RECRUITMENT—A FACT OR AN ARTIFACT?

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The concept of loudness recruitment widely accepted as an abnormal auditory phenomenon does not appear to be justified. Experimental results provided by Stevens and Davis (1938) adequately show that the phenomenon of recruitment is not abnormal. The data shown in the loudness function curve (Stevens and Davis, 1938, p. 118) reveals that the loudness level of 1000 Hz. tone at 40, 70, and 100 dB. SPLs is approximately 1, 10 and 100 sones respectively for normal subjects. Therefore, if an individual has a sensorineural loss of about 40 dB SPL (equal to one sone), there will be loudness loss of I sone throughout the intensity range. That is, he will perceive a tone of 70 dB SPL at a loudness level of 9 sones and a tone of 100 dB SPL at a level of 99 sones. Thus the difference in the loudness perceived by the normal and the abnormal ears is very small.

Adding further to the confusion is the common usage of the decibel concept. It is thought naively that a tone of 60 dB SPL should sound as loud to an individual with a sensorineural loss of 40 dB SPL, as a tone of 20 dB SPL would to an individual with a threshold of 0 dB SPL. But taking into consideration the loudness levels and the absolute sound pressures of these tones (Stevens and Davis, 1938, p. 118) it can be seen that the two ears are *not* stimulated identically either with equal sound pressure or with equal loudness increments but only at equal SLs (20 dB SL in this case). Furthermore, in 'pure' sensorineural cases, the basilar membrane will be stimulated by *all* of the energy reaching the cochlea and not just by the energy corresponding to the sensation level.

Thus the loudness of a tone seems to depend on the energy reaching the cochlea and not on the sensation level of the tone, within certain limits. (The terms 'within certain limits' are used in the sense that there will be inherent variability associated with the psychophysical experiments of this kind and we may have to allow 5-10 dB variability especially with unsophisticated subjects). Therefore, the loudness produced by a tone of 60 dB HL at a normal ear will be equal to the loudness produced by a tone of 60-75 dB HL in an ear with 30 dB of sensorineural loss.

This being the case, how do the tests conventionally used to measure recruitment (Davis, 1960; Newby, 1935; O'Neill and Oyer, 1966; Reger, 1965) fail to show recruitment? In other words, though the intensity level of the tone remains the same why does it not sound as loud? Is it possible that the results of these tests are contaminated by another phenomenon, that of tone decay? A careful

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perusal of the case reports published and some research findings with normal subjects and those with sensorineural hearing loss appear to support the hypothesis that the outcome of the recruitment tests depend on whether the tone decays or not.

First of all, let us consider the ABLB test given to a case with unilateral sensorineural hearing loss. The test would, it is hypothesized, indicate the presence of recruitment if there is no tone decay in the affected ear. Since there is no loss in the intensity of the tone that has reached the cochlea the loudness perceived will be almost equal to that in the normal ear in spite of the reduced auditory acuity. On the other hand, if the tone decays, the subject will need greater intensity levels to compensate for the loss due to the 'decay' of the tone. Hence, he may be said to show no recruitment or he may be said to show partial or delayed recruitment. This is so because, tone decay is not an all or none phenomenon, the amount and rate varying from 0 to 50 dB or more depending on the IL (Owens, 19 4). Thus, partial or complete or no recruitment may reflect the rate of tone decay. Delayed recruitment may be seen in cases where there will be rapid tone decay at low sensation levels with no decay at higher sensation levels. The decruitment phenomenon may also be another manifestation of rapid tone decay even at high sensation levels. In decruitment cases, at equal loudness balance point, the HL at the impaired ear will be greater than that at the normal ear, even at high sensation levels. This is as it should be if there is rapid tone decay even at high SLs.

In normal ears, jnd is a function of the intensity level of the tone (Riesz, 1928). Even in the case of subjects with sensorineural loss, it has been found that the jnd is a function of the *intensity* level of the tone and not of the sensation level (Swisher *et al*, 1966; Luscher, 1955). If at a particular level there is tone decay, then the jnd at that level will be larger, indicating no recruitment or partial recruitment as compared with a normal ear.

The same is true of the SISI test. Some studies reported recently have shown that the SISI scores obtained depend not on the SL but on the IL reaching the cochlea (Herbert, Young and Weiss, 1969; Young and Herbert, 1967). Thus in all three groups, normal, conductive loss and sensorineural loss without tone decay, high SISI scores will be obtained when IL of tone reaching the cochlea is about 60 dB SPL whereas those with retro-cochlear type of sensorineural loss showing high tone decay, fail to detect the 1-dB increments at the same intensity levels. This failure, it is surmised, is due to tone decay because of which the tone is not perceived with a loudness corresponding to the set IL.

Yantis and Decker (1964), however, found no consistent trend in SISI scores with variations in threshold. Their data is difficult to interpret for the following reasons:

1. The data is for subjects with sensorineural loss without regard to diagnostic classification. In other words, we do not know whether the low SISI

scores obtained by subjects with high thresholds was due to tone decay or not.

2. The range of threshold in the group 0-15 dB HL is rather wide. A subject either with normal hearing or with sensorineural loss with a threshold of 10 or 15 dB (re ASA Zero) can easily get higher SISI at 20 dB SL.

