex and the cortical segment. The kinaesthetic receptors are the mechano-receptors of the locomotor system. This group includes both joint receptors, represented by the Ruffini corpuscles, the joint Golgi organs and the modified Vater-Pacini corpuscles, with the paraarticular Pacini corpuscles, as well as the Golgi tendon organs. The normal development of the motor activity, the fine analysis and the precise coordination of the movements require the permanent information of the central nervous system on the spatial position of the body, its various segments and especially the degree of contraction of each muscle. Our organism, especially in the biped posture opposes permanently to the gravitation force which tends to put it down. The relative change of the stimulus is proportional with the relative change of the stimulus. They found that the so-called method of amplitude estimation resulted in values with very dispersed intervals, therefore, they applied the correlation of the analyzers.

Key words: biophysics, joint receptors, modelling

Introduction

The anatomical-physiological apparatus of sensations is called analyzer and it is made of three parts, tightly connected between them: the receiver or the analyser's peripheral segment, the afferent pathway which takes the excitation to the cerebral cortex and the cortical segment of the analyser. [1]

The peripheral segment – the receiver:

– is represented by specialized structures integrated in the sense organs;

– stimulated by the variation of an energy form and finally the action potential (nervous inflow) which propagates in the following segment;

– the receiver – it only performs a gross analysis.

The intermediary – leading segment is formed of:

– direct pathways – they are specific pathways, with a few synapses, through which the nervous impulses are lead rapidly and they are projected in the cortical areas, in specific areas;

– indirect pathways – nonspecific nervous pathways, with a lot of synapses and through which the nervous inflows are led slowly, in the cortical areas, where they project diffusely and non specifically.

The central segment is represented by two types of cortical areas:

– primary cortical area, where the fibres of the leading pathway are projected;

– secondary cortical area connected with the primary area.

The associative function does not have a specific area, but it is realized by the entire cerebral cortex. Any excitation which reached the cortex can be associated with any activity of the organism. The entire cerebral cortex represents a reception surface. The perfecting of the function of the analysers is exemplified with those individuals which, after loosing the function of one or more analysers, reach a special development of the function of the integer analysers.

The analyzers in the human organism is kinaesthetic receptors.

The kinaesthetic receptors

The kinaesthetic receptors are the mechano-receptors of the locomotor system. This group includes both joint receptors, represented by the Ruffini corpuscles, the joint Golgi organs and the modified Vater-Pacini corpuscles, with the paraarticular Pacini corpuscles, as well as the Golgi tendon organs. There are free nerve terminations all over. [2] Of all the receptors, the Ruffini corpuscles are the more frequently found, being situated superficially in the conjunctive tissue of the joint capsule and receive information about the position and movements of the articulations. The Vater-Pacini corpuscles are disposed in tendons, joint capsules, muscular fascia, ligaments, periosteum, perichondrium; they have as stimulus the pressure exerted on the structural formations in which they are found and are sensitive to rapid movements and vibrations. The Golgi tendon organs are found in tendons and ligaments. 1–3 nervous fibres enter the corpuscle and they are stimulated by the strong tension of the tendon, being stimulated by the increase of tension in the tendons, determined by the muscular contraction. The free nervous terminations split on the entire thickness of the joint capsule and transmit the joint painful sensibility. [3]

The neuromuscular spindles are found among the muscular fibres and they receive the speed and degree of stretching of the muscle. The most important proprioreceptors are the neuromuscular spindles. They are constituted of groups of 2–10 intraspindle fibres, with sensitive-motor role, situated between the usual muscular fibres (extrasprindle) and in parallel with them. The extremities of the intraspindle fibres can be caught on the tendons and extraspindle fibres or only on extraspindle fibres. An intraspindle fibre has contractile wrinkled extremities and a stronger non contractile central portion, with several nuclei and without myofibrils. The neuromuscular fuse is connected exclusively with the leading proprioreceptive unconscious pathways with the destination cerebellum.

The sensitive innervation of the fuse is formed of primary spiralled terminations, situated in the central area and secondary terminations, fibres situated at the extremities of the central area. The primary terminations, with fast lead, are stimulated by the muscle’s stretching degree. The motor innervation, proper to the contractile ends of the intraspindle fibres is represented by nervous fibres with the origin in the gamma medullar motor neurones, unlike the extraspindle fibres which are innervated by the alpha medullar motor neurones.

