

Vibrotactile poststimulatory threshold shift*

RONALD T. VERRILLO† and RICHARD A. SCHMIEDT
Institute for Sensory Research, Syracuse University, Syracuse, New York

Vibrotactile thresholds of detectability were determined at two frequencies (40 and 150 Hz) and for two contactor sizes (0.005 and 2.9 cm²) before and after a 5-min period of steady Gaussian noise of several bandwidths delivered at an intensity level of approximately 20 dB SL. A duplex system of cutaneous mechanoreceptors may be distinguished, based upon the differential poststimulatory threshold shifts resulting from combinations of adapting stimuli, signal frequency, and contactor size.

The reduction in sensitivity following exposure to stimulation has been investigated on many occasions for all of the sensory systems. Because of its practical importance in everyday life, considerable space in the literature has been devoted to the phenomenon for vision and audition (Cornsweet, 1970; Elliott & Fraser, 1970). By comparison, the volume of literature for vibrotaction is scanty (Hahn, 1968a). The phenomenon has usually been called adaptation, fatigue, or residual masking, which has led to some confusion as to its exact definition and meaning. We have adopted the operational point of view of Zwislocki, Pirodda, and Rubin (1959) and simply refer to the "poststimulatory threshold shift."

We noticed, during the course of several vibrotactile experiments in which masking noise was utilized, that the S's threshold level may be influenced by his immediate prior experience, particularly when a very small (0.005 cm²) contactor area was used. It became apparent that the interpretation of our results depended upon a better understanding of the effects of the prior stimulation. Although a number of attempts had been made to assess the effect of prior stimulation upon threshold levels (Békésy, 1959; Cohen & Lindley, 1938; Hahn, 1966, 1968b; Wedell & Cummings, 1938), the results were not applicable to the experimental conditions in our study.

The observation that the effect was more pronounced for a small contactor area suggested that several receptor populations found in skin (Talbot et al, 1968; Verrillo, 1963, 1966) could be selectively affected. The population of Pacinian corpuscles is frequency dependent above 40 Hz when a sufficiently large contactor (>0.2 cm²) is used and independent of frequency below 40 Hz regardless of contactor size. The non-Pacinian receptors dominate the threshold below 40 Hz for any contactor size and above 40 Hz when very small contactors are used (Verrillo, 1968).

The current experiment was undertaken as a pilot study in order to determine the consequences of prior stimulation under varying conditions of frequency, contactor area, and adapting stimuli. Since the study was exploratory in nature and related to experiments in which a fixed rest period was used, only one point on the recovery curve was utilized. Further investigation will be necessary to establish the entire recovery function for the parameters focused upon in this study.

METHOD

The experimental setup has been described in detail in earlier publications (Verrillo, 1963, 1968). Vibrotactile measurements were made over the thenar eminence on the right hands of three Ss by means of a Goodmans 390A vibrator. The vibrator was positioned so that in the resting position the contactor was pressed 0.5 mm into the skin and had a 1.0-mm gap between the contactor and a rigid support surface.

Displacement of the contactor was monitored by means of a calibrated accelerometer mounted directly below the contactor. The vibrator assembly and S were located within a sound- and vibration-proofed booth. The Ss wore earphones which masked the sound of the vibrator with narrow-band random noise.

Two contactor sizes were used (2.9 and 0.005 cm²) in order to activate selectively Pacinian and non-Pacinian cutaneous end organs. The results of previous research indicate that the response of Pacinian corpuscles is dominant when large contactors are used, while the threshold measurements obtained with a very small contactor are determined primarily by the non-Pacinian neural population.

The signal consisted of a symmetric 1.25-sec on and off pulse train, with a rise-fall time of 10 msec. Wide-band (3-dB bandwidth from 25 to 155 Hz) and narrow-band (3-dB bandwidth from 38 to 42 Hz) Gaussian noise at an intensity level of approximately 20 dB SL was used as the conditioning stimulus. The test, conditioning, and retest periods each had a duration of 5 min. A 1.0-min rest period was interposed before and after the conditioning period to match the time sequence of previous experiments. The same contactor size was used throughout a given sequence which lasted a total of 17 min. The experimental time sequence is shown in Fig. 1. The S's hand remained in place throughout the entire sequence. The control consisted of a sequence in which the conditioning period was silent. The S's task was to detect a 40-Hz or 150-Hz sinusoidal signal before and after the conditioning stimulus using a Békésy recording attenuator.

The shaping of the spectral noise energy was dictated by the frequency characteristics of the several neural populations involved in vibrotaction and by the characteristic of the vibrator. The population of Pacinian corpuscles increases in sensitivity at the rate of 12 dB/octave up to 250 Hz (Sato, 1961; Verrillo,

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†Address: Institute for Sensory Research, Syracuse University, Merrill Lane, Syracuse, New York 13210.

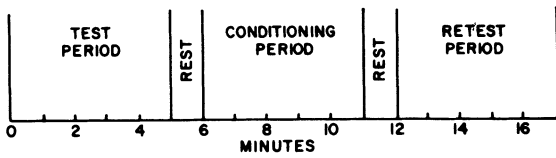


Fig. 1. Experimental time sequence. Vibrotactile threshold measurements at 40 Hz or 150 Hz were made during the 5-min test period and again during the retest period. The intervening conditioning period consisted either of a steady narrow- or wide-band Gaussian noise at an intensity level of 20 dB SL or no noise for the control condition.

