CENTRO DE INVESTIGACIÓN EN TECNOLOGÍAS DE AUDIO
PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE

LOUDNESS

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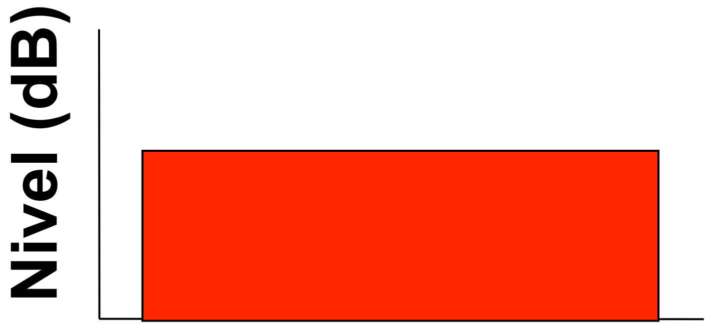
Octubre 2011

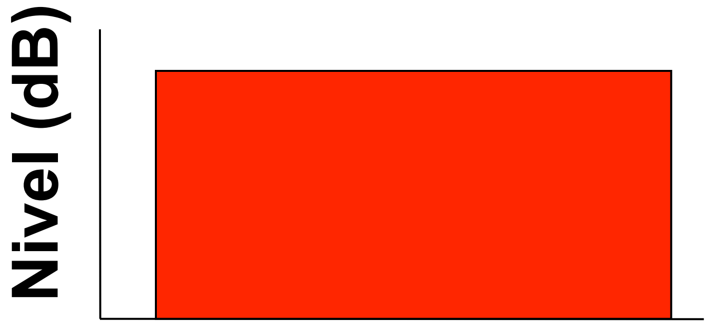
Intensidad y Loudness

Discriminación de intensidad

Intervalo 1



Intervalo 2



¿En cuál intervalo era mayor la intensidad?

Ajustar la intensidad para determinar el umbral

Discriminación de intensidad

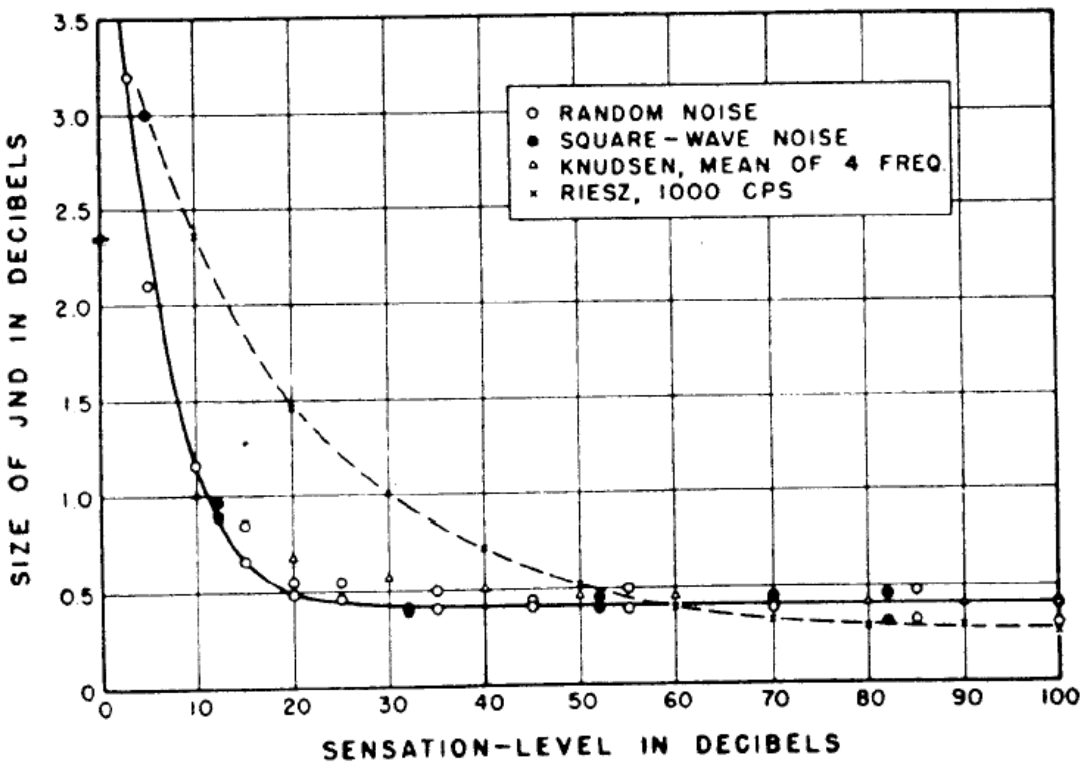
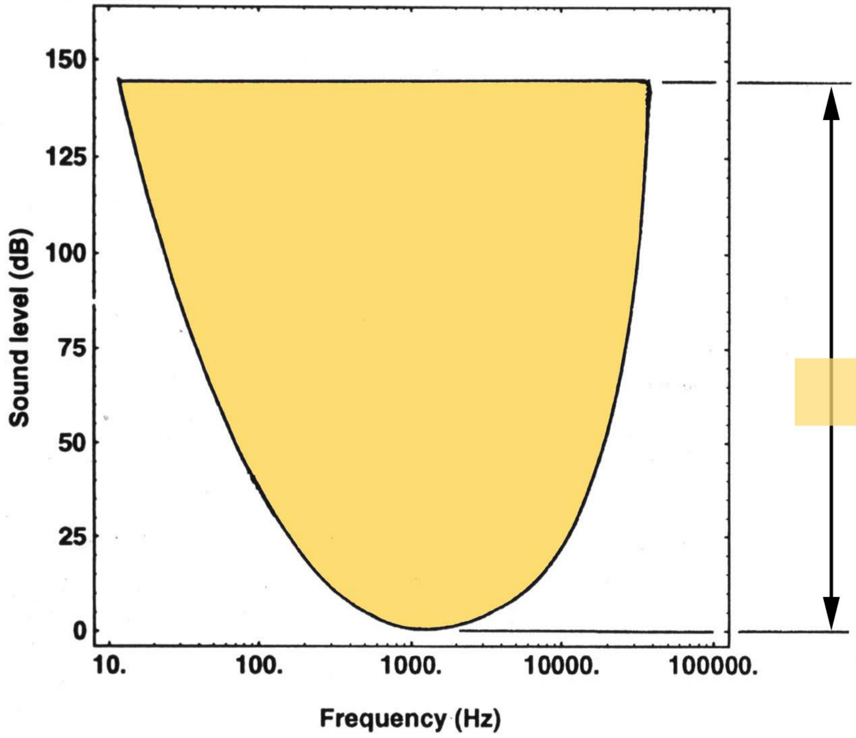
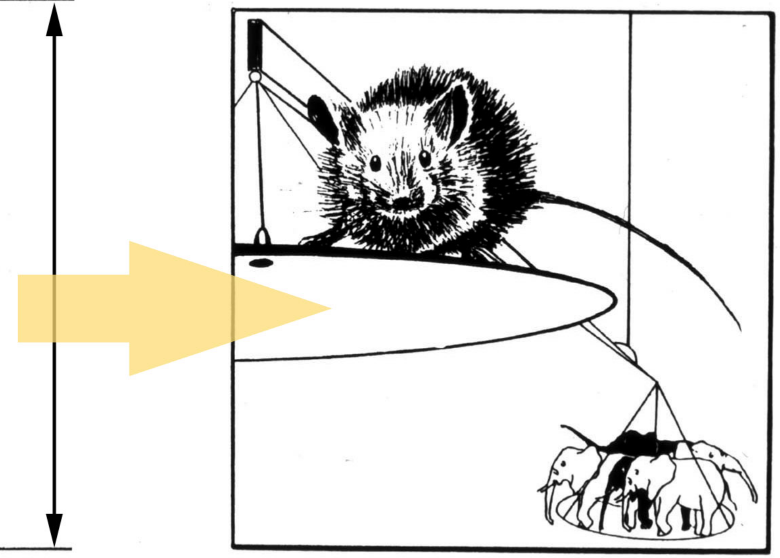


FIG. 3. Increments in intensity heard 50 percent of the time are plotted as a function of the intensity of the noise in decibels above the threshold of hearing. Data for tones are presented for purposes of comparison. The solid line represents Eq. (2).

