XII. SIGNAL PROCESSING*

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A. A QUANTITATIVE DEFINITION OF PERCUSSIVENESS

This is a report on a preliminary study of the subjective definition of percussiveness. Sinusoidal tone bursts at 1000 Hz of the shapes shown in Figs. XII-1 and XII-2 were presented to a subject at a repetition rate of one per three seconds. The subject was allowed to listen to each burst as many times as he deemed necessary and was asked to respond to the leading edge by identifying the burst with percussive onset, smooth onset, borderline between percussive and smooth, near borderline but percussive, or near borderline but smooth. For data processing these responses were given numerical values respectively of 0, 10, 5, 2.5, and 7.5. The subject was tested on approximately 20 different bursts of variable rise time (t_r), fall time (t_f), and overall length (T) on each day of testing, and on about 100 different bursts altogether. The testing on subsequent days overlapped so as to permit us to evaluate consistency of the judgments. The shape of the bursts was achieved by sending a sine wave through two consecutive electronic switches; one controlled t_r, one controlled t_f, and the timing of the switches controlled T. The tests were performed at 65 dB SPL, a level chosen by the subject for clear distinguishability without discomfort. Stimuli were delivered through headphones in a quiet room.

The results were classified according to two types of tone bursts: Class I, where T was essentially equal to $t_r + t_f$; and Class II, where $T \geq t_r + t_f + 20$ ms and $t_f \leq 10$ ms. We noticed that for Class I, if we place the averaged responses on a plot of t_r versus T (see Fig. XII-1) the plane of the graph can be broken up into three areas: an area of precisely the value 10, an area of precisely the value 0, and a solid band in between these two which includes all values between 0 and 10.

We analyze the data as follows. Since an average response of 5 can be obtained in various ways (for example, one judgment of borderline, or one judgment of smooth onset and one of percussive, etc.) and since there were, in actuality, very few

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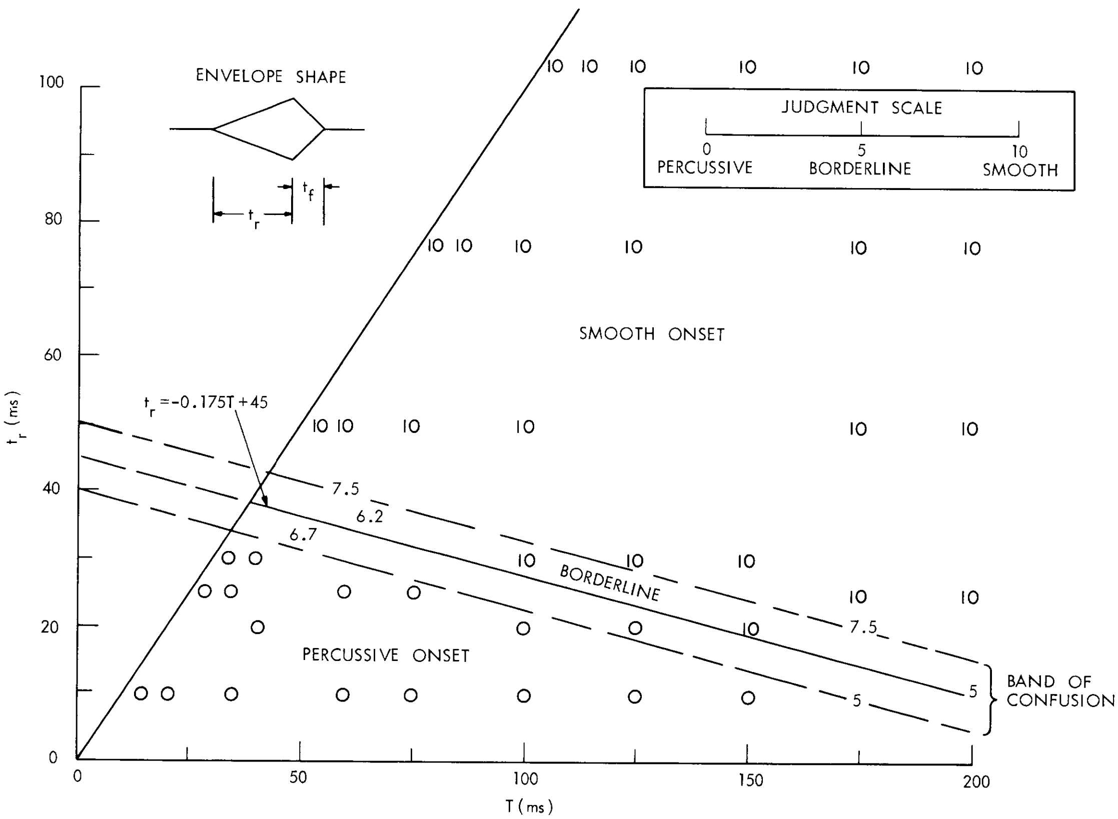

Fig. XII-1. Class I tone bursts.

responses of borderline during the tests, we may choose the center line of the band as the true border. In addition, we noticed that for a given value of T the band is 10 ms wide, and we therefore define this as a band of confusion. Near the center of the band the judgments are difficult to make and not necessarily consistent; near the edges of the band the judgments are difficult but consistent.