1966). The response of the non-Pacinian population is essentially flat across all frequencies (Talbot et al, 1968; Verrillo, 1966). The vibrator response falls off at approximately 6 dB/octave up to 1.0 kHz. In order that all frequency components of the noise have identical subjective threshold levels, the spectral noise energy was shaped by compensation RC networks to yield a constant threshold within ± 0.5 dB (re 1.0 micron peak) for both contactors. The network used with the small contactor compensated for the vibrator response only. No adjustment was needed for the threshold response since threshold is independent of frequency for small contactor sizes (Verrillo, 1963). The network used when testing with the large contactor supplied an additional 6-dB/octave loss to compensate for the increase in sensitivity of the Pacinian population. Voltage adjustments were made at the input to each network to produce a constant voltage output (75 mv RMS), which produced a vibrotactile sensation of approximately 20 dB SL at the vibrator. The resultant total noise energy delivered to the skin was subjectively "flat" in response. Thus, either contactor with its appropriate network yielded the same subjective magnitude at all frequencies within each bandwidth of noise.

RESULTS

Table 1 shows the threshold measurements and threshold shifts obtained by subtracting threshold measurements taken during the test period from those measured after the conditioning period. The data are in decibels referred to 1.0 micron of peak displacement. Thus, positive numbers indicate an increase in the threshold of detectability. A threshold shift of 3 dB is taken arbitrarily as a minimum bound for significance.

Each S was run three times in every experimental condition and average thresholds were calculated. The thresholds reported in Table 1 are the median values for the three Ss. Thus, each threshold value represents the data from nine test sessions.

The results indicated that the control condition, in which no stimulus was delivered, always resulted in an insignificant change in threshold. All other conditions yielded significant poststimulatory effects, excepting only the 150-Hz, 2.9-cm² combination.

DISCUSSION

Assuming that there are two receptor populations in the skin, the results may be interpreted in the following manner:

(1) Since the Pacinian population is dominant when a large contactor is used at frequencies above 40 Hz, it may be concluded that the Pacinian corpuscle is less affected by conditioning stimulation than are the non-Pacinian receptors. This is evidenced in the effect of the 150-Hz, 2.9-cm² condition, which was insignificant in both wide-band and narrow-band cases.

(2) In all cases, including the 150-Hz, 2.9-cm² condition, the wide-band noise conditioning stimulus produced a greater effect even though equal energy conditions existed between narrow- and wide-band noises. It might be conjectured that the receptor firing rate for both populations directly influences the magnitude of the poststimulatory effect, since the wide-band noise contains higher frequencies than the narrow-band noise. It has been shown (Sato, 1961) that it is the displacement cycles of the stimulus above 40 Hz that fire the Pacinian receptor.

(3) Overall, the basic trend indicates that the vibrotactile poststimulatory effect is governed by an interaction between contactor size and stimulus frequency. At 40 Hz the effect is independent of contactor size; at 150 Hz the effect is significant only for the small contactor.

The conclusion that the effect of prior stimulation on different sets of cutaneous receptors may be measured is in agreement with the results reported by Hahn (1968b), who used a different psychophysical procedure to assess the effect of adaptation and recovery over an 8-min period. The differences in the poststimulatory effect between the several populations, which did not appear in Hahn's results, are most likely the result of our having used compensation networks to maintain an equal total energy delivered to the skin under all conditions. Although the effects shown in the experiments are not large, they are consistent both with previous experiments and with the theoretical underlying concepts of a duplex mechanoreceptor

Table 1
Median Threshold and Poststimulatory Threshold Shift for Two Contactor Sizes, Two Frequencies, and Three Conditioning Stimuli

		40-Hz Frequency			150-Hz Frequency		
		Test	Retest	Threshold Shift	Test	Retest	Threshold Shift
Contactor Size 0.005 cm ²	Wide Band	14.5	18.5	4.0	10	16.5	6.5
	Narrow Band	15.25	18.75	3.5	15	18.5	4.0
	Control	15.5	17.0	1.5	13	13	0
Contactor Size 2.9 cm ²	Wide Band	13.5	17.5	4.0	-9.0	7.0	2.0
	Narrow Band	11.25	14.5	3.25	-9.0	-9.0	0
	Control	13.25	14	0.75	-6.75	-6.5	0.25

Note—Values are reported in decibels referred to 1.0 micron of peak displacement.

system in skin. It seems reasonable that the effects would have been more pronounced had the 1.0-min rest period been omitted from the experimental time sequence. The effect of this variable will be studied in future experiments.

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Arousal and memory*

JOHN GORMLY and JOSEPH LALKA

Rutgers—The State University, New Brunswick, New Jersey 08903

The following study was designed to see if the relationship between arousal and recall interval is sufficient to account for data on differential recall of arousing and nonarousing events. Similar studies allegedly support a Freudian model of unconsciously motivated repression. Skin conductance was continuously recorded while 96 undergraduates attempted tasks similar to those which appear in tests of intelligence. Ss attempted the tasks under one of eight experimentally induced conditions designed to produce various levels of arousal. The experimental manipulations, which were intended to create arousal through varying amounts of threat to a person's self-esteem, were not successful in producing differential arousal in high and low threat conditions; all conditions were highly arousing to the Ss. Therefore, the design was not suitable for its intended purpose. There was, however, a significant and replicated relationship between the number of sessions of testing S agreed to attend and arousal across the temporal duration of the first session ($p < .05$ for males and $p < .01$ for females).

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Theoretical research in psychology has often utilized memory as a primary dependent measure. Investigations in the area of perceptual defense have yielded results