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ONCE MORE ABOUT MECHANISM OF VOICE PRODUCTION

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At the present time the mioelastic model is considered to be the received model of voice production, i.e. the periodical oscillations of vocal chords. This model assumes the merely physical mechanism of glottis opening-closing.

With that the nerve-impulse mechanism is used physiologically only for the comparatively slow changes of frequency of vocal chords oscillations (for instance for intonation formation). The neurochronaxical theory that implies control of vocal chords oscillations by means of change of neuron impulses frequency was turn out from the frame of scientific consideration [1]. Yet recently a number of experimental factors have been revealed that allows to speak of interaction of mentioned above mechanisms and to propose a modulation theory of voice production.

The main questions that makes us to return to the problem of voice production are following:

1. What induce the low frequency components of spectrum.
2. What can explain the often enough observed bifurcation of discrete components of spectra of children and diseased with ectomated larynx.

According to the classical mioelastic theory the frequency of periodical oscillations of vocal chords – the fundamental frequency of voice other things being equal is directly proportional to the square root from the value of under chords overpressure.

However the changes of under chords overpressure value is not the sole reason of changing frequency of vibration of vocal chords. The observations with stroboscope let see that the frequency is inversely proportional to the length of vibrating part of vocal chords, and this length can be voluntarily regulated by an executant due to interlacing of muscle fibers of every vocal muscle. Moreover by the central nervous system the value of fundamental frequency is linked by direct proportional relation with the size of upper larynx resonator. Its length changes due to reflex movements of larynx.

According to the neurochronaxical theory by Husson vocal chords of human vibrate not passively from the air current action but actively periodically contract and relax with the sound frequency thus regulating the passing of air impulses through larynx and therefore the fundamental frequency of sound. The fact (Husson made observations of diseased with ectomated larynx) give the seal to the theory is that during the phonation of vowels the fundamental frequency of voice and the frequency of neuron impulses leading to vocal chords coincide absolutely. Yet one of the objections of Husson adversaries is that the transmission of control impulses of high frequency (over 1000Hz) to vocal chords can't be provided because of the presence of refractor phase of nerve.

In his turn Husson responds referring to the experimental data explaining them firstly by means of more highly developed functional possibilities of the system "nerve - vocal muscle" evolutionarily developed in human and secondly by means of the presence of enough number of conductors in excitor nerve each of them having impulses displaced in phase. By him this mechanism can account for the sum frequency that is much higher than the frequency in every separate conductor.

By Husson's reckoning the forces of neuromotor origin that make vocal chords to vibrate are approximately ten times as great as the forces of mioelastic origin that are determined by the value of under chords overpressure. This leads to almost absolute independence of frequency of vocal chords oscillations from the change of this pressure value.

Considering this Husson's implication the main one, the disciples of mioelastic theory prove experimentally direct dependence of fundamental frequency of vocalist's voice from sound intensity that singers can't overcome even if they want to do it, and on this foundation they make implication that the Husson's viewpoint is not confirmed.

By Husson the role of neural system consists immediately of the control of rhythmic contraction of muscle fibers of vibrator.

From point of view of disciples of mioelastic theory [2] "the neural system regulates the frequency of vibrator by means of more complex, indirect way, i.e. by the way of providing such acoustic mechanical conditions for vibrator that it generates the sound of a certain and not the other frequency. And the system of biological feedbacks on the basis of … auditory, vibrational, proprioreceptor analyzers that signal the central neural system about the state of sound production organs as well as the results of its activities is of great importance".

One can't disagree with the point of V.P. Morosov [2] about the complex biophysical nature of mechanism of regulation of fundamental frequency of voice, at the same time one shouldn't ignore the actual findings of Husson which are refuted by nobody.

Therefore one can't be silent about discovered by Husson innervation of vocal muscles.

Rather the discovered impulses should be considered as controls of one of the mechanisms of frequency regulation, that strengthen the return of vocal chords to closed state, functioning together with the force due to Bernulli's effect. This allows to control the speed of contraction and gives opportunity to regulate the frequency of vibrations with little efforts, i.e. in energetically more profitable way, by means of more or less earlier chords contractions.

As it is known the spectrum of a signal modulated by amplitude in the easiest case when the carrier and modulating oscillations are sinusoidal, contains apart from the carrier component also two lateral constituents with combinational frequencies that are computed as sum and difference of carrier and modulating oscillations frequencies.

In our case the fundamental frequency oscillation plays the role of carrier oscillation.

It is easy to see that discrete components of spectrum of envelope form combinational products with frequencies of harmonics of fundamental frequencies in the high lateral band of spectrum of a vowel, and spectrum of low lateral band overbends in the point of 0 Hz.

As it is known the spectrum of frequency modulated signal is theoretically infinite. The view of FM signal spectrum with harmonic modulation depends greatly on the index of FM $m = ù_d / ù_m$, where $ù_d$ is devialation (amplitude of change) of frequency, and $ù_m$ is modulation frequency.

In the FM signal spectrum in each lateral band they usually consider m+1 spectral constituents (instead of 1 in the case of AM) that are situated on the frequency axis with an interval equal to modulation frequency. Thus the frequencies of components of FM signal spectrum are the same as in the spectrum of AM signal, but they are much more numerous. This is accounted for the fact that the FM index of measured by us vowels sometimes reached high enough values.

Thus if the central neural system tries to control the instant phonation frequency then right after the operation the discordance of mechanisms of phonation that previously functioned accordingly explained by mioelastic theory and neuromotor mechanisms of control of frequency of vocal chords oscillations. I.e. acoustic mechanical features of oscillation system of voice apparatus of human cause the instant value of fundamental frequency that differs conspicuously from the desired. And desired value is controlled by innervation of vocal muscles, i.e. forces its contraction with other period.

This discordance of phonation systems accounts for the presence of bifurcation harmonic components in vowel's spectra.

From the point of modulation theory the process of neural control of phonation frequency can be considered as a process of frequency modulation in which neural impulses: 1. determine the necessary moment of relax of such part of each vocal muscle that cause the generation of sound of desired frequency, and also 2. determine the moment of contraction of vocal chords for its closing after each impulse. I.e. they determine the period of oscillations by means of change of elasticity of vibrating part of vocal chords.

Thus the spectra of vowels phonated by healthy people can be accounted for (obtained from) not only by means of traditional way of decomposition of air pressure oscillations into spectrum components, but also from the viewpoint of the modulation theory. Standing only on one phonation theory basis one can't explain the observed in the spectra of vowels produced by operated people bifurcations of discrete constituents in which there is preserved the constant frequency interval that doesn't depend on its position on the frequency axis higher of the fundamental frequency.

The all said above gives the opportunity of introducing into the scientific consideration the modulation theory of voice production.

R E F E R E N C E S

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