In Class II, the results plotted in Fig. XII-2 are more erratic. If we choose to maintain the same true border, the band of confusion must be widened on the percussive side to at least 15 ms. Possibly we could change the border slightly and increase the band somewhat less. It is evident, however, that any modification of Class II is strictly conjectural because of the sparsity of the data.

Our conclusions are:

1. There exists a borderline t_b as a function of T for basically triangular tone bursts.

$$t_b = -.175\ T + 45 \text{ ms} \quad \text{for} \quad T \leq 200 \text{ ms}$$

For $t_r \geq t_b$ we have smooth onset; for $t_r \leq t_b$ we have percussive onset.

2. There is a band of confusion of ±5 ms for any value of t_b.

3. For a given T, either t_b, or the width of the band of confusion, or both, are functions of the burst's shape.

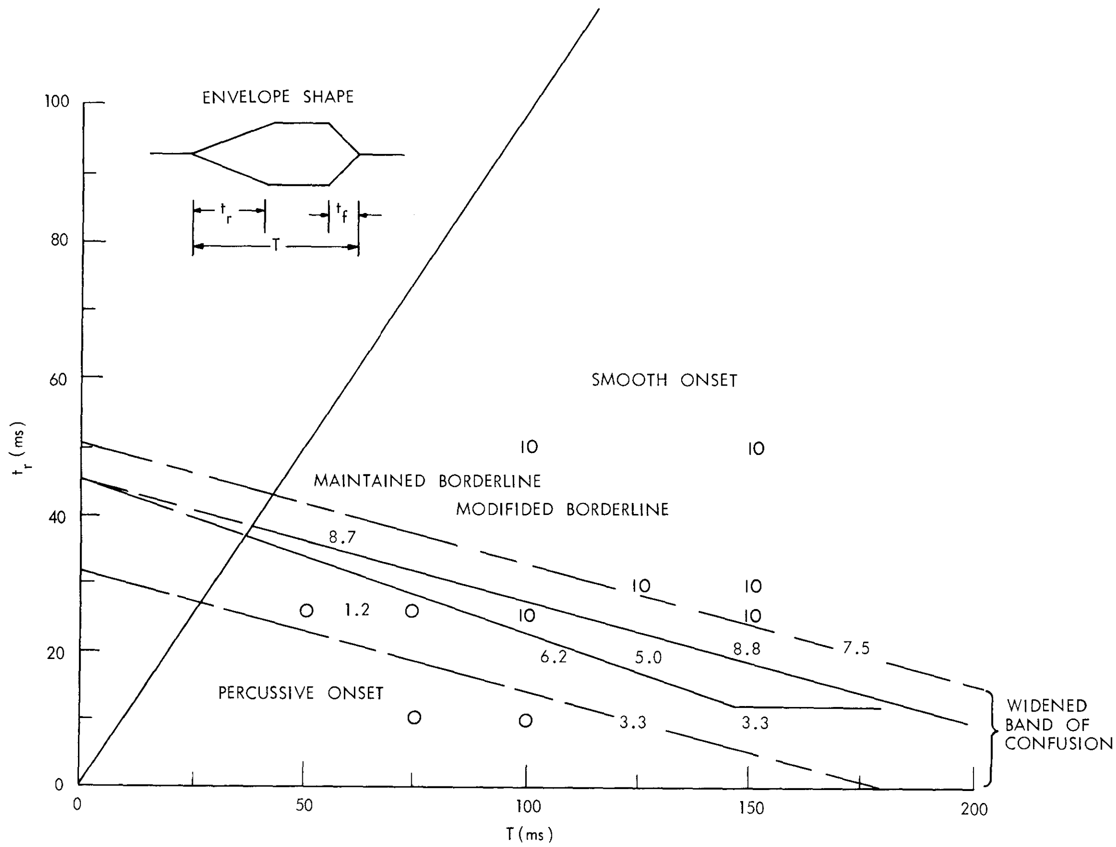

Fig. XII-2. Class II tone bursts.

Although an explanation of the dependence of t_b on T may require more investigation, one possibility is that the subjective judgment of percussiveness may be proportional to the energy concentrations outside of the area of the exact frequency presented. If this is so, shortening the burst length T increases these outside energy concentrations and hence increases percussiveness. This explanation agrees qualitatively with the results. Experiments are planned to see if the agreement is quantitative as well.

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