DIFFERENCE LIMEN FOR INTENSITY

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Since Fowler (2) clearly described the loudness recruitment phenomenon, many clinical workers have attempted to circumvent the limitations of the alternate binaural loudness balance (ABLB) test by devising so-called indirect methods equally applicable to unilateral and bilateral deafness. The fundamental principle of most of these new techniques consists in measuring, for a given pure tone, the minimum perceptible difference in intensity (difference limen for intensity DLI) under special experimental conditions. In this very short report, I shall centre my attention on the method developed by Lüscher and Zwislocki (9).

By this procedure the patient has to detect the changes in intensity of a continuous tone (carrier) whose amplitude is slightly modulated. Fig. 1 A shows how, in contrast to the test tone sometimes employed by certain investigators (1), the envelope amplitude of the output voltage of the audiometer designed by Zwislocki changes fairly abruptly. The transition time during which the envelope amplitude increases or decreases is, however, long enough to avoid the production of any unwanted audible transients. The use of such a trapezoidal, flat-topped signal permits more accurate results than when the amplitude of the test tone is modulated sinusoidally. Furthermore, the subjects can usually perceive the intensity differences better when the rate of fluctuation is 2—3 cps. Finally, it should be stressed that for a given intensity level and a particular test tone the maximum amplitude of the envelope remains unchanged whatever the degree of modulation.

Test procedure. Before starting measurement with the Lüscher-Zwislocki method, the listener is instructed to press the signal button of the audiometer or to raise his hand so long as the test tone appears to be modulating, pulsating or wavering, and to release the signal button or lower his hand as soon as the test tone appears to be completely steady.

After first checking, by means of a few trial attempts, that the listener's responses are reliable, the audiometrist begins the examination proper with a strongly modulated test tone. The degree of modulation is then progressively reduced until the fluctuations in intensity are no longer heard by the subject. In order to facilitate the task of the listener in discriminating loudness changes as the degree of modulation approaches the range at which his discrimination performance deteriorates noticeably, the continuous tone is turned on from time to time by using the modulation interruptor switch on the audiometer; in fact, the sensory judgment is easiest, if two modulation steps are not compared with each other, but each modulation step is

compared with a constant tone. After a relatively short break, the above test procedure is repeated several times. For a given test tone and a particular sensation level (SL), the setting of the modulation (degree of modulation expressed in db or %) at which the subject is able to reach a more or less good performance is then considered to be the exact value of the DLI.

To avoid excessive loss of time, the measurements of the DLI are usually carried out only with test tones of an intensity level of 80 db above the normal threshold. However, in cases where at certain frequencies the air-conduction hearing threshold level of the ear under examination exceeds 60 db, it is recommended to set the intensity of the test tone, if possible, at a level as high as 15—20 db above the patient's hearing threshold. In general, at these fairly high intensity levels above the normal threshold, the recruitment is complete or so far advanced that the loudness discrimination task does not appear too difficult for the patient. Furthermore, according to the recommendations of Lüscher and Zwislocki, test tones ranging from 250 to 4000 cps should be preferred, because, compared with the lower and higher frequencies, the results of measurement are more certain.

Normal DLI. From the practical point of view, it is very useful to write the normal values (lower and upper limits) of the DLI as recorded by Lüscher and Zwislocki for various SL's on the right margin of the audiogram form. As can be seen from Figs. 1 B and C, the DLI for an otologically normal subject decreases as the SL increases. The above specified normal values of the DLI, which have been expressed in per cent and in decibels by using formulae 1 and 2 of Fig. 1 A, are valid for pure tones ranging from 125 to 8000 cps. In this connection it is also interesting to note that at about 70 db above the normal threshold, the DLI remains relatively constant with both frequency and intensity. Moreover, in comparison with the lower sound-intensity levels, the DLI stays almost unchanged in the higher intensity range as the duration of exposure to the test tone increases (1, 8, 11).

