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ABSTRACT

Measurements were made of the transient response of PDR-8 earphones. These data indicate that the original estimate of the onset-duration of auditory stimuli can be revised downward to 0.8 ms. Implicit in the results is a *caveat* on the faith one should have in the output of commonly used earphones with short- or single-transient inputs.

Onset-duration, the duration below which only cues derived from the onset of a stimulus are effective, was first discussed by Tobias and Schubert[1] in 1959 when they attempted to estimate its size in a study of binaural function. They thought that, for stimuli shorter than the onset-duration, changes in waveform should not be perceptible. Although unable to predict a precise value, they did estimate a maximum limit of about 3 ms. To calculate the 3 ms, they assumed that duration was the sole contributor to the weighting of any stimulus segment, although several other onset-weighting factors must have been involved (primary among these being the well-known on-effect[2] and the effect of time-since-onset on "binaural memory"[3]). However, these factors could not be taken into account because of limitations in the available data.

The next step involves finding the onset-duration directly rather than in the indirect and somewhat cumbersome fashion used by Tobias and Schubert. Several techniques — some monaural, some binaural — are possible. For instance, differentially filtered noise bursts of varying duration might be compared, but there is a strong possibility that short bursts would ring the filter for too long to allow proper control of duration. The use of any filter therefore seems inadvisable in this sort of work. (Indeed, if the onset-duration concept is correct, the perception of "sharp" and "dull" — that is, high and low pitched — clicks results from overly long acoustic stimulation, since any *truly* short click should sound like any other on the sharp-dull continuum.)

A more defensible approach, and the first one used in this study, requires a binaural analysis of the stimulus: two binaural conditions are compared at a number of stimulus durations.

[1] Tobias, J. V., and E. D. Schubert. "Effective Onset-Duration of Auditory Stimuli," *J. Acoust. Soc. Am. 31*, 1595-1605 (1959).

[2] Derbyshire, A. J., and H. Davis. "The Action Potentials of the Auditory Nerve," *Am. J. Physiol. 113*, 476-504 (1935).

[3] Tobias, J. V., and S. Zerlin. "Lateralization Threshold as a Function of Stimulus Duration," *J. Acoust. Soc. Am. 31*, 1591-1594 (1959).

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EXPERIMENTS

It was postulated that subjects would make almost 100 percent correct differentiations between interaural correlation conditions[4] of +1 and 0 for long noise bursts and chance differentiations for short bursts. The division between long and short must be the onset-duration. However, judgments were 100 percent correct for any noise-burst length. Phenomenologically, the +1 correlation stimuli were of course in the median plane; 0 correlation stimuli varied in azimuth, probably because of the random interaural time difference in onset. Judgments were necessarily easy on the basis of the localization.

In the second approach, the troublesome 0 correlation condition was not used; a −1 condition was substituted. Since only the rarefaction half-cycle of the waveform actually serves as a stimulus,[5] some "jumping" of the perceived image (as occurred with 0 correlation) was expected, but instead only the commonly reported separation to the two earphones was noted for the −1 stimuli. Here too, judgments were 100 percent correct at any burst length.

However, these apparently negative results can be used to modify the original onset-duration estimate if some use is made of transducer response. If one assumes that an onset-duration exists and that it is of the order of 1-3 ms, it becomes obvious that the signal must not have been adequately specified for the shorter durations. The clear cause of the inadequacy is poor transient response of the earphones. Specification of the stimulus duration below which the phones refused to behave, then, should give a new upper limit for onset-duration.

The procedure was simple: oscilloscope trace photographs were made of PDR-8 earphone responses to two kinds of transient signals, rectangular current pulses and short noise bursts ("short" ranging from 0.09 to 10 ms). The phones were the ones used in the listening experiments although other phones were tried with similar results. Figure 1 shows the response of a phone to several lengths of rectangular pulse: 2, 1, 0.5, and 0.1 ms. At 1 and

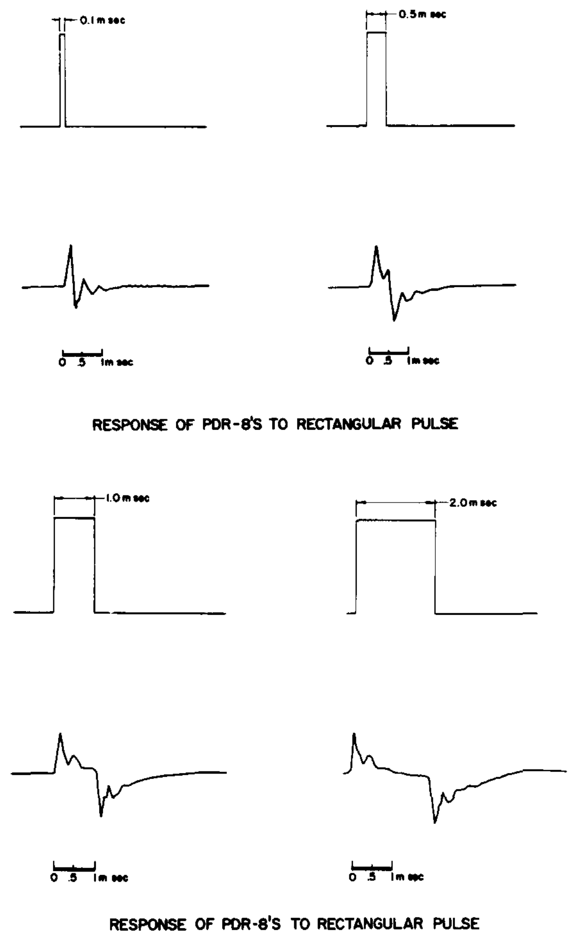

FIGURE 1. Response of PDR-8 earphone to 0.1-, 0.5-, 1.0-, and 2.0-ms rectangular current pulses.