Miller (1947)

Rango de intensidad





Cortesía de Peter Dallos

Discriminación de intensidad y pérdida auditiva

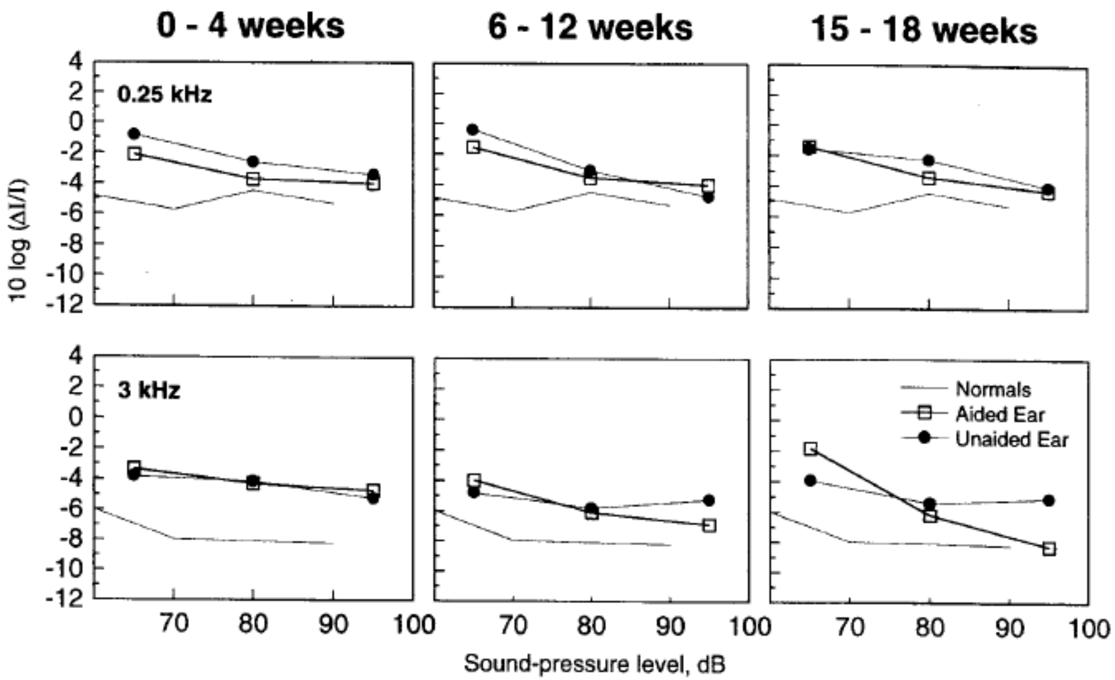


FIG. 1. Group intensity discrimination thresholds as a function of absolute level showing the effect of the amount of experience with the hearing aid. Weber functions for the 0.25-kHz center frequency stimulus are shown in top row of panels, and for the 3-kHz center frequency stimulus in the bottom row. The parameter is the ear, which was either normally aided or normally unaided.

Pérdida bilateral simétrica	<u>Ganancia de ayuda auditiva</u>	
	250 Hz	promedio = 0 dB
	3000 Hz	promedio = 19 dB

Robinson and Gatehouse (1996)

Nivel de Loudness

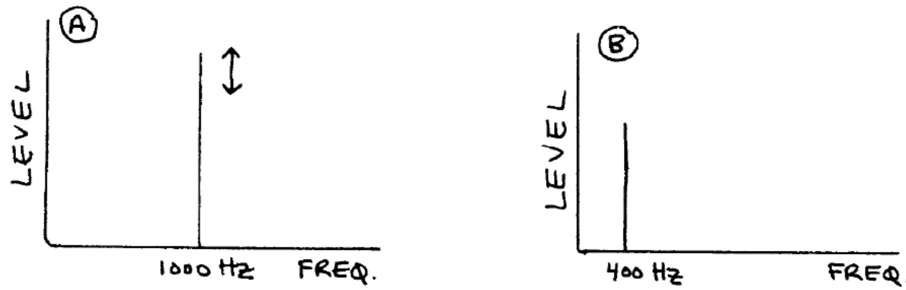
Fono (Phon): El nivel de un tono de 1000-Hz tone en dB SPL que equivale a la loudness de un sonido de referencia

Por ejemplo, si un motor eléctrico es igual en loudness a un tono de 1000-Hz a 65 dB SPL, el motor tiene una loudness de 65 fonos (phons).

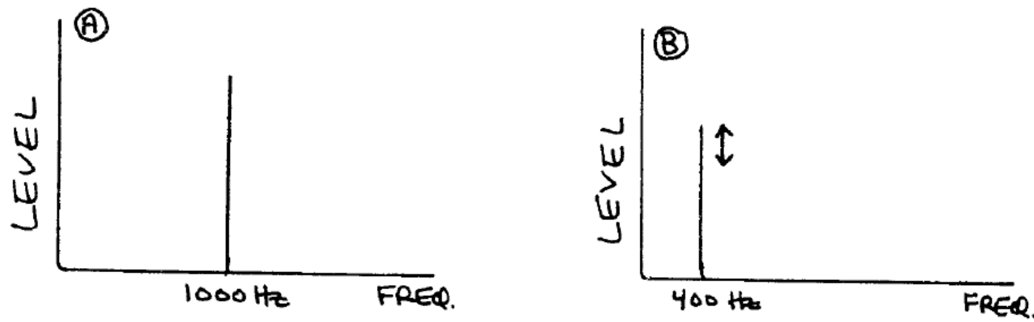
Midiendo fonos

<u>Presentar A y B alternadamente</u>.

<u>Método 1</u>: Ajustar el nivel del tono de 1000-Hz (en A) para igualar la loundess del tono de referencia (en B).



<u>Método 2</u>: Ajustar el nivel del tono de referencia (en B) para igual la loudness de un tono de 1000-Hz (en A).



Contornos de igual loudness (Equal loudness contours)

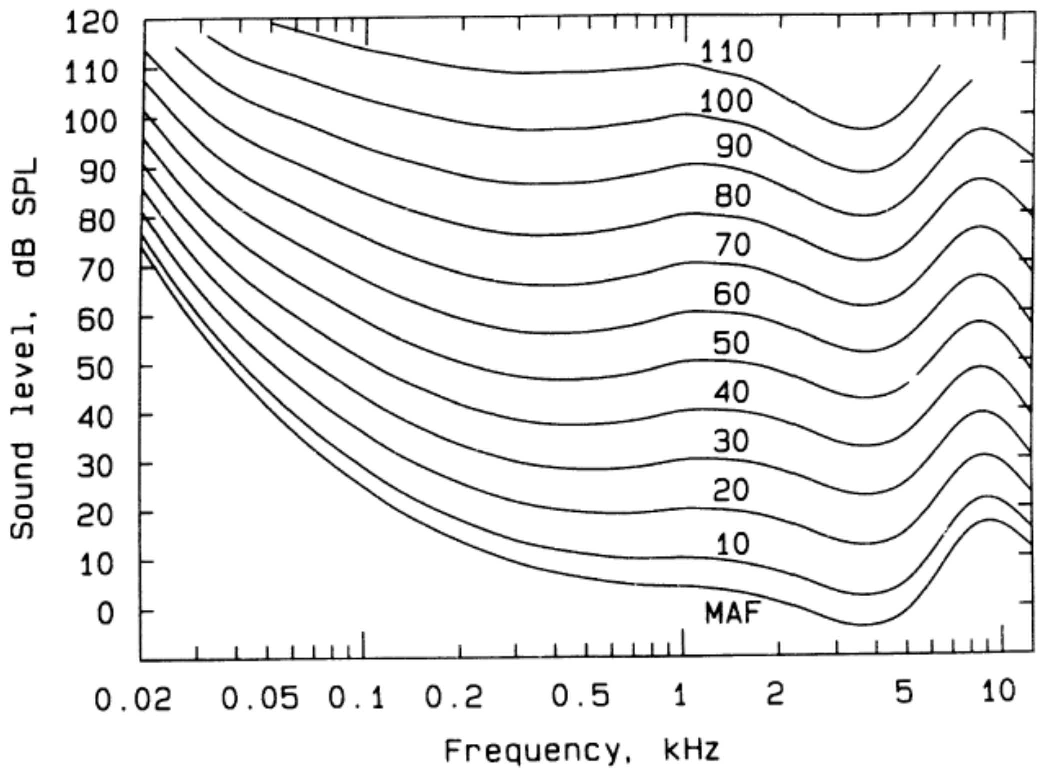
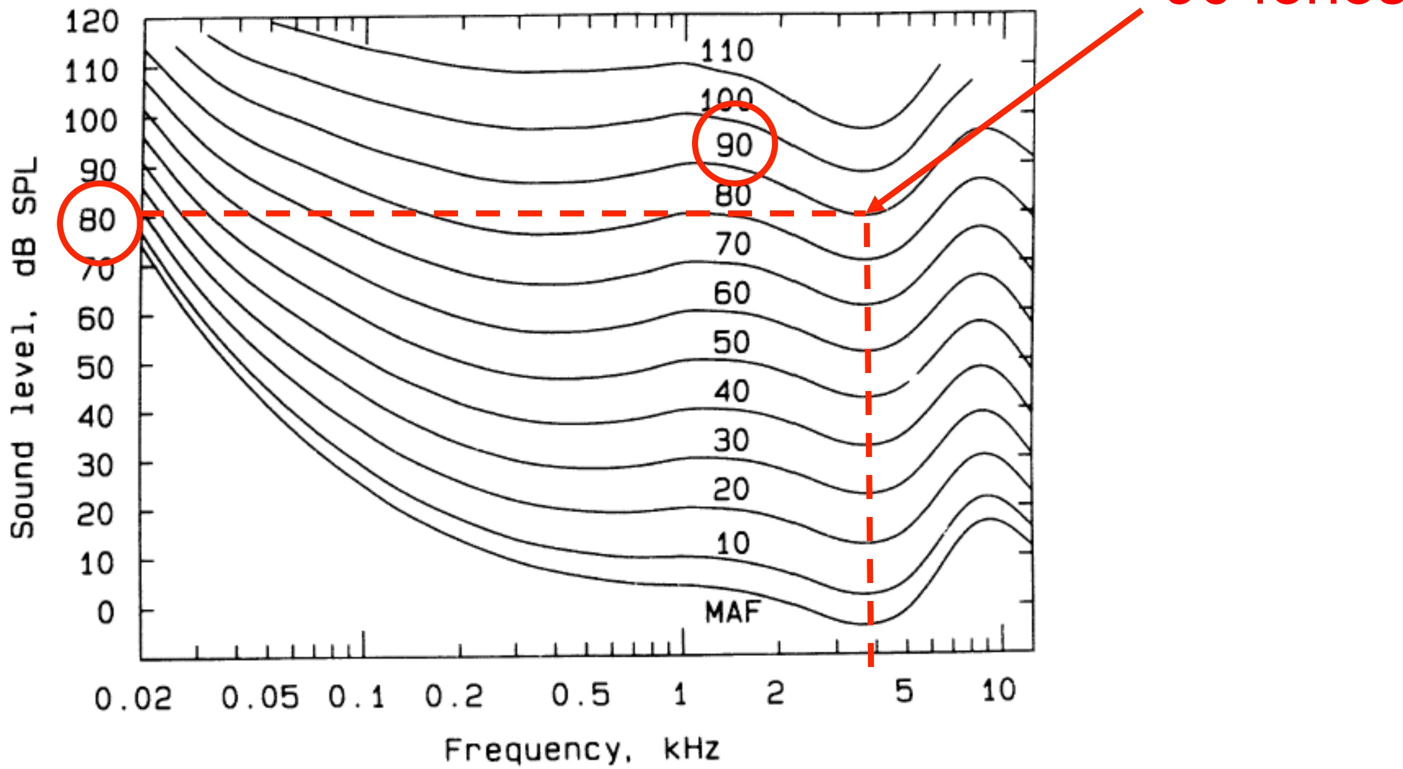


