Discrimination of Pitch in Short Pulses of Sound

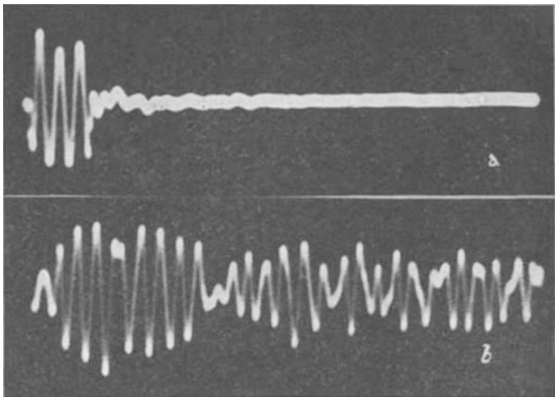
It has been observed, when using short pulses of tone for echo-location in auditoria, that pulses which are too short to give any clear impression of pitch when heard directly from a loudspeaker seem to assume a more definite pitch when radiated into an auditorium. One of us mentioned this point at a recent meeting of the Acoustics Group of the Physical Society, and, as several contributors to the discussion questioned the effect, it is thought that this account of controlled tests will be of interest.

Subjects were asked to adjust an audio-frequency oscillator to the same pitch as that of given pulses of tone, both sounds being received on high-quality earphones and selected at will by a change-over switch. The pulses, provided by a second audio-frequency oscillator in conjunction with a pulse-forming amplifier, were fed to the earphones through four different channels. One channel consisted simply of a variable attenuator, and the other three consisted of similar loudspeakers and microphones in a 'dead' sound measurement room, a normal talks studio, and a reverberation room respectively. The pulse repetition-rate was set at approximately 1 sec., and the length adjusted at each frequency first to 3 cycles, and afterwards to 6 cycles of a given tone. Tests were carried out at six fixed frequencies, and ten subjects took part. The dials of both oscillators were invisible to the subject.

The results were presented as percentage deviations, $|\delta|$, from the true frequency. Plotting on probability paper showed that the distribution of results up to $\pm$ 25 per cent was approximately Gaussian, but the distribution of the small number of errors greater than 25 per cent rapidly became rectangular. This was taken to mean that errors less than 25 per cent were more or less successful attempts to match a recognizable pitch, whereas those greater than 25 per cent represented inability to recognize any pitch at all. These latter were, therefore, noted as 'misses' and excluded from the analysis of the rest.

3-Cycle pulses	Direct	Reverberant	S.D. of difference
Mean of $|\delta|$, all results	13·3	10·35	—
Mean error as percentage of subject's aggregate	28·5	21·7	3·7
Number of misses	31	17	—
6-Cycle pulses			
Mean of $|\delta|$, all results	6·73	5·07	—
Mean error as percentage of subject's aggregate	30·7	19·7	3·8
Number of misses	14	7	—

As no correlation between error and frequency could be found, the mean result for the six frequencies was calculated for each subject under each of the eight conditions. Different subjects showed widely different abilities to match the frequencies of pulse and reference tone, and the means were therefore expressed as percentages of the subject's aggregate score for 3- and 6-cycle pulses respectively. The figures thus obtained were examined to determine the significance of differences between the four channels. No significant difference was found between direct-to-phones- and dead-room-conditions, or between the studio and reverberation room; but there was a highly significant difference (probability considerably less than 0·01) between the first pair (direct) and the second pair (reverberant). The results obtained are shown in the accompanying table.



Pulse oscillograms (*a*) after transmission through dead room; (*b*) after transmission through reverberation room

The spectrum of a continuous tone is a single line; but a tone pulse of finite length has a spectrum the effective breadth of which widens rapidly as the number of cycles diminishes to unity and less. Thus we find mean values of $|\delta|$ for 3-cycle pulses almost exactly twice as much as for 6-cycle pulses (actual ratios 1·98 : 1 for direct sound, and 2·04 : 1 for reverberant sound).

It is not clear, however, why the reverberant sound should give a stronger pitch sensation than direct sound. The reflexions from the walls of the reverberant room cause the short train of waves to impinge upon the ear several times, but there will be no fixed relation between the phases of these repetitions. The accompanying oscillograms are of the headphone signals from the dead room and reverberation room respectively. The breadth of the spectrum of a succession of randomly phased trains is fundamentally the same as that of a single train, and might be expected to have the same effect on the series of elements constituting the cochlea. It is highly probable that the uncertainty of a subjective judgment of frequency in a short pulse is greater than the theoretical limit deduced from the ear mechanism, and the difference of behaviour established by these experiments therefore appears to imply that the brain is capable of making a more accurate assessment of the cochlear response if afforded several opportunities in quick succession.

Increase of reverberation-time beyond a certain point is usually accompanied by prominent eigentones which are shock-excited by the pulse, and thus the room acoustics do not produce further improvement.

This phenomenon, therefore, has implications which do not seem to be fully met by present theories of hearing, and the object of this communication is to bring it to the notice of workers in the field of hearing, to whom it may be new.

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