Evaluation of results. As shown in Figs. 1 B and C, the DLI's (expressed in per cent) are recorded on the audiogram form at the intensity at which they were determined; the values obtained for the right and left ear are located to the right and left respectively of the vertical line corresponding to the tested frequency. By comparing the DLI measured at a given frequency with the normal values, the degree of recruitment can be approximately estimated. If the DLI obtained by a patient has the same value as that of a normal listener at an equal above-threshold intensity (Fig. 1 B), it may be presumed that recruitment is completely absent. On the other hand, if, for a given test tone, the DLI of a patient with hearing loss has the same value as the normal DLI at the intensity used during the test session (Fig. 1 C), it may be assumed that recruitment is complete. In the light of the clinical examples of Figs. 1 B and C, these latter assumptions seem to be acceptable.

In the cases (partial recruitment) where the measured DLI does not fulfil one of the above two conditions, those portions of the hearing loss which are uncompensated or compensated by recruitment can be roughly evaluated with the aid of the following two formulae:

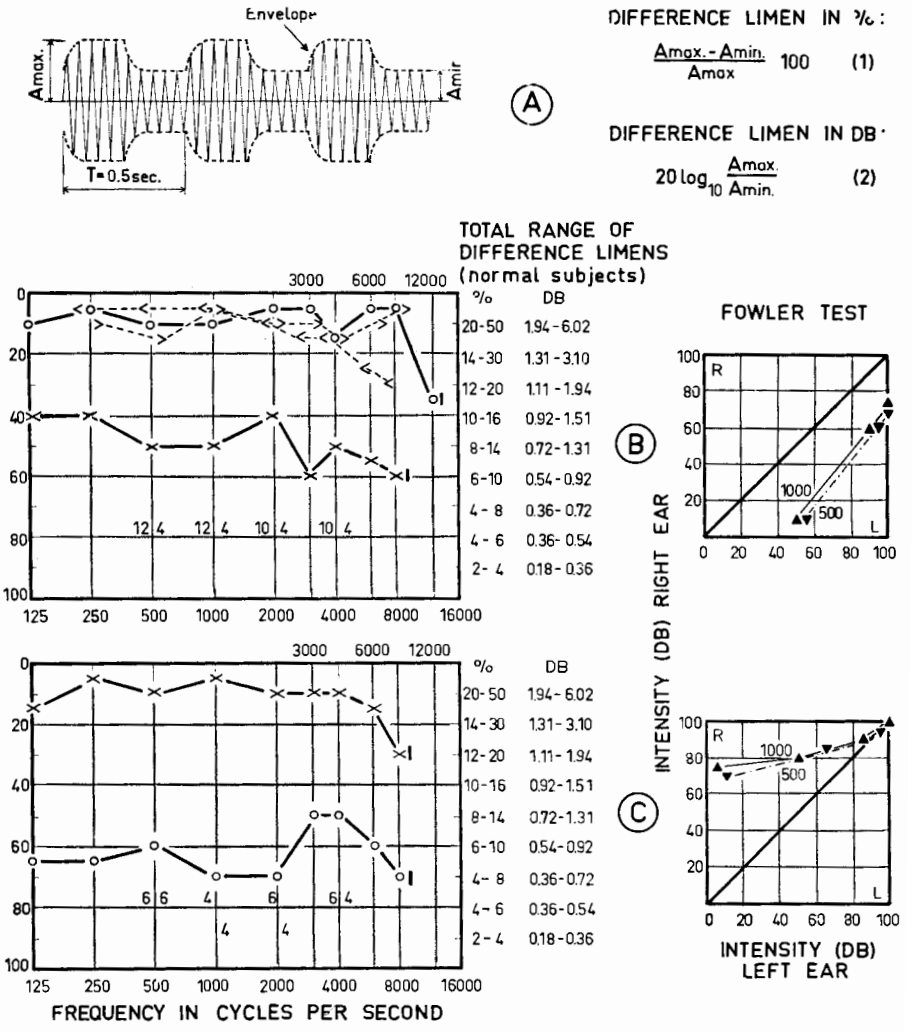

Fig. 1A. Diagram showing the envelope variations of the electric output voltage of the audiometer designed by Zwislocki (degree of modulation: 50%; frequency of the envelope variations: 2 cps.). For the sake of clarity the frequency of the carrier (test tone) is shown as being much lower than would normally be the case.