FIG. 2.3 Equal-loudness contours for various loudness levels. The test sounds were presented binaurally from the frontal direction. The absolute threshold curve (the MAF) is also shown. Data from Robinson and Dadson (1956).

Contornos de igual loudness (Equal loudness contours)



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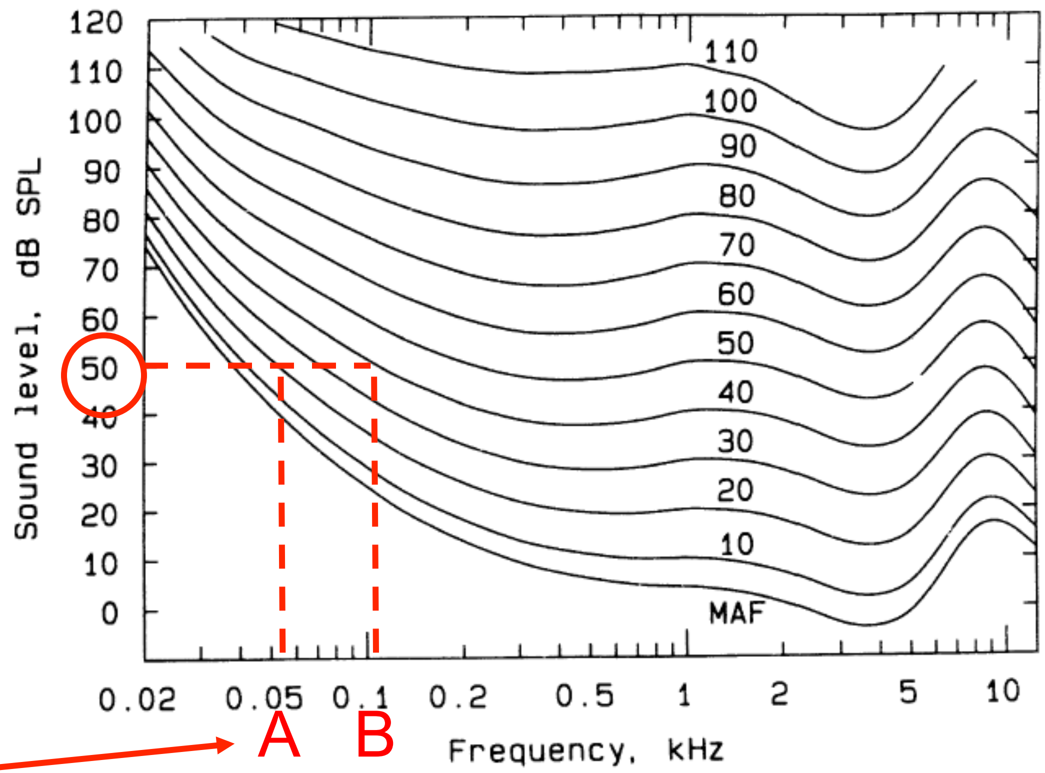
Contornos de igual loudness (Equal loudness contours)

¿Cual tono es más intenso?



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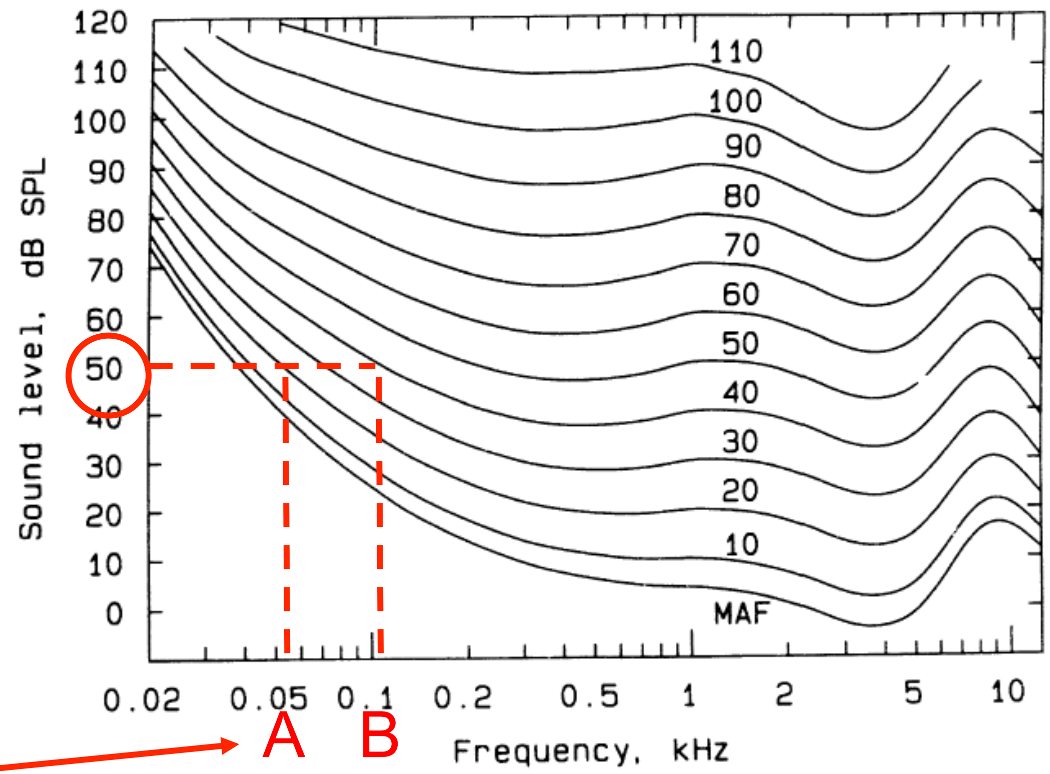
Contornos de igual loudness (Equal loudness contours)

¿Cual tono suena más fuerte?



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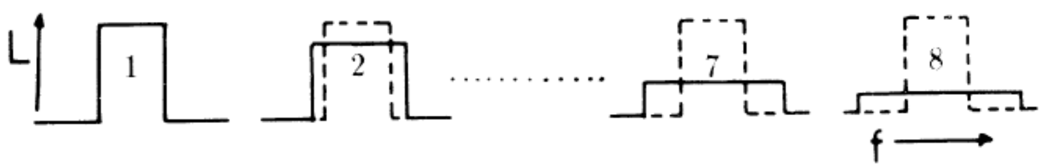
Sumación de Loudness



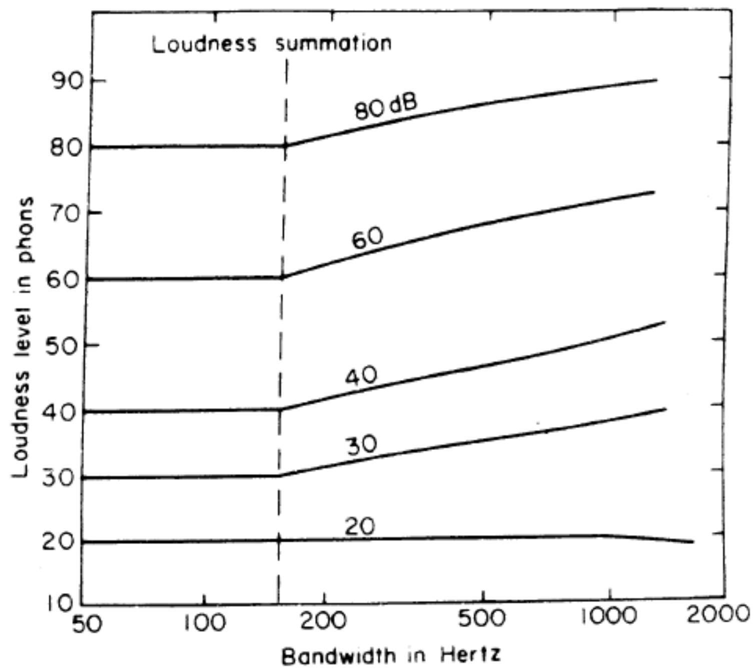


FIG. 3.2 The loudness level in phons of a band of noise centred at 1 kHz, measured as a function of the width of the band. For each of the curves, the overall sound level was constant, and its value, in dB SPL, is indicated in the figure. The dashed line shows that the bandwidth at which loudness begins to increase is roughly the same at all levels tested (except that no increase occurs at the lowest level). From Feldtkeller and Zwicker (1956) by permission of the authors and publisher.