3. With regard to high SISI scores obtained by subjects with high tone decay, it is not made clear whether they are false SISI scores, that is, the subjects perceiving the increments as emerging from the background of silence, the continuous tone having decayed.

4. With regard to subjects with normal tone decay securing low SISI scores, the presentation level of the SISI test is not known.

5. Their data also show some subjects with complete recruitment having got low SISI scores. In these cases we know neither the presentation level nor the amount and rapidity of tone decay. Hence, we are unable to draw any conclusion from their data.

Dix (1968) has shown that the Loudness Discomfort Level (LDL) both for normals and for subjects with 'end-organ deafness' was between 90-105 dB, in spite of the hearing loss being as much as 80 dB in the 'end-organ deafness' group. In cases with conductive hearing loss no LDL could be established even at the maximum audiometric limits. This is as expected. The conductive impairment reduces the intensity level at which the tone reaches the cochlea. Further support to this view comes from findings in the same study that for those with conductive loss of less than 20 dB, LDLs were elevated by the amount of hearing loss. Similarly among subjects with 'nerve-fiber' deafness it was seen that no LDL could be established within the maximum audiometric intensities.

Results from Jerger and Harford's (1960) study on simultaneous binaural balance test also appear to support the hypothesis put forward in this paper. It was observed by them that the subjects with cochlear type of impairment require approximately equal HLs in both ears at point of balance whereas the subjects with retrocochlear type of impairment required greater HL at poorer ear at point of balance.

The present hypothesis does not hold that the loudness recruitment as measured by ABLB and tone decay cannot occur in the same subject. Whether or not recruitment is present depends on the procedure employed—does it allow the tone to fade? It is generally accepted that continuous tone as a stimulus is more susceptible to tone decay rather than an automatic pulsed tone; in the former instance it is highly unlikely that tone decay *and* recruitment will be positive unless the tone fades at a slow rate, and in the latter case it is more likely that recruitment will be positive even if tone decay is rapid and the intensity levels are high.

Thus it seems that the results of all the above tests depend on the rapidity with which the tone decays. However, the results of these tests do not always

reflect the vagaries of tone decay as tone decay itself may be affected by other factors such as tinnitus. Also during SISI test rapid tone decay may contribute to a spuriously high SISI score. These two are mainly responsible for obtaining equivocal results in some cases.

In conclusion, it may be said that the present conception of tone decay and recruitment as two different phenomena independent of each other seems to be due to the methodological differences in measuring tone decay and recruitment and the dependence of the latter on apparently insignificant factors—at least to the experimenters not very familiar with these facts—such as duration and nature of the tone. With the sophisticated instruments incorporating automatic pulsed tones we should see more and more patients with retrocochlear lesions exhibiting both recruitment and tone decay.

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REFERENCES

Blegvad, B. (1969) Differential intensity sensitivity and clinical masking. *Acta Otolaryngol.*, 67, 428-434.

Davis, H. (1960) Audiometry. In Davis, H. and Silverman, S. R. (Eds.), *Hearing and Deafness.* Rev. Edn. New York: Holt, Rinehart and Winston.

Dix, M. R. (1968) Loudness recruitment and its measurement with especial reference to the Loudness Discomfort Level Test and its value in diagnosis. *Ann. Otol. Rhin. and Laryng.*, 77, 1131-1151.

Herbert, F., Young, I. M., and Weiss, B. G. (1969) Clinical application of intensity difference limen. *Acta Otolaryngol.*, 67, 435-443.

Jerger, J. and Harford, E. (1960) Alternate and simultaneous binaural balancing of pure tone. *F. Speech Hearing. Res.* 3, 15-30.

Luscher, E. (1955) *Acta Otolaryngol.* 45, 402. Quoted from Blegvad (1969).

Newby, H. A. (1965) *Audiology.* 2nd Edn. London: Vision Press Ltd.

O'Neill, J. J. and Oyer, H. J. (1966) *Applied Audiometry.* New York: Dodd, Mead & Company, Inc.

Owens, E. (1964) Tone decay in Vlllth nerve and cochlear lesions. *J. Speech Hearing Dis.* 29, 14-22.

Reger, S. (1965) Pure tone Audiometry. In Glorig, A. (Ed.). *Audiometry: Principles and Practices.* Baltimore: The Williams and Wilkins Company.

Riesz, R. R. (1928) Differential intensity sensitivity for pure tones. *Phys. Rev.*, 31, 867-875. Quoted from Stevens and Davis (1938).

Stevens, S. S., and Davis, H. (1938) *Hearing: Its Psychology and Physiology.* New York: Wiley.

Swisher, L. P., Stephens, M. M., and Doehring, D. G. (1966) The effect of hearing level and normal variability on sensitivity to intensity change. F. *Aud. Res.*, 6, 249. Quoted from Blegvad (1969).

Yantis, P., and Decker, R. (1964) On the short increment sensitivity index (SISI test). *F. Speech Hearing Dis.*, 29, 231-246.

Young, I. M., and Herbert, F. (1967) Significance of the SISI test. F. *Aud. Res., 7,* 303-311.