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Speech rhythm disorders arising as result of synchronization induced in couple oscillators

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It is possible to consider a stuttering from point of view of engineering acoustics, if the stuttering is defined as the speech rhythm disorder. Really, voice sounds of speech are formed by voice folds, peripheral resonators and articulators of the speech tract (oral cavity, nose, labiums, tongue, tooth and so on). Energy for acoustic oscillations is supplied by airflow from lungs.

Speech tract control is carried out with the help of the brain. We shall term the basic electrical brain unit as a neurone. To describe electrical properties of neuron we shall use the elementary model — Leaky-Integrator-and-Fire model (LIF) [1]. LIF's potential is the sequence of impulses with period ~1 ms, so LIF is oscillator also. In terms of electricity, the brain functioning can be represented as nonlinear interaction between LIFs. This interaction is characterized by some coupling strength [2]. If LIF potential exceeds threshold of the spike generation, this LIF is termed as active one. The active LIF can interact with the next LIF in two ways:

1) If active LIF can provoke in the next LIF the potential oscillations exceeding threshold, then this active LIF is termed as the "excitatory" LIF.

2) If active LIF can "inhibit" a potential in the next LIF up to the level below threshold, then this active LIF is termed as an "inhibitory" LIF.

The relative number of "excitatory" ("inhibitory") per one second LIFs is termed as "excitatory" ("inhibitory") activity of the brain. Activities are measured in Hz. On the periphery such activity leads (with the help of special cells) to tension of voice folds muscles and another muscles, for example, muscles of the lung diaphragm, labiums etc. In particular, such control forms the beginning and the end of the voice segment in speech. Otherwise, the brain controls the speech rhythm.

Stuttering is the phenomenon of distinction between the stuttering rhythm and the rhythm of normal speech. Extensive experiments confirm the rhythms are organized in accordance with the square-law map with control parameter [3, 4]. The long-term examinations of both age-specific phonetics and the various forms of the stuttering prove the control parameter has neural-physiological sense of "inhibition". This "inhibition" exists in the neural ensemble responsible for observed rhythm. Square-law map has set of the stable states, in other words, some rhythms has stable duration of the segments. This set of the stable states is termed as the

scenario of rhythms, because the transitions between these states correspond to regular rhythms of children's bubbling and repetitions at the early form of stuttering. The normal adult speaker acquires irregular, chaotic speech rhythm due to incremental inhibitory influence of the cortex. However at the further increasing of inhibition the fluency disorders occur again. These disorders form the pauses of silence, perseverations and so on. Otherwise, these disorders have neurotic character. Such stuttering accompanying both by disorders in form of the repetitions and in form of neurotic disorders, is called inconvertible, "chronic" stuttering. Namely such stuttering is "stumbling-block" for the clinicians since reduction of disorders-repetitions needs the increasing of inhibition in control centers, and, on the contrary, reduction of the neurotic disorders needs the decreasing of inhibition in the same centers [3].

However this inconsistency disappears if the linear relation between "inhibitory" activity and control parameter in the scenario of rhythms is taken into account [4]. On the other hand, taking into account delays between the adjacent oscillators, only the "inhibitory" population of oscillators is capable to create the synchronic clusters. Three regimes are possible:

1) LIFs operate synchronously in-phase at medial values of the coupling strength between them.

2) LIFs operate synchronously in-antiphase at low values of the coupling strength.

3) Synchronization disappears in the presence of enough large values of the coupling strength [2].

These facts are in accordance with the solution of Fokker-Plank equation used in hydroacoustics as well [1]. Really, "inhibitory" activity slowly oscillates with gradual damping to level of the background activity. This background level corresponds to the complete desynchronization of "inhibitory" LIFs during 200 ms [1].

It is possible to assume, splashes of the activity oscillations, which continue about 40–50 ms above level of background "inhibition", lead to appearance of the neurotic disorders typical for increasing inhibition at the "chronic" stuttering. The splashes of oscillations, which last about 40–50 ms below level of background "inhibition", lead to appearance of the repetitions with convulsive features typical for decreasing "inhibition". The experimental facts confirm splashes below background inhibition lead to arising of the convulsive features in muscles [5].

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