Demostración de sumación de Loudness

Demonstration 3. Critical Bands by Loudness Comparison (1:09)

This demonstration provides another method for estimating critical bandwidth. The bandwidth of a noise burst is increased while its amplitude is decreased to keep the power constant. When the bandwidth is greater than a critical band, the subjective loudness increases above that of a reference noise burst, because the stimulus now extends over more than one critical band.

The subjective loudness of a complex tone is fairly complicated, but for combining the loudness of two or more tones, the following rules of thumb usually apply:

1. If the frequencies of the tones lie within the critical bandwidth, the loudness is calculated from the total intensity: $I = I_1 + I_2 + I_3 + \ldots$
2. If the bandwidth exceeds the critical bandwidth, the resulting loudness is greater than obtained from a simple summation of intensities. As the bandwidth increases, the loudness approaches (but remains less than) a value that is the sum of the individual loudnesses: $S = S_1 + S_2 + S_3 + \ldots$

In this demonstration, a noise band of 1000-Hz center frequency and 15% bandwidth (930-1075 Hz) is followed by a test band with the same center frequency and bandwidth (see *1* in the figure below). The bandwidth of the test band is then increased in 7 steps of 15% each, while the amplitude is decreased to keep the power constant. When the bandwidth exceeds the critical bandwidth, the loudness begins to increase.

13

Commentary

...power. Compare the loudness of reference and test bands. The demonstration is repeated once."

References

- T.D.Rossing (1982), *The Science of Sound* (Addison-Wesley, Reading, MA). Chap. 6.
- B.Scharf (1970), "Critical bands," in *Foundations of Modern Auditory Theory*, ed. J.Tobias (Academic Press, New York), pp. 157-202.
- E.Zwicker and R.Feldtkeller (1967), *Das Ohr als Nachrichtenempfänger* (Hirzel Verlag, Stuttgart).

Demostración 3

Loudness recruitment

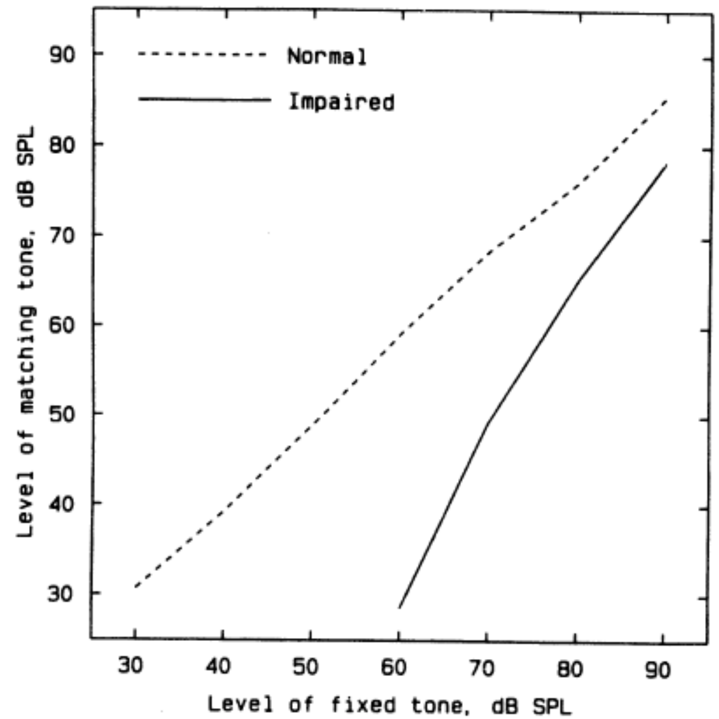


FIG. 2.12 Mean results of measurements of loudness recruitment obtained by Moore *et al.* (1985a) for five subjects with unilateral cochlear hearing loss. A tone of fixed level in the impaired ear was alternated with a tone of variable level in the normal ear. Subjects were asked to adjust the variable tone until the sounds appeared equally loud in the two ears. The mean level of the loudness match in the normal ear is plotted as a function of the level in the impaired ear (solid line). For comparison, the mean results from three subjects with normal hearing in both ears are also shown (dashed line).

Escalamiento de Loudness

Sono (Sone): Un sono se define arbitrariamente como la loudness de un tono de 1000-Hz a 40 dB SPL. Un sonido tiene una loudness de 2 sonos si es juzgado como el doble de intenso que un tono de 1000-Hz a 40 dB SPL.

Loudness (L) es una función exponencial de la intensidad física (I):

$$L = kI^{0.3}$$

donde *k* es una constante.

Escalamiento de Loudness

Método de medición de sonos:

<u>Estimación de magnitud</u>: sonidos con variadas intensidades son presentados y el auditor le asigna un número a cada uno de acuerdo a su loudness

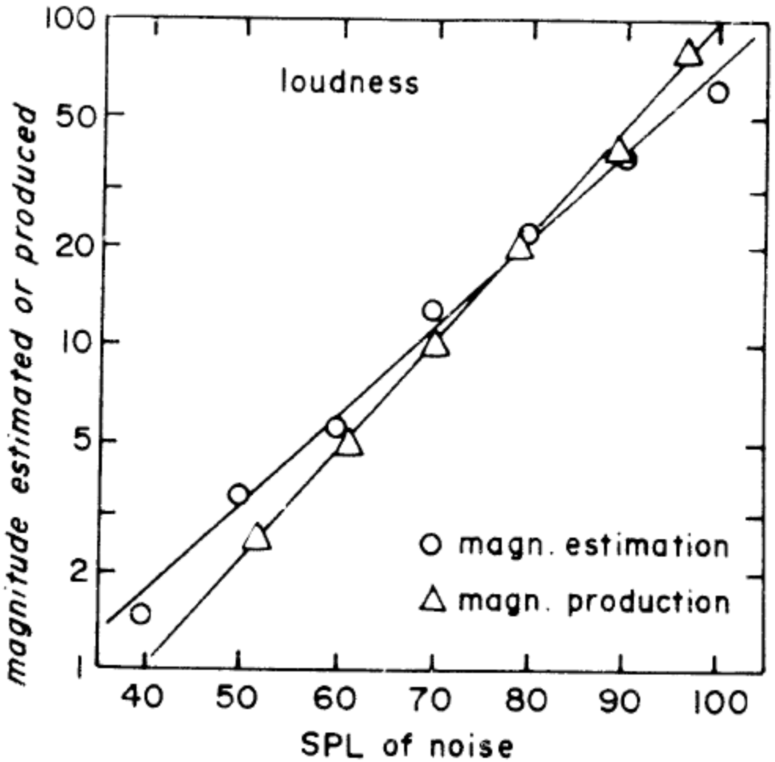
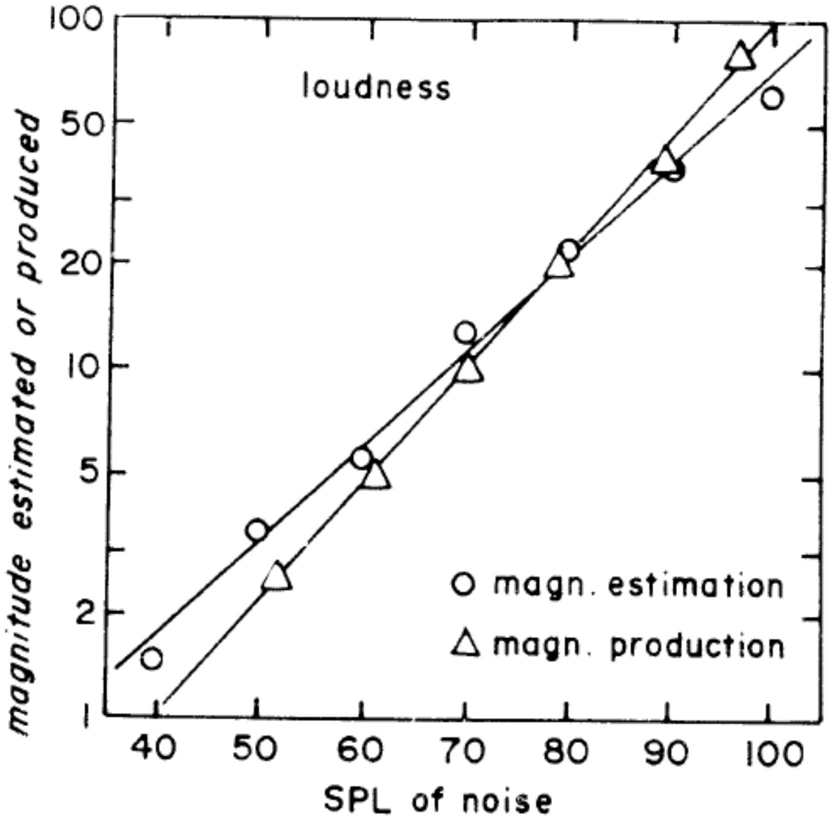


Figure 1.6. Circles: Magnitude estimates of the loudness of a band of noise, as functions of sound pressure levels in decibels (magnitude estimation). Triangles: loudnesses plotted as functions of average sound pressure levels produced (magnitude production). The exponent of the power function (*re* sound pressure) by estimation is .6, the exponent by production is .7. [From Stevens and Greenbaum (1966). Courtesy of the authors and *Perception & Psychophysics*.]

