



The Biophysical Modelling of the Equilibrium Receptors

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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 simplest equilibrium takes place then two forces of equal size and directly opposed act simultaneously. If several forces act on different directions on an object, the object can be in equilibrium only if the effect of one is cancelled by the others. The equilibrium analyser is situated in the internal ear. The receptors of the macula are stimulated mechanically by the otoliths. Their stimulation takes place in static and dynamic conditions. This way, correcting motor reaction of the position of body and head are triggered at the level of the nervous centres, in order to maintain the equilibrium for the entire duration of movement. The vestibular sense is not a proper equilibrium sense, but an important component of the mechanisms which contribute to the adjustment of equilibrium, next to the kinaesthetic, visual, tactile analysers and cerebellum. 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.

Keywords: biophysics

INTRODUCE

The connection between the organism and the environment is made through the analysers, real information channels, which receive, lead and integrate the excitations in the environment as specific conscious sensations. [1, 2]

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.

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 BIOPHYSICS OF EQUILIBRIUM

The simplest equilibrium takes place then two forces of equal size and directly opposed act simultaneously. If several forces act on different directions on an object, the object can be in equilibrium only if the effect of one is cancelled by the others. The equilibrium analyser is situated in the internal ear, which verifies the modifications of the body's positions, in report with its weight centre, position, direction, speed of movements. [3]

In the bone labyrinth there is the membrane labyrinth, which is not tightly connected to the bone labyrinth, but it is bathed in perilymph, which protects it from the external mechanical and thermal influences. The membranous labyrinth is made of three semicircular canals, placed in three different plans (horizontal, frontal, sagittal) and two satchels called sacula and utricula. Inside the membrane labyrinth there is the endolymph. [4] At the end of each semicircular canal, there is a dilatation (ampulla) in which there is a small prominence like a crest. In this crest there are the sensorial cells with cilia, immersed in a gelatinous mass, which covers the crest like a cupola on its entire extension. In the sacula and utricula there is a prominence in each (macula) in which there are sensorial cilia cells covered by a gelatinous mass which contains small crystals called otolithes (calcium salts shaped as conglomerates).

The receptors of the macula are stimulated mechanically by the otolithes. Their stimulation takes place in static and dynamic conditions. When the head stay still, the otolithes push with their weight on the cilia of the sensorial cells, which send impulses to the centres, informing them about the position of the head in report with the direction of the gravity vector. The macular receptors discharge impulses even in the absence of the movements of the head, which proves that they adapt very little. By tilting the head with 1° from the static position, the discharges of impulses in the otolithic receptors increase. This is the threshold of the head tilting difference. [5] The frequency increases progressively with the degree of head tilting.

When the head and the body suffer lineary accidents (ahead, backwards or laterally), the inertia forces push the otolithes which are denser than the endolymph, in a sense opposed to the displacement. This way, correcting motor reaction of the position of body and head are triggered at the level of the nervous centres, in order to maintain the equilibrium for the entire duration of movement. The ampullary crests and the jelly cupolas, which are found at the base of the

semicircular canals, represent the second receptor organ of the vestibular analyser, responsible for maintaining the equilibrium in the conditions of the circular accelerations of the head and body. The cilia of the sensorial cells in the semicircular canals are mechanically excited by the moving of the endolymph. Any rotation of the head triggers the simultaneous rotation of the semicircular canals situated in the plan of that rotation. Because of the inertia, endolymph in these canals will suffer a relative displacement in the opposite sense and will tilt the cupula in the sense of this displacement. [6]

The action potentials generated at the level of the vestibular receptors are transmitted by the first sensitive neuron of the vestibular pathway (in the Scarpa ganglion) to the vestibular bulbar nuclei, where the second neuron of the pathway is found. From here, the vestibular stimuli distribute in several directions: to the archicerebellum, responsible of the automatic maintaining of the equilibrium; towards the reticulate formation of the brain stem and the medullar motor neurons, for the adjustment of the muscular tonus and the body posture; towards the motor nuclei of the ocular nerves which ensure the fixation of the eyes during the rotation movements of the head; towards the thalamus and from here towards the cerebral cortex, to ensure the conscious feeling of equilibrium. [7]

