Harmony of Brain Rhythms

On the Centenary of the Birth of Academician M.N. Livanov

I proved harmony like higher mathematics ….

A.S. Pushkin

Mikhail Nikolaevich Livanov.

As early as in the times of Sir Isaac Newton, the Englishman D. Hartley asserted that the material basis of the inner world in humans is certain periodic body processes. The mystery of brain periodic processes and their relation to the psyche were elucidated by the outstanding Russian scientist Academician M.N. Livanov (1907–1986) and his students and followers.

At the beginning, Mikhail Nikolaevich Livanov was born on October 20, 1907, in Kazan into the family of a prominent biologist. In 1840, Livanov’s father, Nikolai Aleksandrovich, published the fundamental work Routes of Animal World Evolution. His mother, Natal’ya Aleksandrovna, was a professional painter and teacher at a secondary school. Livanov studied at the famous Kazan University where he received both a biological and a technical education. His teacher was A.F. Samoilov, one of the founders of world electrophysiology.

Livanov was one of the first who, following the German psychiatrist H. Berger, created with his own hands a Russian electroencephalograph—a device for recording brain electric potentials, the so-called electroencephalogram (EEG). Before the discovery of the EEG, the brain was a kind of “black box”: it could be studied only by comparing the acting signals and the body’s response. The EEG made it possible to look into this box and to learn how the brain functions. Livanov had started to create the Russian electroencephalograph back in his student days and finished it in Moscow where, upon graduating from the university, he worked at the Botkin Hospital first as a probationer and then as a mechanical physicist. In 1933, he became head of the Laboratory of Electrophysiology at the Institute of the Human Brain [1]. He rented a room in the remote settlement of Zhavoronki. He had to rise at 4 a.m. and go to work by a local train to be in time for the first Moscow streetcars.

Discreteness of wave neuron processes. The first EEG records were made at the Institute of the Human Brain. Since EEG reflects the total activity of a great number of nerve cells, one might expect that it would look like an unordered curve resembling the white noise curve. However, Berger had already understood that it was not so. EEG made it possible to differentiate clearly certain main rhythms. Livanov devoted his life to the study of these rhythms. In the 1930s, the intensity spectra of baseline fluctuations of biopotentials in the brain cortex of rabbits were first plotted. The young scientist made an important observation. It turned out that one of the frequencies (about 5 Hz in rabbits and about 10 Hz in humans) had the highest intensity. Depressions were seen along the sides of this peak, and the frequencies of the next peaks changed spasmodically, the frequency of the previous peak differing from the fre-
quency of the next one by a certain value of 5–15% of the frequency of the main, dominant peak. Livanov rechecked his discovery in experiments with induced potentials—electric fluctuations arising in response to an external stimulus. Flares, acoustic snaps, and weak electric shocks were used as stimuli.

Livanov also used more complex signals: flashes gradually increasing in frequency. The intervals between the flashes corresponded initially to the periods of the slowest EEG fluctuations, about 1–3 Hz (δ-rhythm), then the frequency smoothly increased to 8–13 Hz (α-rhythm) and up to 30 Hz and higher (β-rhythm and γ-rhythm). The phenomenon of the so-called rhythm assimilation was discovered: the frequency of the EEG waves followed the frequency of stimulation. However, this rhythm assimilation was no mere repetition of the smoothly increasing stimulation frequency. It turned out that certain periods of the EEG fluctuations were changed in discrete steps by other periods as soon as the duration of the intervals between the stimuli became different from the duration of the previous intervals by 10% [2].

Because of these findings, the following question arose: what causes sporadic changes in the EEG frequency? The answer could be found by a more careful study of the spectra of brain electrical activity. A method not long before elaborated by the Russian physiologist N.A. Bernshtein was used. This approach was hard manual labor; however, it led to very important results. It turned out that the EEG consists of distinct frequency components that, as might be assumed, reflect the activity of individual nerve ensembles. With a gradual increase in the stimulation frequency, the nerve ensembles seem to pass on the baton from one group of cells to another.

This discovery related the electric activity of the brain to another fundamental thesis formulated by the founders of Russian neurophysiology N.E. Vvedenskii and A.A. Ukhtomskii. Proceeding from the data on the rhythmic nature of nerve excitation, they introduced the concept of functional lability. It was demonstrated that each nerve structure has a frequency at which it works, a coincidence of the rhythms of two different structures being the basis for establishing relations and exchanging information between them. All this, however, was studied on comparatively simple nerve preparations. Livanov’s discovery lay in the fact that he had established that this regularity was also applicable to the functioning of both the brain and the brain cortex, its most perfect formation. He also demonstrated that the frequency of EEG rhythms reflects this important parameter of the work of nerve structures [3].

Thus, it was established that information in the brain is coded as the rhythmic activity of nerve ensembles. “Brain music” is performed by an orchestra consisting of a great number of groups of nerve cells, each of which performs its own part entering the general flow of harmonious (or, when ill, disharmonious) brain work. Let us use still another comparison. When playing the violin, one may make the sound of any pitch within its sounding range; everything depends on the place where the player’s finger stops. Unlike the violin, the piano sound is discrete, and it is impossible to produce a sound between two keys. Livanov demonstrated that