Fig. 1B. Audiogram of B.O., 38 years, m. Unilateral middle ear deafness with slightly impaired bone conduction in the higher frequency range. A radical operation with tympanoplasty was undertaken on the left ear 5 years ago.

In Figs. 1B and C the audiometrically measured air-conduction and bone-conduction curves are indicated by the following symbols:

O—O Air-conduction curve of right ear.
X—X Air-conduction curve of left ear.
> ····> Bone-conduction curve of right ear.
<····< Bone-conduction curve of left ear.

The total range (lower and upper limits) of the difference limens (expressed in % and db), as recorded at various sensation levels by a population of otologically normal subjects is given in the right margin of the audiogram form. The small graphs of Figs. 1B and C show the results of the measurements obtained with the aid of the alternate binaural loudness balance test (Fowler). Parameter: frequency of the test tone in cps.

Fig. 1C. Audiogram of S.M., 54 years, f. Unilateral cochleo-neural deafness due to Ménière's disease. Since the bone-conduction curves coincide more or less with the air-conduction curves, the former have not been drawn on the audiogram form.

$$\text{Hearing loss uncompensated by recruitment} = I_{DL(l)} - I_{DL(n)} \quad (3)$$

$$\text{Hearing loss compensated by recruitment} = HL_{AS(l)} - \left\{ I_{DL(l)} - I_{DL(n)} \right\} \quad (4)$$

Where $I_{DL(l)}$ = intensity at which the DLI was measured.

$I_{DL(n)}$ = intensity at which the mean of the normal DLI coincides with the DLI found.

$HL_{AS(l)}$ = air-conduction hearing threshold level of the ear under examination for the corresponding test tone.

Accordingly, by considering in Fig. 1 B the DLI's which have been recorded with a test tone of 4000 cps., one obtains for the left ear:

$$I_{DL(l)} = 80 \text{ db}; \quad I_{DL(n)} = 50 \text{ db}; \quad HL_{AS(l)} = 50 \text{ db}$$

Consequently (at 4000 cps.) the uncompensated and compensated portions of hearing loss are then equal to 30 and 20 db respectively.

Discussion. In accordance with the definition of loudness recruitment, i.e. an abnormally rapid increase of loudness with intensity, the ABLB test is the only way of ascertaining the relation between loudness and intensity in clinical patients (4,5). Nevertheless, by comparing the results of measurements obtained by the Lüscher-Zwislocki method and the ABLB test, it has been repeatedly proved at the Audiological Centre of Basel that, except for a relatively small number of special cases, one can get nearly the same information with both methods about the presence or absence of loudness recruitment by following the above described procedure.

Although the physiological mechanism of loudness recruitment and the neural basis of intensity discrimination have not yet been clarified in an entirely satisfactory manner (4, 10), the chief diagnostic value of the DLI determination, as in the case of the ABLB test, is related to the differentiation between disturbances in the organ of Corti and retrocochlear diseases. Furthermore, according to Lüscher (7), abnormally high drops in sensitivity to intensity differences are observed by patients with psychogenic deafness.

Since, from the diagnostic point of view, loudness recruitment is only one of the symptoms of cochlear impairment (3, 5), it should undoubtedly be possible in the future to establish a more accurate diagnosis in cases of cochleo-neural deafness by combining the Lüscher-Zwislocki method with other tests (6).

LE SEUIL DIFFERENTIEL D'INTENSITE

Après avoir indiqué brièvement le principe fondamental de la plupart des procédés utilisés pour la recherche du recrutement, on considère en particulier la méthode recommandée par Lüscher et Zwislocki. On rappelle notamment les caractéristiques physiques du son modulé que ces derniers auteurs ont employé, lors de leurs investigations concernant le seuil différentiel d'intensité. De plus, on décrit un procédé d'examen qui (selon les expériences faites dans le Centre d'Audiologie de Bâle) facilite notablement la tâche du sujet. A la lumière de deux exemples cliniques, on montre finallement comment, du point de vue diagnostic différentiel, les résultats de l'épreuve de Lüscher et Zwislocki peuvent être évalués.

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