Escalamiento de Loudness

Para sonidos sobre 40 dB, la loudness de dobla cuando la intensidad se incrementa en 10 dB.



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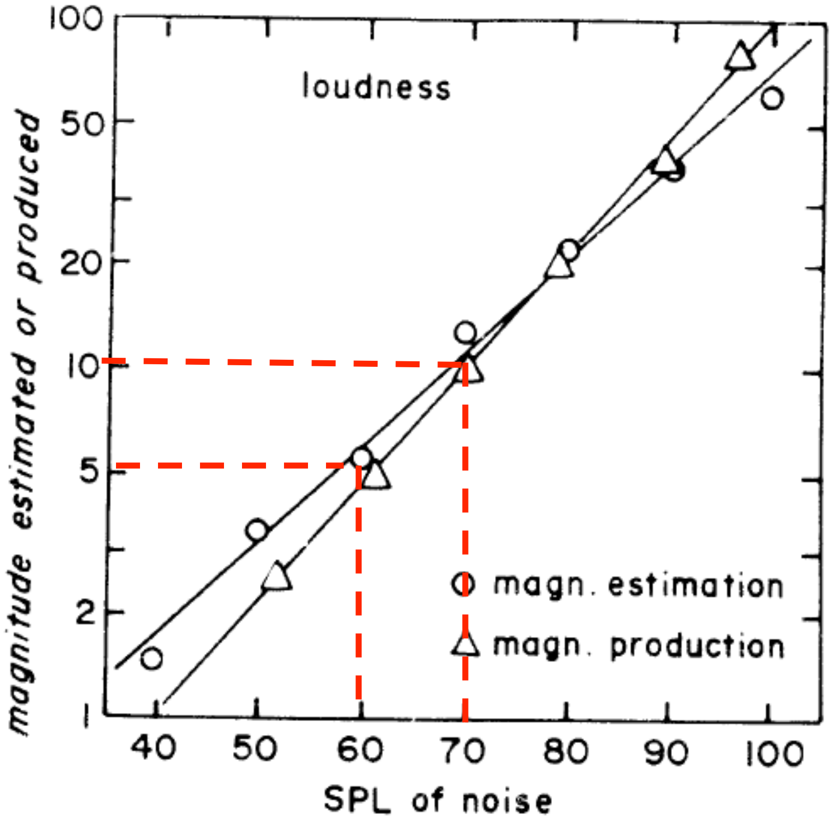

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Demostración del Escalamiento de Loudness

Demonstration 7. Loudness Scaling (2:58)

Establishing a scale of subjective loudness requires careful psychoacoustical experimentation involving large numbers of subjects. A scale of *sones*, established on the basis of work by Stevens (1956) and others, has been widely used to describe subjective loudness. On this scale, the loudness in sones S is proportional to sound pressure p raised to the 0.6 power:

$$S = Cp^{0.6},$$

where C depends on the frequency. In other words, the loudness doubles for about a 10-dB increase in sound pressure level. Other investigators have found that the exponent varies with tone frequency (generally increasing at low frequency and low level) and spectral content. Some investigators find the exponent to be as great as one (loudness proportional to sound pressure p), which leads to a loudness doubling for a 6-dB increase in sound pressure level (Warren, 1970).

In this demonstration, a reference sound of broadband noise alternates with similar sounds having levels of 0, ±5, ±10, ±15 or ±20 dB with respect to the reference tone. The tones are 1 s long, separated by 250 ms of quiet, and the trials are separated by 2.25 s of quiet. To help establish a scale, the reference tone is first presented along with the strongest and weakest sounds that will be heard. It is suggested that the reference tone be assigned a loudness of 100, although some teachers may prefer to use 30, or 50 or some other number.

You may wish to plot all the student responses on a graph of subjective loudness (log scale) versus sound level (linear scale) to establish an average loudness scale. In this case, it would be advantageous to have each listener designate a test tone that sounds "twice as loud" as the reference tone by 200, and one that sounds "half as loud" by 50.

Commentary

"In this experiment you will rate the loudness of 20 noise samples which are preceded ... First you hear the reference sound, followed by the strongest

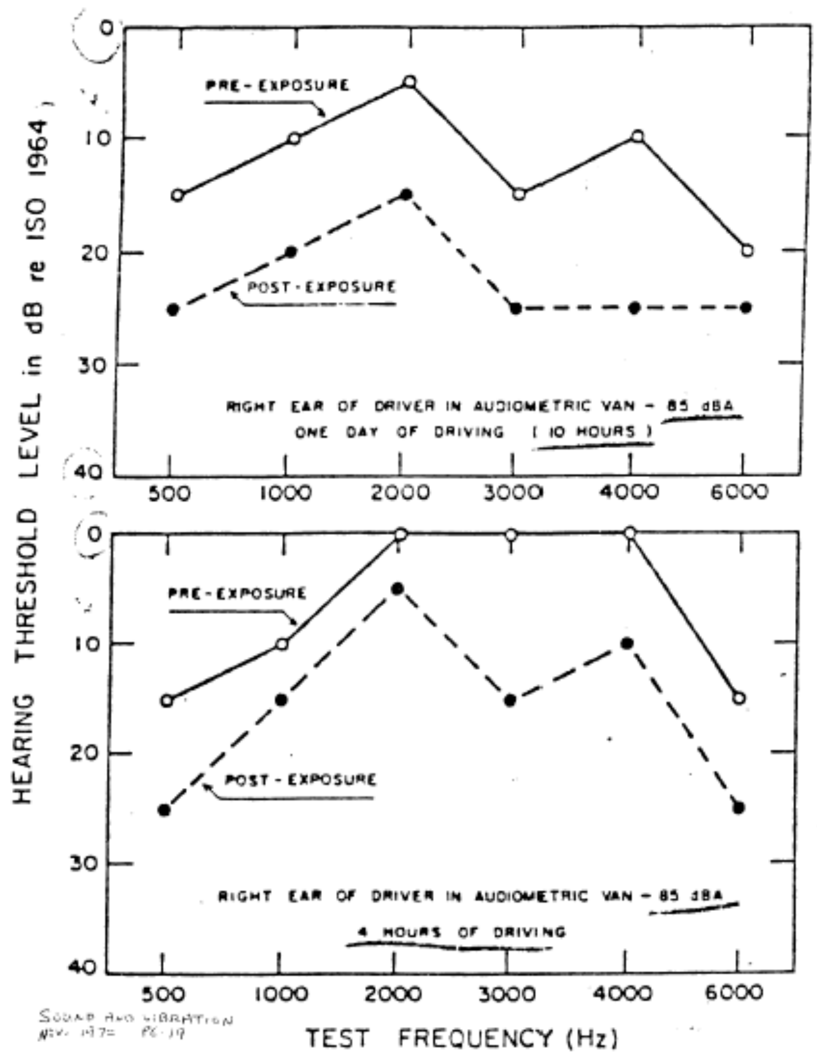
loudness relative to the reference.

References

- G.Canévet, R.Hellman and B.Scharf (1986). "Group estimation of loudness in sound fields," Acustica 60, 277-82.
- R.M.Warren (1970). "Elimination of biases in loudness judgements for tones," J Acoust. Soc. Am. 48, 1397-1403.
- D.W.Robinson (1957). "The subjective loudness scale," Acustica 9, 344-58.
- S.S.Stevens (1956). "The direct estimation of sensory magnitudes-loudness," Am. J. Psych. 69, 1-25.