The cortical segment is represented by the somesthesic areas 1 and 2, so that the projection of the sensibility of the dermatomes generally overlaps the one of the myotomes. The information at the level of the articulations are projected especially in the posterior region of the postcentral gyrus and the ones of the neuromuscular spindles in the anterior regions and in the depth of the central fossa, until the motor cortex. This way a sensitive-motor area is obtained, which puts in agreement the effectuation of the cortical motor commands with the sensitive proprioceptive and exteroceptive information regarding the way this is executed. [4]

The normal development of the motor activity, the fine analysis and the precise coordination of the movements require the permanent information of the central nervous system on the spatial position of the body, its various segments and especially the degree of contraction of each muscle. On the basis of this information, processed by the upper nervous centres, postural and movement feelings appear and it elaborates commands which determine the muscular tonus and the muscular contractions afferent to the various movements.

This information is provided by the visual, cutaneous receptors but also by certain specific receptors found in the locomotory apparatus: the kinaesthetic receptors. The kinaesthetic or movement analysers form the receptors, the nervous terminations in the muscles, articulations, tendons, aponeuroses, joint capsules, periosteum and perichondrium and the centre of the analyser (cortical area) is found in the central ascending circumvolution. After the effectuation of various movements these receptors are stimulated and the kinaesthetic feelings are received by the cerebral cortex with the help of the mechanisms of reverse afferentation. Muscular relaxation is prevented by the extension and activations of the spindles, which, on their turn, trigger a reflex contraction. This mechanism produces a stretch and a relaxing muscular tension – muscular tonus. [5, 6]

Our organism, especially in the biped posture opposes permanently to the gravitation force which tends to put it down. Hence, the antigravity muscles (back muscles, buttocks muscles, anterior thigh muscles and the leg posterior muscles) are permanently solicited and, hence, the neuromuscular spindles are stimulated. Although gravity acts permanently on them, the neuromuscular spindles do not adapt. If they adapted, we would fall off our feet.

The unconscious proprioceptive information arrived from the neuromuscular spindles lays at the basis of the control exerted by the upper nervous centres (cerebellum, thalamus) on the muscular tonus and the voluntary muscles. In the joints the so called „activation angle" appears which has a different value for each articulation and type of movement. Knowing this has a special importance in the clinical and biophysical evaluation of the degree and type of joint mobilization. For example, in the upper limb of human, table 10 contains the values of the angles in the three main plans. [7]

In this case, the movements' perception threshold, translated in joint mobilization, depends on one side by the angular amplitude and on the other side by the speed of its modification, so that in the passive movements the perception of the proximal articulations is more increased in report of the one of the distal articulations. Hence the conclusion is that at the level of the central nervous system, the information received from the articulation weights more than the information received from the muscles themselves. [8, 9]

The information received from the tendons must be seen as „passive" information about the state of the muscles due to the fact that the information from the receptors are foreground compared to the tension state of the muscle itself. The kinaesthetic analyser does not fulfil these functions alone. Its role is to supply the previously processed necessary information to the brain, starting from the locomotor apparatus. Based on them, the motor command is elaborated, the muscular tone and posture are adjusted, the control of the way the voluntary command is fulfilled. [10]

Hence, the kinaesthetic analyser is a basic component of the feed back circuit which regulates the somatic motor sensitivity. In the normal functioning of the kinaesthetic analyser, we feel the position of the limbs, their direction, the speed of movements, the coordination of movements. The movement performed by the right arm, through coordination can also be performed by the left arm. If the kinaesthetic sensitivity is disturbed, that person looses the capacity to coordinate their movements, they cannot maintain balance with closed eyes.

Modelling

According to Stevens, the relative change of the stimulus (ΔI/I) is proportional with the relative change of the stimulus (ΔE/E):

$$\frac{\Delta E}{E} = k.\frac{\Delta I}{I}$$

Solving the above equation results in the following power function:

$$E = k\left(\frac{I}{I_0}\right)^n$$

where $\mathbf{I_0}$ is the intensity of the threshold stimulus, **n** is the constant characteristic of the type of perception. If we illustrate the power function in a log-log coordinate system, we get straight lines. Attempts were made to determine the value of **n** with psychophysical methods.

They found that the so-called method of amplitude estimation resulted in values with very dispersed intervals, therefore, they applied the correlation of the analyzers. [11, 12] The **n** was determined for each sensory organ, but its value depended to a great extent on the form of the stimulus that reached the sense organ, and on the state of the sense organ compared to its environment. Thus, Steven's law depends to a great extent on whether the sensory organ of the given person is of an average or an above-average sensitivity (sight for painters; hearing for musicians; touch for the blind).

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