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Notes on Auditory Sensitivity.

Frequency Discrimination *

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3 Discrimination of Sound Differences

Two sounds that can be distinguished with a specified degree of reliability are said to be *discriminable*. If the sounds differ only in the value of a single physical parameter (e.g., intensity, frequency, duration) the difference in the values of the parameter across the two sounds is often called the *Just Noticeable Difference* or *JND* (sometimes the *Difference Limen* or *DL*) in the parameter. In current parlance, listener’s are said to have a finite *resolution* for the parameter.

3.1 Frequency

Like intensity discrimination, frequency discrimination has been studied using a variety of methods. In the *AX* method (or the classical method of constant stimulus differences) two tone bursts are presented in temporal sequence. The first tone (A) is fixed in frequency. The second (X) tone differs from the first only in frequency: its frequency is greater or less than that of A. The task of the listener is to determine whether the frequency of the second tone is higher or lower than that of the first. In the *ABX* method (Munson and Gardner, 1950), three tones differing only in frequency are presented in temporal sequence. The task of the observer is to determine whether the third tone (X) is more similar to the first tone (A) or the second (B). Surprisingly, most listeners require a greater frequency difference (between A and X, or between A and B) for the ABX than the AX method to achieve a given level of performance.

**Rosenblith and Stevens, 1953**

The results of several sets of measurements of the JND or Difference Limen for frequency are shown in (e.g., Fig. 6). In this Figure, the closed circles represent data taken by the AX method, the open circles the ABX method, data taken by a frequency modulation (Shower and Biddulph, 1931) procedure by crosses, and data taken by a quantal method by squares. Almost all the data lie within the dotted lines, which represent a spread of one decade.

Perhaps more informative are plots of the relative Difference Limen $\Delta F/F$ for both the AX Method and for a frequency modulation technique (Fig. 7). These plots suggest that whereas the relative DL decreases by roughly an order of magnitude between 0.125 and 2.0 kHz when measured by the frequency modulation technique, it varies by only a factor of two when measured by the AX Method.

**Moore, 1973**

The width of the spectrum of a tone pulse decreases monotonically with the duration of the pulse. Thus one might expect that frequency discrimination would be a function of duration. Measurements of the effect of duration on frequency discrimination were made by Moore (1973).
Moore measured frequency discrimination tone bursts that were switched on and off at random phase with 2 ms rise/fall times. Data were taken using a two-interval forced-choice procedure, without feedback. Two listeners were tested using a fixed frequency difference for blocks of 100 trials. Three blocks were measured (on different days) defining one point on the empirical psychometric function. One listener was tested using an adaptive procedure (PEST; Taylor and Creelman, 1967) set to converge on the 75% correct point. The listeners exhibited performance improvements (learning or practice effects) over a period of two weeks of 2 hours per day testing. After no further improvement could be detected, the two listeners who used the fixed procedure were tested for roughly 100 hours and the listener who used the PEST procedure was tested for roughly 200 hours.

Stimuli were presented at a constant (across frequency) loudness level of roughly 50 phons, but the presentation levels of the two tones being compared were not randomized. The measurements of $\Delta F/F$ for the subject who was tested using the PEST method are shown in Fig. 8. Results for the other listeners are essentially similar. Measurements indicate that $\Delta F/F$ decreases as a function of duration for all frequencies, although the changes as duration is increased from 100 to 200 ms are small. For each duration $\Delta F/F$ decreases as $F$ increases from 250 Hz to 2000 Hz, and then increases. For all listeners there is a sharp increase in $\Delta F$ as $F$ increases from 4 to 6 kHz. Moore attributes these results to the use of
place cues only for frequency discrimination at frequencies above 5 kHz, while both timing and place cues are used below 5 kHz.

**Wier, Jesteadt, and Green, 1977**

Data on the effect of intensity and base frequency on frequency discrimination obtained by Wier et al. (1977) are shown in Figure 9. They measured frequency discrimination for 500 ms bursts of tone using an adaptive two-interval forced-choice procedure that converged on the 70.7% correct point. The presentation level of the tones were not randomized. Four listeners received four or five consecutive 100 trial adaptive blocks to measure the frequency DL. Stimuli were presented in a low level (0 dB Spectrum Level) noise that was low-pass-filtered to 10 kHz. The noise raised thresholds by 5–15 dB relative to the ISO standard. Estimates of the frequency DL were obtained at distinct frequencies between 200 and 8000 Hz and over the range 5–80 dB SL.

The data show a large effect of frequency and a smaller effect of intensity on frequency discrimination. The effect of frequency is approximated by the dotted lines in Fig. 9.

\[
\log \Delta F = S(L) + T(L) \sqrt{F}
\]

or

\[
\Delta F = C(L) e^{T(L)\sqrt{F}}
\]

where L is the Sensation Level (in dB). This dependence of \( \Delta F \) on frequency is roughly the same as that found by others who used pulsed tones (Fig. 10), in particular it is fairly consistent with the measurements of Rosenblith and Stevens (1953) and Moore (1973). The dependence of frequency discrimination on sensation level is frequency dependent. While
Figure 8: The JND in frequency for pure tones as a function of frequency and duration. From Moore (1973).

the $\Delta F$ decreases with sensation level for $L \leq 40$ dB, it increases or remains constant at 80 dB SL for $F = 400, 600$, and 8000 Hz, but continues to decrease for the other frequencies tested.
Figure 9: The JND in frequency for pure tones as a function of frequency and sensation level as obtained using an adaptive 2AFC procedure. The abscissa is proportional to $\sqrt{f}$. The dotted line is a fit to the critical band data of Zwicker, Flottorp, and Stevens (1957). From Wier, Jesteadt and Green (1977).

Figure 10: The JND in frequency for pure tones as a function of frequency. From Wier, Jesteadt and Green (1977).
References