Demostración 7

Corrimiento temporal del umbral



Estimación del ruido de fondo

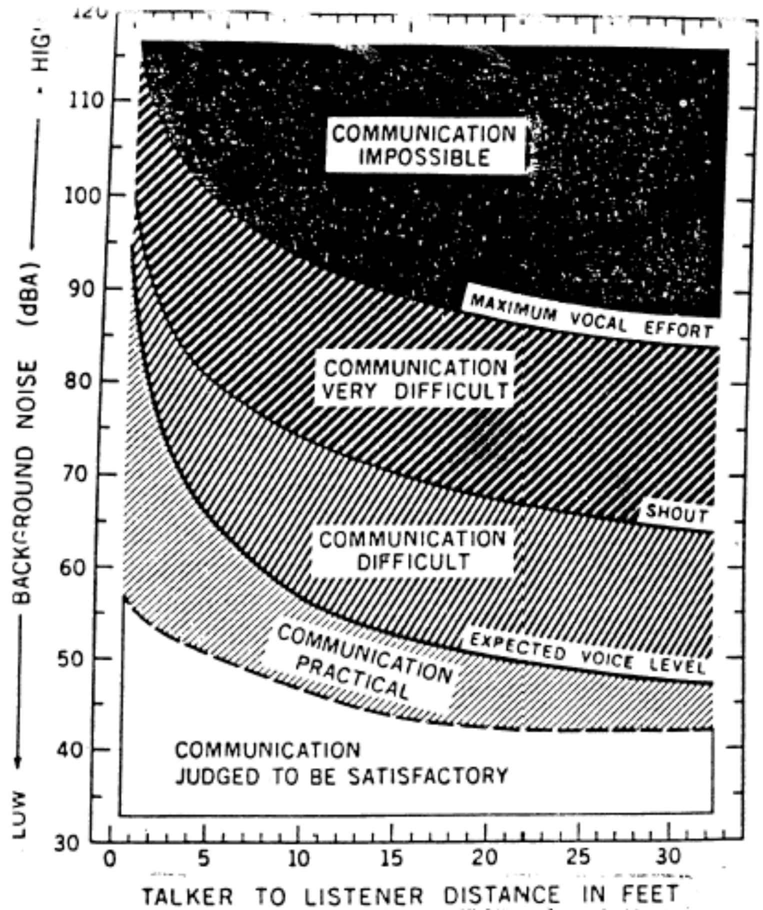
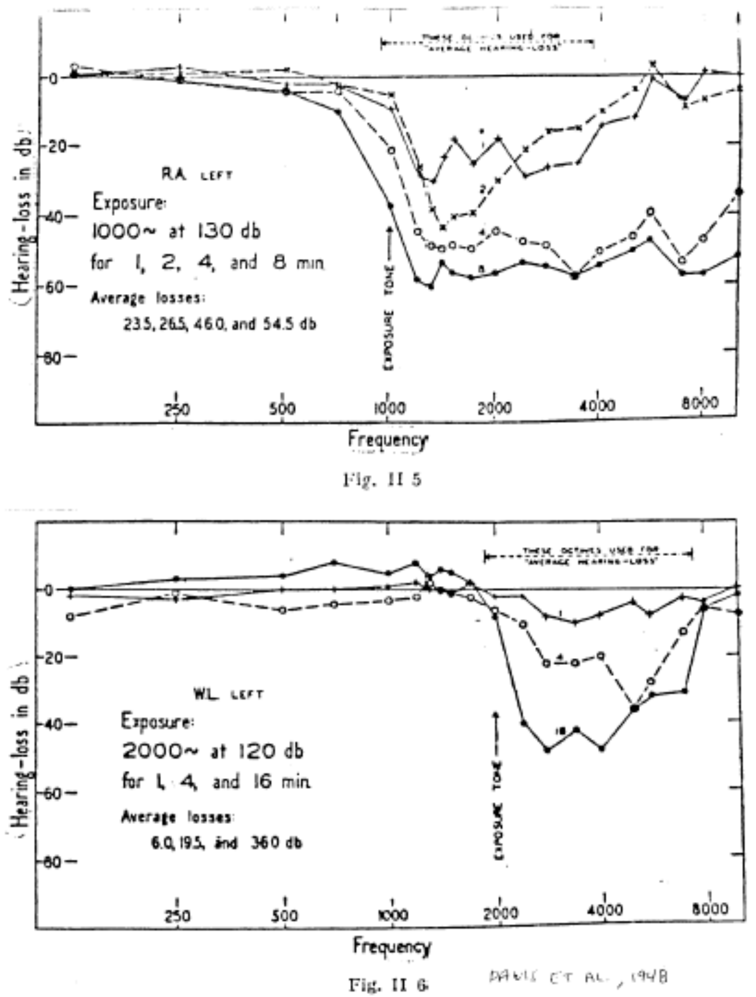


FIG. 15. Simplified chart that shows the quality of speech communication in relation to the A-weighted sound level of noise (dBA) and the distance between the talker and the liste

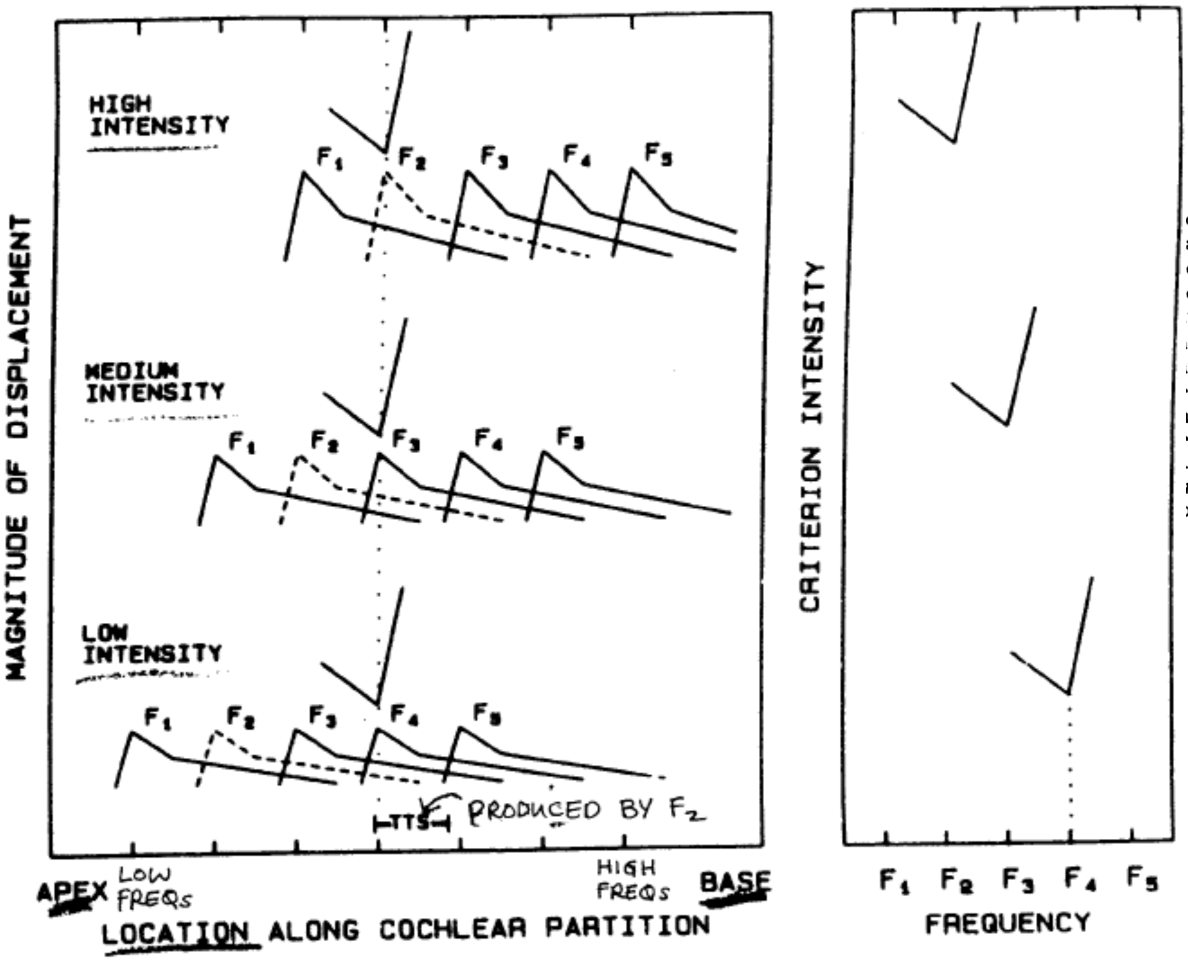
Miller (1974)

Corrimiento de media-octava



Davis et al. (1942)