2 ms, the acoustic pattern was the characteristic symmetrical double response – positive following the initial transient, negative after the release. The form of the response was the same for both pulse lengths. For 0.5 ms, the phone started to produce the same output but was unable to complete the first response before the second half started. The very early second half in the 0.1-ms case produced a waveform that looks quite different from any of the others.

[4] Licklider, J. C. R. "The Influence of Interaural Phase Relations upon the Masking of Speech by White Noise," *J. Acoust. Soc. Am.* *20,* 150-159 (1948).

[5] Tasaki, I. "Nerve Impulses in the Individual Auditory Nerve Fibers of Guinea Pig," *J. Neurophysiol.* *17,* 97-122 (1954); and H. Davis. "Biophysics and Physiology of the Inner Ear," *Physiol. Rev.* *37,* 1-49 (1957).

In *all* cases, the acoustic duration was well over a millisecond, and the shortest possible duration (found by measuring the positive part of the 1 or 2 ms waves) is at least 0.8 ms. Thus, even if the signal were an infinitesimally short transient, these phones would respond for nearly a millisecond.

The possibility that noise bursts might behave differently led to similar measurements on gated noise inputs. Figure 2 shows some typical results for noise bursts of 2, 1, 0.5, and 0.1 ms, switched with very short rise and decay times. The 2-ms samples varied from one another much as should be expected for random input, and the acoustic duration, exclusive of the 8-kc ringing, was 2 ms. The 1-ms samples were similar except for their duration which was perhaps 1/2 ms more than the 1 ms of electrical activity. Each of the 0.5-ms bursts actually extended beyond a millisecond acoustically, and the 0.1-ms bursts produced activity for 0.7-0.8 ms. In this last case, the phone seemed to behave almost as if it had been hit by short rectangular pulses of varying amplitude, which is what would be predicted.

CONCLUSIONS

It is now necessary to derive some information from these waveforms to allow a revision of the onset-duration estimate. First, it is worth noting that the contribution of the phone to the stimulus becomes relatively large for inputs of perhaps 1.5-ms duration or less. But the datum which is directly useful is the length (0.7-0.8 ms) of the click-like sound produced by very short noise bursts. In the situation in which stimuli are either interaurally in-phase short bursts or 180° out-of-phase short bursts, subjects can differentiate perfectly between the two conditions. Thus, the onset-duration if it exists must lie below 0.8 ms.

One further point deserves restatement. Since psychophysical experiments of this sort are designed, in effect, to discover interaural correlation problems which cannot be solved in any fashion by the binaural system, it is necessary to conclude that transduction by standard earphones cannot be used. Matched phones will simply *add* similarity to the stimuli at the two ears no matter what the electrical input may be. The more closely the phones are matched, and the shorter the duration of the electrical activity, the worse the problem becomes. Attempts to produce dichotic or incoherent short-duration stimuli are doomed to be confounded by the interaural similarities forced upon the stimulus by standard transducers.

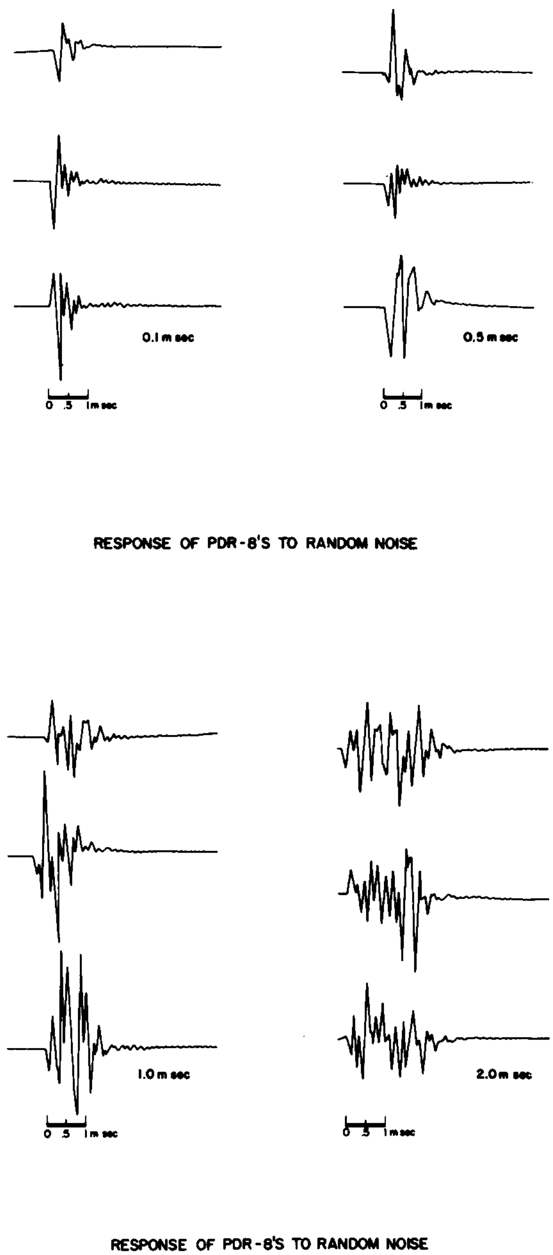

FIGURE 2. Typical responses of PDR-8 earphone to 0.1-, 0.5-, 1.1-, and 2.0-ms rectangular bursts of noise.

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