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Review Article

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Simultaneous Hearing of Polytones

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ABSTRACT
The paper deals with a very difficult topic of hearing, which consists in simultaneous reception by the auditory receptor of an unlimited amount of information encoded in a sound wave. The received information is processed in the auditory cell and transmitted to the brain. The signal path must be as short and fast as possible, without the multiple energy transformations described in the traveling wave theory. The molecular mechanism of hearing, described in submolecular theory, refers to the transfer of energy to the receptor, as well as the conversion of the mechanical energy of the sound wave into the receptor potential and further into the action potential.

The submolecular and electronic levels enable the simultaneous transmission and reception of an unlimited amount of information in the form of encoded, quantized sound wave energy.

Mechanism of Hearing

A sound wave is a vibration of environmental particles propagating in an elastic medium (air, water, solids) [1]. The source of sound is a vibrating body that transmits vibration energy to the particles of the environment, and these particles vibrate around their equilibrium position. Sound is heard and recognized correctly by the human ear when all wave parameters are preserved. The frequency is between 16 Hz and 20 kHz; the intensity is between the hearing threshold and the pain threshold. The length of the sound wave in air is from 18 m to 1.8 mm. In other mammals, the hearing range is wider, even up to 100 kHz. For the sake of voice, the state of sound waves is complicated by the process of formation, anatomy, genetics, resonators, respiration, phonation, articulation [2].

The transmission of information concerns amplitude, frequency, harmonic components, length of sound, melody, accent, phase. For analysis, polytones and listening to musical concerts are taken, when 50 or 100 musicians simultaneously generate sounds of different intensity, different frequency and various other components. (Ludwig Von Beethoven – Symphony No. 9 – 53 musicians, Gustav Mahler – Symphony No. 8 – 160 musicians!).

The problem is how so much, so diverse information encoded as wave energy – simultaneously reaches the receptor, is received, transmitted to the auditory cell and to the brain, where a faithful representation of the music being listened to is created [3,4]. This representation is saved, it can be played back, even after some time. A trained musician can recognize instruments that make individual sounds, which indicates that the sound wave produced reaches the receptor unchanged.

Theoretically, there must be the possibility of transmitting and receiving the waves generated by a given instrument, unlike others.

Air plays an important role in hearing as a medium for sound waves. The air molecules are in constant motion, temperature

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dependent, and the energy generated by the sound source (music, larynx in the case of speech) is superimposed on this movement. Wave superposition — this is an important moment of transmission, it is the phenomenon of superimposition of at least two waves at the same point in the medium, consisting in the addition of their intensities, creating a resultant wave. The component waves of the superposition move unchanged after leaving the interaction, just as they did before the superposition.

Particles have: an electric charge, or are neutral, they have: rest mass, mechanical momentum, magnetic momentum. The steady state is the minimum energy of a particle before receiving external energy (sound wave) [5].

The atoms in the molecule are linked by chemical bonds.

Molecule diameter = 2 x 10-8 cm - is the minimum distance at which 2 molecules of the same gas approach each other during a collision of molecules.

The section between collisions is the free path. A molecule collides in a second 2.3 x 10^9/s = 2 billion/s, Diameter of an air molecule = 2 x 10^{-7} mm, Nitrogen 3 x 10^{-7} mm, Oxygen 2.9 x 10^{-7} mm, CO2 3.3 x 10^{-7} mm, Hydrogen 2.3 x 10^{-7} mm. Mean free path 2.1 x 10^{-4} mm = 1000 molecule diameters In 1 cm^3 of air there are 2.7 x 10^{19} to 2.7 x 10^{21} molecules (2.7 trillion to 2.7 sextillion).

The change in momentum is equal to the added impulse and consists in accelerating or decelerating the momentum of particle. The added impulse (energy) the molecule transmits to the next molecule, while it itself returns to the basic energy level. There are about 1 billion such collisions in 1 s. A sound wave in air travels at 340 m/s. This means that approximately 3,000 air molecule collisions occur within a space of 1 mm. Regardless of the number of collisions, the energy transmitted to subsequent particles, encoding information, does not change, even after a change of environment to the auricle, eardrum, ossicles, soft tissues or the cochlear bone casing. The information contained - encoded in the energy transmitted from the sound source to the receptor does not undergo transformations (contrary to Bekesy's theory) and distortions.