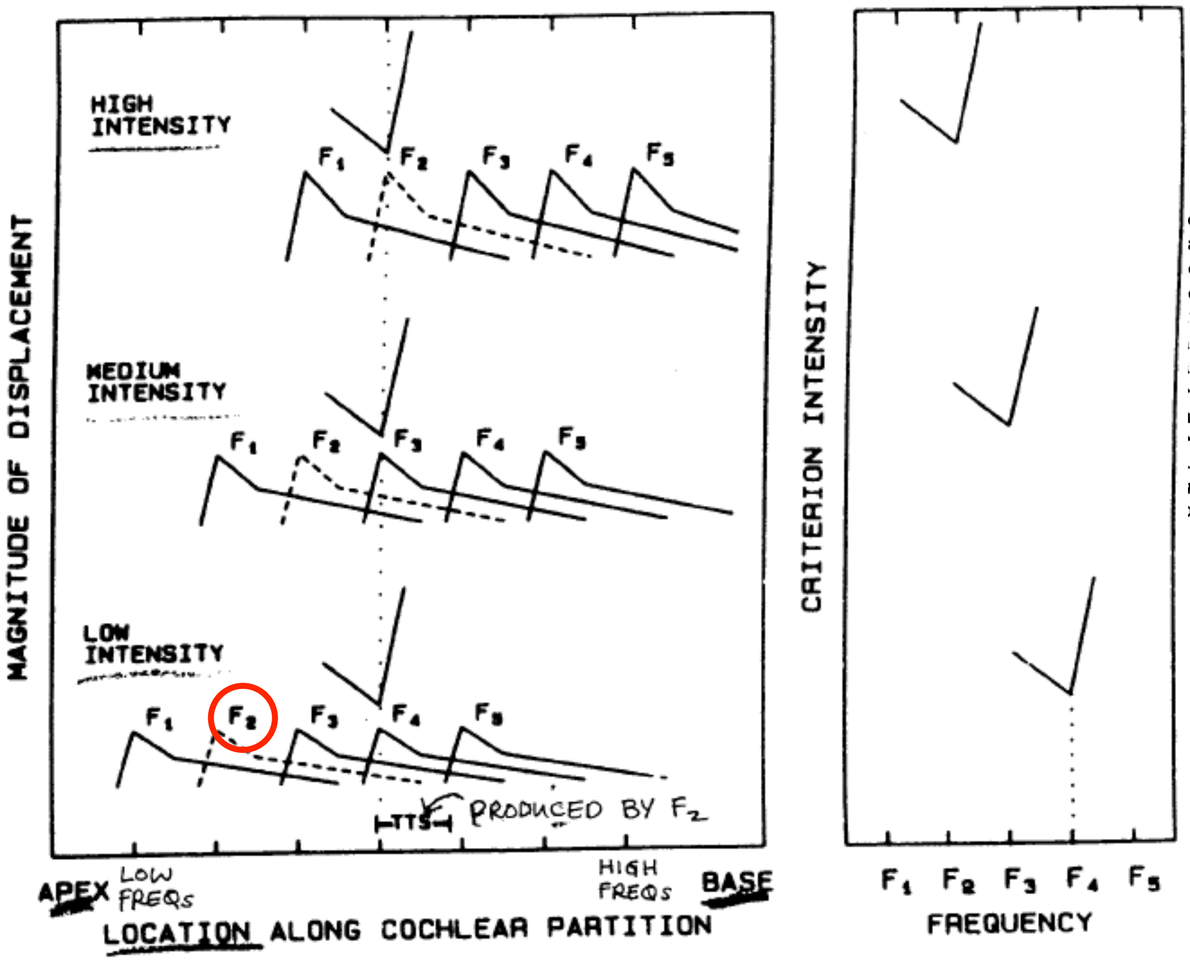
Corrimiento de media-octava



chematic representation of migration of the traveling-ave envelope with increasing intensity. Shown at the eft, on the dimension of cochlear position, are the op halves of the displacement envelopes for five tones t each of three intensities. For each intensity, a eural tuning curve is shown above the TW envelopes, nd then is shown again in the right panel, now cor-ectly located on the frequency dimension. The bar arked TTS at the bottom left is meant to indicate the egion of "fatigue" produced by tone F2 at the highest ntensity shown; at "threshold" intensities, F2 itself ould show little or no aftereffect of the exposure, ut frequencies above the exposure frequency would.

McFadden (1986)

Corrimiento de media-octava



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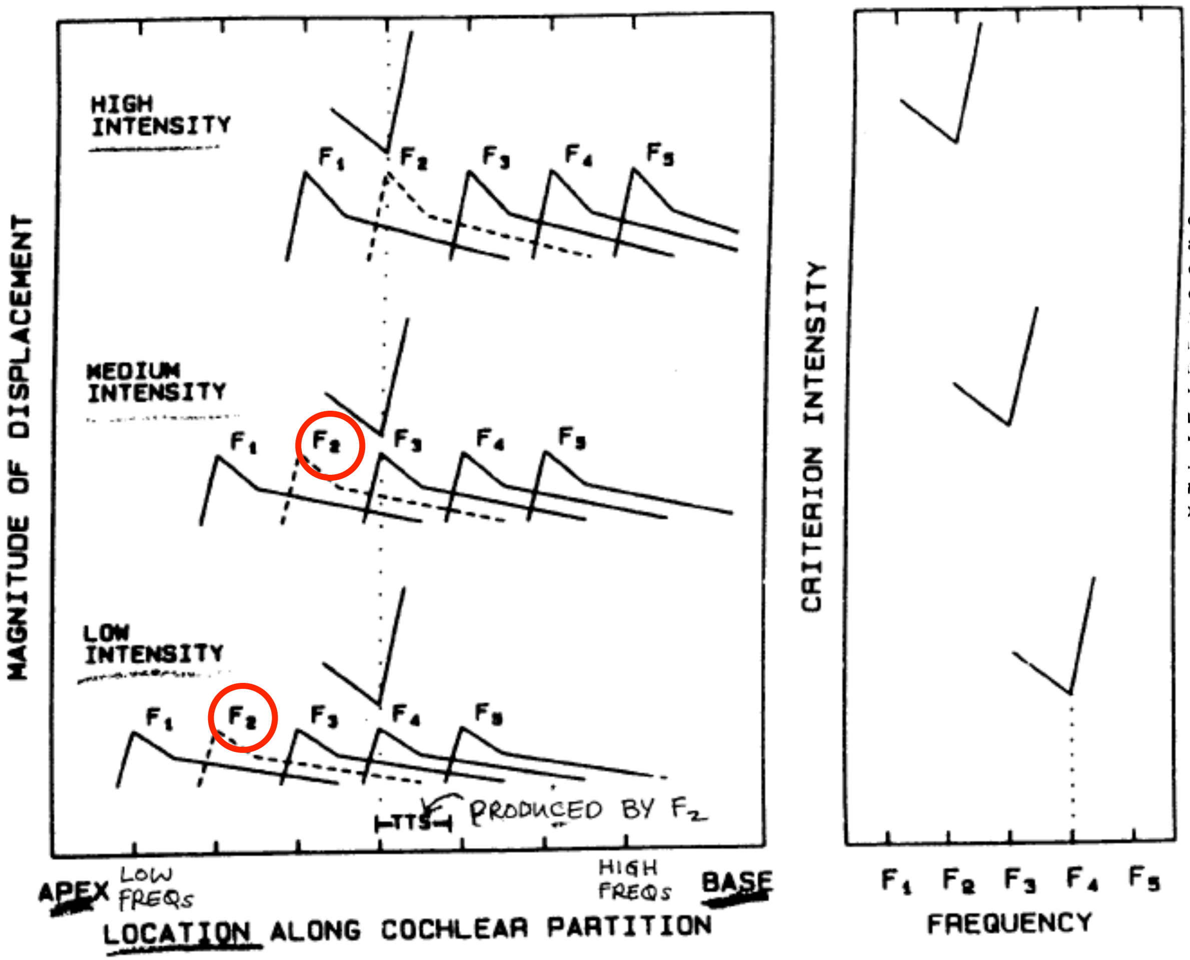

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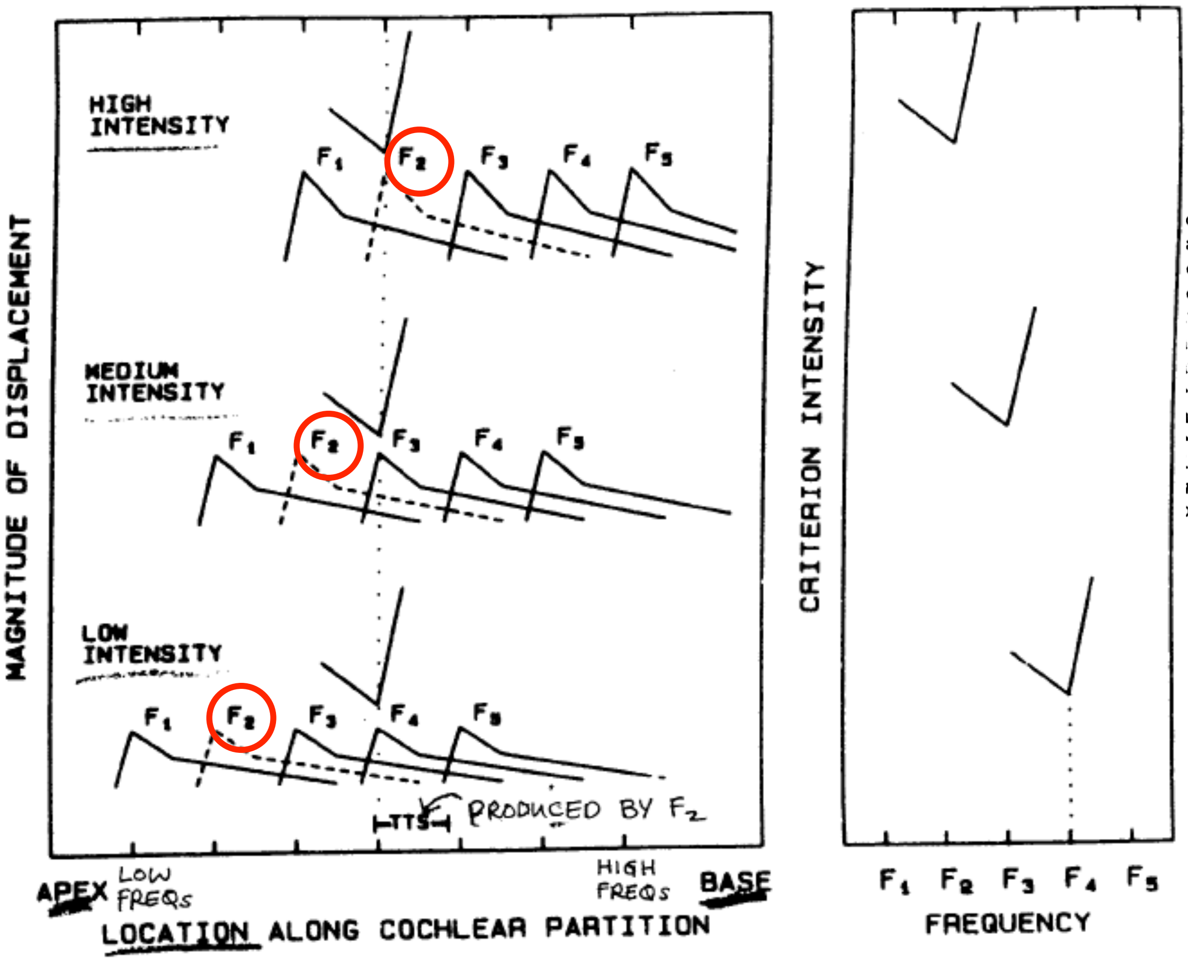

