MATHEWS

Mini Review

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New Significant Remarks on Bekesy's Theory of Hearing

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MINI-REVIEW

The remarks concern the reception of speech perfectly modeled in the organ of speech. Discussing these procedures requires separate paper. A huge amount of information is encoded in the generated sound wave and sent to the hearing receptor, where it is received and transmitted to the hair cell. This is where the initial analysis takes place and the transmission to the centers in the brain [1]. The path of the signal is long, complicated, and the transmission must be fast and accurate [2]. There are several ambiguities in the description of this path according to Bekesy's traveling wave theory.

Many of these have already been discussed in previous papers on hearing [3]. In this work, I would like to draw attention to facts that have so far been overlooked.

Voice recognition consists of many elements encoded in a sound wave. The smallest element heard is a sound, which is divided into vowels and consonants. Sounds form words. There are gaps between sounds and words. The consonants have different durations: plosives - voiceless - 70-95 ms, fricatives - 65 ms, plosive-fricative - 67 ms, voiced - 82 ms. The duration of vowels depends on the position of a given vowel. Vowels before a syllable are on average 60-80 ms. Vowels before a pause last on average 95-118 ms. The sound properties of speech overlap with the word sequence of speech. This gives language an emotional meaning. It is the accent, intonation, length of sound and melody that express emotions by changing the modulation of the voice. Accent is achieved by pronouncing a given phrase louder, increasing its duration, or increasing or decreasing the frequency. Accent can be dynamic, rhythmic, or melodic. In Polish language, the penultimate syllable is usually stressed. Long words sometimes have double stress. The main stress is on the first syllable and the second stress is on the penultimate syllable, e.g. in the Polish word "***praw***dopo***do***bnie" (probably). A given syllable can be strengthened by increasing its frequency or by increasing its duration. In an interrogative sentence, the ascending melody is important - it is a change in voice modulation to express emotion.

This information is stored in the sound wave. Can it all be encoded in the way that was mapped out 96 years ago? According to Bekesy's theory, thanks to wave resonance, information is transferred to the basilar membrane and forms a traveling wave, growing from the oval window to the cap. There are a few problems emerging here: The sound wave is

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a longitudinal wave and the wave on the basilar membrane is a transverse wave. If we draw the vectors of the forces of these waves, then the addition of vectors is not so obvious. The natural vibrations of the basilar membrane were incorrectly determined. The load on the basilar membrane caused by the massive organ of Corti lying on it was not taken into account. The resonant frequency depends on the magnitude of the resistance forces in the system. Damping increases with vibration frequency, and also increases with vibration amplitude. If the fluid in the tympanic cavity - on one side of the eardrum causes an attenuation of about 30 dB [4], how much attenuation does the fluid on both sides of the basilar membrane adhering to the basilar membrane 24 hours a day cause? Bekesy erroneously assumed for his calculations that the sound wave travels on both sides of the basilar membrane and pressure differences give rise to a traveling wave. He did not take into account the Reissner's membrane, connecting the atrial duct to the cochlear duct. There is also the problem of the difference in the speed of the sound wave in the cochlear fluids - 1450 m/s and the speed of the traveling wave on the basilar membrane - 8-100 m/s, depending on the frequency. If the average speed of the wave traveling on the basilar membrane is assumed to be 50 m/s, then in 1 ms the sound wave travels 1450 mm, and the wave on the basilar membrane moves 50 mm. New information is recorded on every millimeter of sound wave. Is it possible to accurately record on a wave 30 times slower? How is this information encoded by the traveling wave crest? [5].

We hear female and male voices at the same time, differing in frequency and intensity - how strongly damped resonance works in such a case. How does the basilar membrane encode this? How does the enormous package of information occurring simultaneously encode the endolymph fluid driven by basilar membrane movements consistent with the amplitude and frequency of sound? A greater difficulty arises in the case of polytones. The possibility of amplifying quiet tones by the contraction of outer hair cells seems unlikely. A sound wave is not a simple harmonic wave of constant intensity and constant frequency. The mechanism of mechanical signal amplification is time-consuming and energy-intensive.

After many milliseconds, there is a completely different wave on the basilar membrane, it may not require amplification, but the new energy added disrupts the transmission of the wave that is on the basilar membrane at that time. A wave below the auditory threshold cannot be amplified by this method, because the wave does not have the energy necessary to depolarize the hair cell. If quiet sounds are amplified by 30 dB, why do we still hear them as quiet? The amplification of the auditory signal at the molecular level in the hair cell is described. It refers to a signal that has been received, but with too little energy to reach the brain [5]. In the case of a cochlear implant due to partial deafness, the insertion of electrodes into the tympanic canal immobilizes the basilar membrane. This prevents the formation of a traveling wave, cochlear fluid flow, tilting or bending of the hairs of hair cells, and the tip-link mechanism is completely disabled. Hearing is still as it was before the surgery. This indicates the existence of a different pathway for the auditory signal to the receptor. This issue was discussed in the paper "Submolecular theory of hearing" [5]. The sound wave's resonance with the transverse wave of the basilar membrane is opposed to hearing sounds lasting tenths of a millisecond, when one or two periods of the sound wave are unable to transmit information to the basilar membrane [6,7].

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