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## Some Basic Experimental Results in Audition

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## SOME BASIC EXPERIMENTAL RESULTS IN AUDITION

A. R. Root

The thesis in which this paper had its inception is founded in the proposition that in explaining the nature of hearing, it is extraneous to consider the complex or compounded wave as a synthesis of partials; that reference to the nature of the complex wave itself is adequate. A series of experiments has been conducted with a large number of accurately constructed siren discs. When two holes are cut upon a disc with a space between them corresponding to one-thirty-sixth of the circumference, for example, and the disc is rotated at a rate of not less than one r. p. s., a single discrete sound is heard. Designating the distance or time-interval between two such holes as an "impulse-period," we have derived the following principles which have repeatedly been verified within the limits of frequency rates of 64 d. v. to 1088 d. v.:

(1) A single impulse-period is sufficient to produce the hearing of pitch-quality which is definite and verifiable.

(2) In sounds of short duration in which there is a recurrence of a particular period, the larger the number of consecutively recurring periods, other things being the same, the more tonal or the more dominant is the pitch-quality, the longer the duration and the louder is the sound up to a certain point beyond which a law of diminishing effect is operative, except for the factor of duration. The point at which this law of diminishing effect for tonality and loudness operates varies from two to five periods within the frequency rates investigated.

(3) The sensation of continuous uninterrupted tone is not dependent upon a consecutive recurrence of an impulse-period; gaps or intervals which are multiples of the period may occur between the stimulus-period and its recurrence, and the sensation of tone of the same pitch-quality is still received in *somewhat*<sup>1</sup> the same manner as though the period recurred consecutively. In hearing there is a persistence of excitation within the hearing mechanism itself which accounts for the fusion of discontinuous periods.<sup>2</sup>

<sup>1</sup> This refers to the conclusions under (5) and (6).

<sup>2</sup> This is not in agreement with Kucharski (*C. r. Soc. biol.*, vol. 97, p. 191-193, 1927) who concluded that the abatement of sensory excitation in audition was extremely rapid and that fusion of discontinuous excitations cannot be produced.

Thus it was found, for example, that a period of  $1/180$  second (frequency rate of 180 d. v.) need recur at a rate of but twenty times per second to produce the sensation of a continuous uninterrupted tone of a frequency rate of 180 d. v., and this is not an ascertained maximum limit.

(4) The interval possible between a period and its recurrence in the hearing of a continuous uninterrupted tone varies with the period itself; the smaller the period, the relatively and absolutely longer may be the interval between the recurrence of impulse-periods.

(5) The interval between the recurrence of an impulse-period constitutes an impulse-period of its own which upon regular recurrence produces the sensation of a continuous tone corresponding to its period. By an extension of this principle with that of (3) there may be formed complex recurring patterns of different successive periods in which tones are heard corresponding to each of the constituent periods, the period of recurrence of the entire pattern itself being considered as the fundamental period, the smaller constituent periods producing the sensation of secondary tones, the whole being heard as a pitch-complex or complex tone. Thus large differences in "timbre-quality" can be built up with the same "fundamental" period; chords can be produced where there are not simultaneously recurring periods corresponding to all the tones heard; likewise other sound-complexes of other known kinds can be built up through consecutively differing periods.

(6) Extending (4), the longer the interval between the recurrence of a period the less intense or dominant does the tone from this period become in relation to lower tones produced from the longer intervals which separate it; or positively, the greater the rate of recurrence of an impulse-period, other things remaining constant, the relatively more intense and dominant is the tone from this period. There seems to be a process of summation in the internal ear such that rate of recurrence of a period produces changes in the intensity of the tone heard in addition to changes in intensity due to changes in the amplitude of the wave.

(7) When an impulse-period recurs at irregular intervals the sensation of a continuous uninterrupted tone corresponding to the particular recurring period is heard behind the sensation of noisiness.

(8) A recurring difference in intensity, the periods otherwise remaining identical, creates a period of its own which also is

adequate to produce the sensation of a tone corresponding to its period.

(9) The sensation of a continuous, smooth, uninterrupted tone from periods created by intensity differences is not dependent upon a consecutive recurrence of these periods; gaps or intervals may occur between one such period and its recurrence and the sensation of tone is still perceived, although with diminished relative intensity.

(10) Not only the recurrence of a particular intensity difference may create an impulse-period, but there are certain very definite principles operating to produce effective periods between intensities which differ from one another.

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