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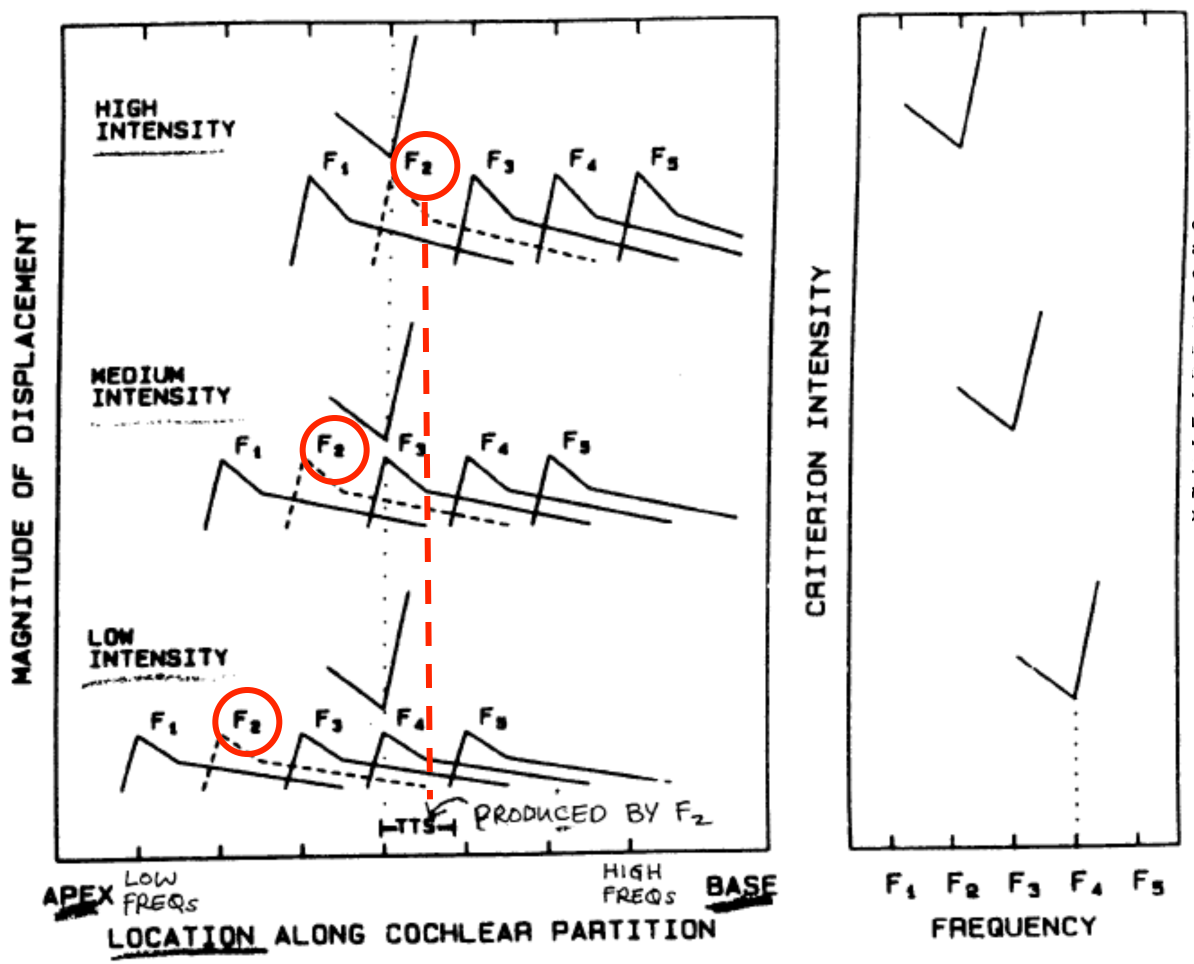

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McFadden (1986)

Pérdida auditiva

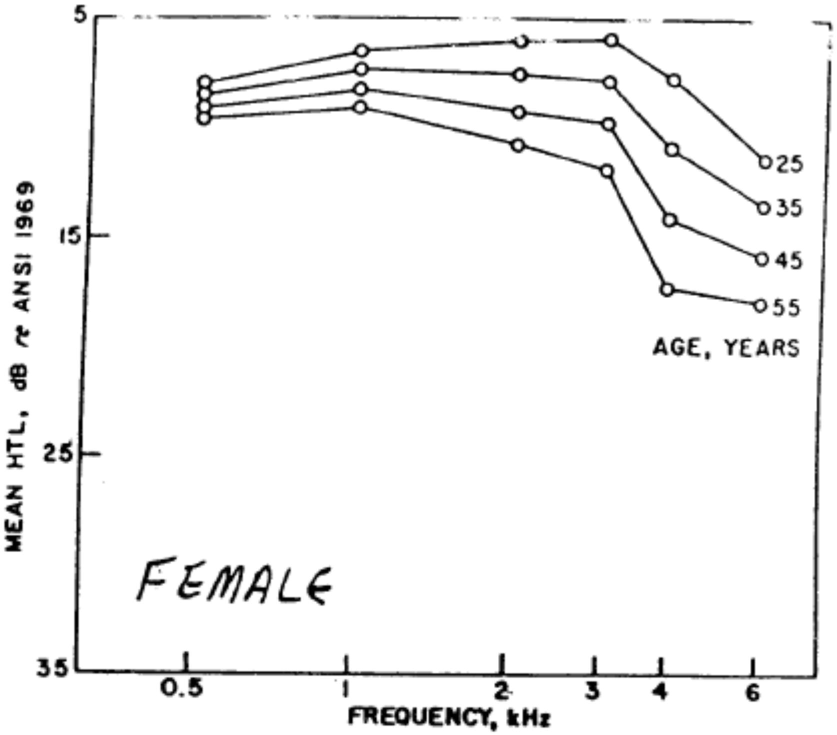
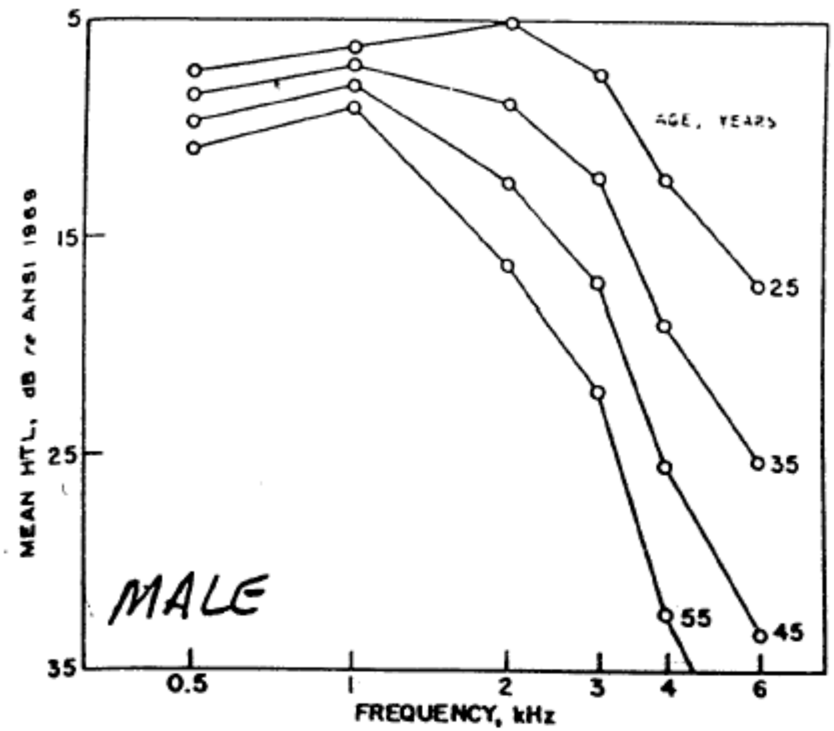


FIG. 2. Audiogram format of the North Carolina female aging curves (non-normalized) (1976).



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Berger et al. (1977)