The effect of rise time on vibrotactile thresholds*

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Thresholds of detectability were determined for vibration over the thenar eminences of six Ss at frequencies of 25 and 250 Hz as a function of the rise times of the envelopes of sinusoidal bursts. The results showed no effect over rise times ranging from 16 microsec to 160 msec, indicating that for long (1,000 msec) sinusoidal bursts the rise time is not an important parameter in the determination of vibrotactile thresholds.

Displacement rise times of sinusoidal bursts used in vibrotaction experiments varies in different studies and often is not reported at all. This parameter of the stimulus is thought to be important in threshold experiments, since the stimulation of the nerve ending within the Pacinian corpuscle is known to be dependent upon some critical velocity of the mechanical displacement (Lowenstein & Mendelson, 1965). Working with encapsulated, decapsulated, and an artificial corpuscle, Lowenstein and Mendelson showed that the capsule transmits fast mechanical transients well, but does not transmit slow transients to the center of the corpuscle where the nerve ending is located. Hill (1967) used 10-Hz square waves with variable rise times to show that psychophysically determined thresholds on skin did shift as a function of rise time. Maximum sensitivity was obtained for rise times of 4 msec or less. Thus, in two experiments differing widely in experimental approach and conditions, rise time emerges as an important parameter. The present experiments were performed to determine the effect of rise time using stimuli most frequently encountered in vibrotactile experiments, i.e., the rise time of pulsed bursts of sinusoids of relatively long duration.

APPARATUS AND METHOD

Detailed descriptions of the apparatus and experimental conditions are given in previous publications (Verrillo, 1963, 1968). Thresholds of detectability for vibrotaction were determined for six Ss using a Békésy recording attenuator. The stimulus signal consisted of 25- and 250-Hz sinusoids pulsed in a time sequence of 1 sec on with a 1-sec interstimulus interval. The threshold measurements were made for a randomly presented sequence of rise times at values of 16 microsec and 4.0, 8.0, 16, 30, 60, and 160 msec.

The rise times were produced by means of a Grayson-Stadler electronic switch (Model 829C), and they were measured directly from the response of a Goodmans (Model 360A) vibrator while it was loaded by a S's hand in the normal testing position. Measurements were made from the output voltage of an Endevco accelerometer (Model 2221) displayed on the screen of an oscilloscope. The accelerometer was mounted directly on the moving element of the vibrator. Rise time was defined as the time in which the signal increased from 10% to 90% of its total amplitude. Rise times measured in this manner are approximately 60% greater than the indications on the electronic switch. The lowest value of rise time (16 microsec) could not be observed directly, so this value was arrived at by increasing the switch marking ("Fast" or 10 microsec) by 60%.

The Ss were located inside a booth that provided insulation against unwanted noise and vibration. Stimulation was perpendicular to the surface of the skin with a contactor size of 2.9 cm^2. The contactor protruded through a hole in a rigid surface which supported the forearm and hand of the S. This served to prevent surface waves on the skin from spreading beyond the locus of stimulation. Measurements were made over the thenar eminence of the right hand. Narrow-band random noise was delivered via insert earphones to prevent the Ss from hearing any acoustic output from the vibrator. Thresholds are reported in decibels referred to 1 micron of peak displacement.

RESULTS AND DISCUSSION

The rise-fall times of sinusoidal bursts at 25 and 250 Hz had no detectable effect on the individual thresholds of the Ss or on the median thresholds taken across Ss. At 25 Hz, the thresholds measured between 13 and 15 dB for all rise-fall times, and at 250 Hz the range of thresholds was between −15.5 and −17 dB. The thresholds obtained are consistent with data reported from previous experiments (Verrillo, 1963, 1966, 1968). There was no observable tendency for the threshold to vary systematically as a function of the rise-fall time.

This is not a contradiction to the findings of Hill (1967) and Lowenstein & Mendelson (1965), since they used rectangular pulses of short duration. It is important to remember that the frequency-sensitive skin receptors respond mainly to the onset and cessation of square-wave signals. Neural firing ceases during the static portion of the signal. This means that for square waves, the effective stimulus occurs during the rise- and fall-time portions of the signal. In effect, the skin receptors respond to short pulses of velocity at onset and offset, and rise time becomes synonymous with effective duration. For a pulse of 4.0 msec duration, the frequency spectrum is effectively limited to a maximum frequency of 250 Hz. For narrower pulses, the effective bandwidth is wider and includes 250 Hz, which is in the region of maximum sensitivity for the skin. This may explain the flat low-threshold portion of Hill's curve. For rise times longer than 4.0 msec, the energy is effectively limited at progressively lower frequencies. The threshold is then determined by frequencies in a region where skin receptors become progressively less sensitive. This is reflected in Hill's data by an increasing threshold as a function of rise time greater than 4.0 msec. For bursts of sinusoids, the receptors respond to each cycle of the carrier frequency and energy is summated over the duration of the burst. Thus, the threshold of detectability is governed by the carrier frequency of the stimulus and the burst duration. The results reported here are consistent with this reasoning.

The effect of rise time at values between 16 microsec and 160 msec may be ruled out as an important parameter in the determination of vibrotactile thresholds for sinusoidal bursts of long duration (1,000 msec). Under these conditions, the threshold appears to be completely determined by the carrier frequency rather than by the rate of growth of the envelope of the signal. The effect of rise time on stimuli of shorter duration should be investigated systematically.

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