The cortical projection of the vestibular analyser is at the level of the upper wall of the Sylvius solcus (parietal lobe) near the acoustic areas of the upper temporal gyrus. Attached to the vestibular cerebellum, the entire labyrinth system is brought in the adjustment of the posture tonus, in order to balance the body in tight connection with the change of the position in space and the modifications that the gravity vectors produce. [8] In this sense, the labyrinth system lies at the base of the origin of the compensating labyrinth reflexes during the displacement, so the coupled intervention both of the semicircular and the otolith organs implies a perfect coordination through some mechanisms which are not known that well.

Due to inertia, the endolymph in these canals achieves a relative movement in opposite direction determining the advancement of the cupula in the direction of this movement. The receiving of the circular movements is possible only due to the orientation of the semicircular canals in the three plans of the space. The horizontal and lateral semicircular canals inform on the movements around the vertical axis and the vertical canals informs on the movements around the horizontal axes (jumps, falls).

The actions of the vestibular pathways on certain nervous centres and particularly those responsible for the movement of the limbs and the eyeballs can determine a series of reactions from the eye muscles, neck, limbs and displacements of the eyeballs. Unlike the ampulla information of the semicircular canals issued only in the initiation and stop of the movement, those coming from otolithic organs are supplied both during the movement of the head and during the maintaining of the position.

The modifications of the position of the head influence the body position (posture). The reflexes which determine the posture are called static or postural reflexes. Together with the vestibular analyser of postural restoration and also involve the cutaneous, kinaesthetic and visual analysers, the cerebellum and the nuclei of the 3rd, 4th and 6th cranial nerves. The destruction of the labyrinth determines initially serious disturbances of the static and dynamic equilibrium.

After a period of time, proprioceptive compensating mechanisms interfere which take over some functions of the labyrinth and determine the correction of the body position.

The vestibular apparatus offers adequate information which allow, on one side, the reflex adaptation of the bodies and limbs' position related to the one of the head, maintaining the normal attitude of the head and body with the static and static-kinetic restoring reflexes, with a special role in the biped standing, equilibrium and orientation of the organism towards the spatial coordinates of its life environment. [9]

If the adequate excitation of the vestibular apparatus exceeds a certain limit (too fast rotation, strong rocking, unusual positions of the body and head, etc), they cause a series of vegetative reactions: dizziness, cold sweats, redness or skin paleness, nausea, vomit, modification of the heartbeat rhythm, acceleration of breathing etc. Balance disorders can be added as well as disturbances in the precision of the movements of the upper and lower extremities, due to the influence of the vestibular apparatus on the equilibrium and muscular tonus. [10]

The vestibular sense is not a proper equilibrium sense, but an important component of the mechanisms which contribute to the adjustment of equilibrium, next to the kinaesthetic, visual, tactile analysers and cerebellum.

The character and intensity of these reactions varies from person to person. In the person with an increased excitability of the vestibular apparatus, this reaction can appear during a boat trip (sea sickness), plane trip or other transportation means. After the end of the journey, these phenomena usually disappear quite fast. The research made on sports people showed that the vestibular apparatus can be trained and that its function improves under the influence of physical exercise.

The equilibrium is a complex function which allows the maintaining of the standing position and walking. In the equilibrium multiple structures of the nervous system interfere: motor nerves, cerebellum, deep sensibility and the internal ear. A normal equilibrium implies a good functioning of the structures responsible for sight, bones and articulations.

The equilibrium disturbances can have various forms. Vertigo is a fake feeling of movement of the body in the space or of the space in relation with the body, tied to a disequilibrium between the two internal ears. It is frequently accompanied by sickness, sweat, pallor and especially restlessness. The affecting of the cerebellum, also called cerebellum syndrome, is manifested through muscle coordination difficulties, equilibrium loss, orthostatic position disturbances and walking disorders.

MODELLING

According to Stevens [11, 12], the relative change of the stimulus ($\Delta I/I$) is proportional with the relative change of the stimulus ($\Delta E/E$):

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

Solving the above equation results in the following power function:

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

where 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. 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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