Vibrations occur around an equilibrium position – kinetic energy and potential energy are exchanged – this is the total energy. Vibrations are the oscillations of individual atoms that add up to form the oscillations of the molecule. The second vibration is the rotational movement of atoms that changes the angles of chemical bonds. Every change in oscillation, rotation, and change in bond angles is associated with a corresponding portion of energy. This is how the energy encoding information is transmitted from one molecule to the next molecule all the way to the receptor. Each molecule can accept and transmit an amount of information proportional to the square of the number of atoms in the molecule. A 10-atomic molecule can accept and transmit 1010 changes of energy — that is, so much information at once. The transmission of information between molecules takes place at the electronic level - electron clouds [5]. The transmission takes place in attoseconds = 10-18 seconds. This ability to transmit a huge amount of information simultaneously makes it possible to listen to such symphonies.

The second problem is the transfer of information from the sound wave to the auditory cell receptor - it takes place on the same principle. Sound wave molecules endowed with additional energy—that is, information—transmit information to competent sound-sensitive molecules. There is a genetically determined ability of the receptor to receive energy at a certain frequency.

The receptor receives the mechanical energy of the sound wave and converts it into the energy of the chemical bonds of the sound-sensitive molecules and then into the receptor potential, by regulating the openness of the potassium mechanosensitive channel in the membrane of the auditory cell.

The energy encoded in sound wave is quantized, meaning that an integer multiple of a quantum of energy represents one piece of information. The amount of such separate energy packets is unlimited in the sound wave that reaches us. The number of molecules that receive information in the receptor is genetically determined and distributed in the organ of Corti along the basilar membrane. The capacity of each molecule carrying information depends on the number of atoms that make up the structure of the molecule. The amount of information a molecule can hold is proportional to the number of atoms that make up the molecule. A 10-atom molecule can hold and carry 1010 pieces of information. With 20 atoms, this is 1020 pieces of information. These are unimaginable possibilities. A 4-atomic molecule can accept and transmit 10,000 pieces of information. A 5-atomic molecule can already carry 100,000 pieces of information, a 6-atomic one million, etc.

Information is generated both in voice and music at the same time, with different intensity, quantity and volume of information. But in aggregate, the amount of information produced is less than the ability of environmental molecules to absorb information (air in 1 cm3 2.7 sextillion molecules). A molecule with basic energy has the ability to accept external energy in the form of energy quanta, and when it collides with another molecule, it gives off energy to the molecule, which, when colliding with the next one, gives off to it the excess energy that it previously received. There are 10 billion such collisions of molecules with information transfer per second. In this way, the sound wave reaches the auricle and the eardrum. It is then transmitted to the ossicles, temporal bone and labyrinth housing until it reaches the receptor. The energy of the wave reaching any point of the environment becomes the source of a new spherical wave. The sound wave absorbed by the auricle and the eardrum undergoes constructive interference with the energy transmitted through the connection of the ossicles with the housing bone, and especially with the wave energy transmitted from the stirrup plate to the bone [6].

Low frequencies transmitted to the cochlear fluids are transmitted through the fluid, soft tissues and bone to the receptor. The receptor receives information by converting the mechanical energy of the sound wave in a molecular and electronic manner through conformational changes of sound-sensitive molecules into a mechanism that regulates the flow of potassium ions from the endolymph into the interior of the hair cell, initiating the depolarization of the hair cell.

The thesis of simultaneous depolarization of OHC and simultaneous contraction of the whole cell for each wave frequency is questionable. Cell depolarization depends on ion channels in the lateral and lower walls of the hair cell. The described operating cycle of ion channels does not ensure hearing up to 100 kHz. Nor does it ensure simultaneous hearing of an unlimited amount of auditory information.

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