# Vibrotactile sensitivity and the frequency response of the Pacinian corpuscle[1]

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*Threshold responses to vibratory stimuli are compared for psychophysical and electrophysiological experiments. There is a striking similarity between the two sets of data. The hypothesis that a duplex mechanism for taction is supported and there is compelling evidence that the Pacinian corpuscle is the neural transducer of vibratory stimuli.*

After a century of investigation and controversy, the question of cutaneous receptor specificity remains open to question. Von Frey (1897) neatly and firmly based cutaneous sensibilities on a foundation of four morphologically distinct types of nerve endings. By 1912 this foundation had been broadened to include as many as 34 separate terminations (Botezat, 1912). In a series of papers the Oxford group (Weddell, Palmer, & Pallie, 1955) brought down this edifice asserting that there was no anatomical evidence that specific end organs exist in mammalian skin.

Using psychophysical methods, Békésy (1940) concluded that vibration and pressure were mediated by separate receptor systems. Geldard (1940) on the other hand, finding a coincidence between pressure and vibration spots, marshalled considerable evidence showing that one set of receptors served both types of stimuli.

In a series of psychophysical experiments on human glabrous skin, the present author demonstrated that when very small contactors are used, the frequency response from 25 to 640 cps is essentially flat (Verrillo, 1963). As the area of the contactor is increased, a family of parallel U-shaped curves is generated with a maximum of sensitivity in the region 250-300 cps. This data has led to the hypothesis that there are two (at least two) functionally distinct types of mechanoreceptors involved in taction: one whose response is dependent upon frequency and one that is frequency independent. A repeat of this experiment on the hairy skin of humans (Verrillo, in press) supports these findings.

The hypothesis of a duplex mechanism for mechanoreception would be strengthened if a receptor responsive to vibration were known. Scott (1951) and others have demonstrated that the Pacinian corpuscle is sensitive to vibratory stimulation. More recently, neural units sensitive to vibration were located in the leg of cat (Hunt & McIntyre, 1960) and identified as Pacinian corpuscles (Hunt, 1961). Those units investigated by Hunt followed the physical stimulus at a 1:1 ratio from about 40 to 90 cps up to the region of 800 cps.

Sato (1961) was able to measure the frequency characteristics of Pacinian corpuscles, *in situ* in the mesentery of cat. His data provide a unique opportunity for comparing the electrophysiological and psychophysical information. Figure 1 compares the frequency response of two Pacinian corpuscles (Sato, 1961) and psychophysical thresholds obtained on the glabrous skin of the human hand (Verrillo, 1963).

Appropriate transformations of Sato's data have been made in order to make them comparable on the same coordinates with the psychophysical data. All of the threshold values are absolute. Threshold for the physiological data was defined as a steady neural firing recorded from the axon in response to direct mechanical stimulation of the intact corpuscle. Psychophysical thresholds were obtained by the method of limits, each data point representing the median of three tests on each of three subjects.

The data show a striking similarity in the general shape of the functions for a large contactor (2.9 $cm^2$) and for the Pacinian corpuscle. Both functions have a slope of about -12 db per doubling of the frequency with a minimum in the region 250 - 300 cps (solid lines), before rising again in the upper frequencies. The psychophysical curve for a small contactor (.02 $cm^2$) is essentially flat (dashed line) and in the lower frequencies (25 - 40 cps) the data for the large contactor also follow a flat curve.

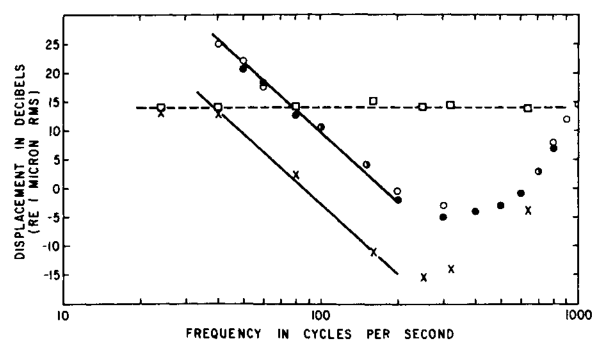


**Fig. 1. Absolute thresholds as a function of the frequency of sinusoidal vibration. ● , 0 - Response of two Pacinian corpuscles in cat mesentery, tested electrophysiologically *in situ* (Derived from Sato, 1961). ▢ , X - Responses of three human subjects, tested psychophysically on the glabrous skin of the hand. Contactor areas: X - 2.9 $cm^2$; ▢ - .02 $cm^2$ (Verrillo, 1963). The slope of the solid lines drawn to fit the data points is -12 db per doubling of the frequency. The dashed line is the curve for the very small contactor.**

In an earlier paper (Verrillo, 1963) this flat curve was interpreted as the response of frequency independent receptors. These receptors dominate the threshold response until a sufficient number of frequency dependent endings can summate spatially, as the contactor size is increased, producing the downward slope of the curve. Békésy (1939) also has recorded a relatively flat frequency function from 0.3 cps to about 20 cps. Since neither Hunt (1961) nor Sato (1961) were able to elicit response from Pacinian corpuscles below 40 cps, it is reasonable to assume that another type of receptor is responsible for the psychophysical threshold at frequencies below the region of 40 cps.

The evidence reported here support the hypothesis that two functionally distinct systems of nerve terminations mediate tactual sensitivity. Both psychophysical and electrophysiological evidence support this hypothesis. When the two types of data are compared on the same coordinates, it is evident that the Pacinian corpuscle, a morphologically distinct terminal, is the nerve ending that determines the threshold response to vibratory stimuli.

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## Note


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