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Intensity discrimination of tone bursts and the form of the Weber function*

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Intensity discrimination functions were determined for tone bursts at four test frequencies: 250, 1,000, 4,000, and 7,000 Hz. Slopes of best-fitting lines (ΔI in dB SL vs I in dB SL) indicate a "near-miss" to Weber's law at all four frequencies. The use of information provided by harmonics of the stimulus is discussed; it is concluded that—at least for high-frequency tones—such cues are not the basis for the improved acuity found at higher sensation levels.

The fact that intensity discrimination for tone bursts does not follow Weber's law has been used by McGill and Goldberg (1968a, b) to support a neural counting model of detection and discrimination (McGill, 1967). Specifically, plots of ΔI in dB SL against I in dB SL (SL = sensation level) were well fitted by linear functions whose slopes were approximately 0.9. (The slopes would have equalled unity had Weber's law obtained.) More recently, Viemeister has proposed that the " 'near-miss' to Weber's law reflects the observer's use of information at aural harmonics" of the test tones (Viemeister, 1972, p. 1265).

Since the studies cited above all used tones at or near 1,000 Hz, the question remains of whether intensity discrimination functions at other frequencies would also show improved discrimination at higher intensity levels. Earlier studies by Harris (1963) and by Campbell (1966) used several test frequencies, but yielded discrepant results. We have computed intensity discrimination functions for the data given in Harris's Table 1. Weber fractions for levels of 20 phons and above were averaged across listeners. Slopes of the best-fitting lines were 1.01, 0.97, and 0.96 for test frequencies of 125, 1,000, and 6,000 Hz, respectively. While these data would appear to support Weber's law, Campbell's results (1966, Fig. 2), with frequencies of 250, 1,000, and 4,000 Hz, are more in accord with McGill's observations of the "near-miss" to Weber's law.

Since the existence of the "near-miss" at frequencies other than 1,000 Hz was in question, and since this issue bears on the choice among possible mechanisms mediating auditory intensity discrimination, we undertook to investigate tonal intensity discrimination at four frequencies between 250 and 7,000 Hz.

PROCEDURES

Intensity difference limens were determined for two Ss, using a two-interval, forced-choice variation of the blocked-trials staircase method. The Ss were young adults, one male and one female, with normal audiograms. Weber fractions, (ΔI/I) corresponding to approximately 75% correct decisions were computed for four frequencies of tone: 250, 1,000, 4,000, and 7,000 Hz.[1] The stimuli were bursts of tone presented at three SLs: 30, 50, and 70 dB. They were presented to the S's right ear through a PDR-10 earphone mounted in a MX/41-AR cushion. Each burst lasted for 250 msec and had a nominal rise/fall time of 10 msec. The interval between the two tone bursts comprising a trial was 550 msec. Indicator lights marked the observation intervals and provided feedback.

RESULTS AND DISCUSSION

Results for the two listeners are presented in Table 1. Weber ratios are given in decibels. Regression lines (ΔI in dB SL vs I in dB SL) were fitted to the data; slopes are given in the last column of Table 1. The data show that, for both Ss, discrimination is more acute at 70 dB SL than at the lower levels. This is so at all four test frequencies. Furthermore, there is a suggestion in the data for the two Ss that the slopes of the regression lines for the 4,000- and the 7,000-Hz conditions are less than those for the two lower frequencies.

That our Ss made significant use of information at harmonics of the test tones seems unlikely. If harmonics produced by the earphone provided spurious information, this should have been most useful at 250 Hz, where the transducer had to be driven hardest

Table 1
Weber Fractions (ΔI/I in dB) and Slopes of Intensity Discrimination Functions for Tone Bursts

Stimulus Frequency (Hz)	Sensation Levels 30 dB	50 dB	70 dB	Slopes
250	−4.5	−7.1	−9.1	0.89
	−4.2	−4.5	−7.8	0.91
1000	−4.9	−6.1	−10.3	0.87
	−5.5	−5.2	−8.8	0.92
4000	−5.6	−6.3	−11.0	0.87
	−1.5	−1.5	−6.9	0.87
7000	−4.0	−5.0	−11.6	0.81
	−3.0	−2.3	−7.8	0.88

Note—For each condition, the upper value refers to δ S1 and the lower value to δ S2.

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to produce the three sensation levels. For example, input signals producing equal sensation levels at 250 and 1,000 Hz differed by 16 dB for S 1 and by 22 dB for S 2.[2] Even if the tones at 250 and 7,000 Hz were equally impure, harmonics within the auditory spectrum are more numerous and more audible in the case of the lower frequency.

A similar argument can probably be made with respect to subjective harmonics. If the "near-miss" is somehow a function of aural harmonics, one would expect this departure from Weber's law to be greatest at 250 Hz and virtually absent at 7,000 Hz. Since this is not the case, we conclude—at least with respect to high-frequency tones—that the "near-miss" to Weber's law can occur in the absence of harmonic distortion.

If harmonics of the stimulus (equipment-produced or aural) are not used by the listener, two other kinds of "off-frequency" information may provide the basis for the better discrimination found at higher levels. These are: listening for "energy-splatter" (Leshowitz & Wightman, 1971), and listening at the edges of "excitation patterns" (Siebert, 1968; Zwicker, 1970). Both mechanisms, as well as neural counting models, remain among the more plausible explanations of the "near-miss" to Weber's law.

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NOTES

1. For a standard intensity, I, the difference limen, ΔI, is defined as follows:

$$\Delta I = I_{75\%} - I,$$

where $I_{75\%}$ is the intensity of the stimulus that is "just noticeably louder" than I. Since ΔI, $I_{75\%}$, and I are all intensities, they can be referred to each other or to some other intensity, e.g., the listener's absolute threshold.

2. System distortion was measured at the output of the earphone as follows: Sound pressures generated in a 6-cm^3 coupler (ANSI Type 1) were transduced by a condenser microphone (W.E. 640-AA), whose output was amplified and fed to a wave analyzer (G.R. Type 736-A). At 70 dB SPL, the second harmonic (the principal distortion component) was approximately −60 dB re the fundamental at each test frequency. Increasing tonal intensity to 90 dB SPL increased the relative level of the second harmonic by 3-4 dB. At 70 dB SL, therefore, there was slightly more distortion at 250 Hz than at the higher frequencies.

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