ABSTRACT

Article of A.A. Benditsky and A.A. Kovalev

CONTRAST BETWEEN LIGHT AND SOUND WAVELENGTHS PERCEIVED BY HUMANS

A quantitative interrelation between the physical parameters of electromagnetic and acoustic waves perceived by the sight and hearing organs of a human has been discovered. It is shown that visible light wavelengths can be correlated with the range most used by humans for acoustic communication, including, in particular, verbal dialogue. It is shown, that maxima of spectroscopic sensitivity of the eye receptors are placed on the scale of wavelengths like musical consonance intervals (the small third, major third, quart).

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Optical and audio channels are the main paths through which humans acquire information about the surrounding world. Normally, comparing these two channels, attention is paid to their differences: different resolution, information capacity, etc. (see, for example [1]).

However, comparison of some physical features of optical and sound waves gives unexpected results. It turns out that in a certain range of audio frequencies, there is an approximate correspondence between the product of the light wavelength λ_l multiplied by the velocity of light in vacuum c and the product of the sound wavelength λ_s multiplied by the velocity of sound v, namely:

$$\lambda_l \cdot c \approx \lambda_s \cdot \mathrm{v}\,. \tag{1}$$

Expression (1) allows the light and sound wavelengths perceived by humans to be brought into correlation. Transform (1) as follows:

$$f_s \approx \frac{\mathrm{v}^2}{\lambda_l \cdot \mathrm{c}}\ . \tag{2}$$

Assuming that in (2) $c = 3 \cdot 10^8 m/s$, $v = 331 m/s$, we find that visible range between $(\lambda_l)_{\min} = 0.4 \mu m$ and $(\lambda_l)_{\max} = 0.8 \mu m$ corresponds to the range of audio frequencies of 456-913 Hz.

The question naturally arises as to whether the relation (1) is casual. Let us try to answer it, considering certain features of how a human intercepts sound and colour.

Let us remember the elements of musical acoustics, in particular how the twelve-tone scale is constructed [2]. The number of the tones constituting an octave is divided into partite intervals. An interval is defined as the ratio (not the difference) of frequencies of the corresponding tones. The ratio of frequencies of the nearest semitones is equal to 1.0595. The ratio of frequencies of the tones constituting an octave, is equal to 2. The quantities of intervals with the same name in various octaves are equal to each other. The range of frequencies used in music, which is close to the maximum, lies between 16 and 7900 Hz (9 octaves, a grand piano). Actually it is limited by margins of 30–4000 Hz, while the speech range is within about 40–3000 Hz.

Let us substitute the frequency values of musical tones in expression (2) and define to what electromagnetic radiation wavelengths they can correspond.

Results are as follows.

1. The visible light occupying the range of 0.4---0.8 micrometers corresponds (according to the relation (1)) to the sound of the second half of the first octave and the first half of the second octave.

2. Each note in the range of 456–913 Hz can be correlated by means of formula (1) with a sector of the visible spectrum according to the dispersion of white light. (On wide sections, there is room enough for three tones in the red and violet wavebands).

3. The acoustic octave which corresponds to the range of visible light is the most usable in music and speech. Let us note that the first formant (resonance) of the human voice lies in the range of 400–800 Hz. The frequency of the power maximum of male conjoint speech, 500 Hz [3], also falls in this interval.

The following interesting fact was also discovered. As is known, the maxima of spectroscopic sensitivity of the eye colour receptors are at wavelengths of 420, 534, 564 nanometers, and those of black-and-white glass ophthalmic spatula – at the wave length of 498 nanometers [4,5]. Musical tones corresponding to them under formula (1) appear in parted intervals which approximately coincide with the lengths of known musical intervals: 3 semitones, 4 semitones, 5 semitones. In musical terminology, these are the so-called harmonious intervals, – the small third, the major third, the quart.

Naturally, we have analysed the available literature, and in particular, numerous publications on colour music light shows. We have not found publications in which correspondence between light and sound wavelengths are determined by means of equation (1).

It follows from the above estimates that equation (1) is not a simple numeral coincidence, but reflects features of how human organs of sight and hearing perceive and process incoming information. The following reasons can be cited in favour of such an interpretation.

The lengths of sound waves heard by the human ear are optimum for the functioning of the alternative channel, additional to the optical one: the acoustic information reception channel. In fact, it is possible to introduce the concept of “significant” objects for a human being. It is apparent that the characteristic size of such objects falls in the range from centimetres to tens of metres. These sizes are in the range of sound wavelengths heard by a human. A simple explanation to such correspondence is that the sound with such wavelengths enables a person to hear the invisible. This means that thanks to diffraction, sound within the said range “flows round” “significant” non-transparent objects.

On the other hand, as is known, there is the onomatopoeic theory of the origin of speech. It links the acoustic pattern accompanying any natural phenomenon and its visual perception to the pronunciation by a person of sounds corresponding to that phenomenon. Ancient humans probably found for themselves examples for imitation and repetition of the sound constructions accompanying natural processes. Indeed, the maximum spectral density of the acoustical radiation caused by these phenomena lies within tens of Hz to 3 kHz, i.e. just where the human speech range is [6].

The above explanations quoted by authors, are, of course, of a qualitative character.

The principal results of the work amount to the following.

1. The quantitative relation linking the wavelengths of visible light and audible sound has been discovered, and this relation includes physically comprehended parameters – the velocities of light and sound distribution.
2. It is shown that the lengths of visible light waves correspond (according to the equation (1)) to the range which is the most used by humans for acoustic communication, including, in particular, verbal dialogue.
3. It is shown that maxima of spectroscopic sensitivity of the eye receptors are placed on the scale of wavelengths as are the musical consonance intervals (the small third, major third, quart). In particular, it enables the influence of colour-and-music synesthesia on a human being to be justified more objectively.

From our point of view, the discovered correspondence between the lengths of light and sound waves can be used in researches of the higher nervous activity of humans.

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