AN OBJECTIVE METHOD OF VALIDATING PURE-TONE THRESHOLD *

M. RAGHUNATH

Because of the serious limitation of the pure-tone audiometry, more and more objective techniques are sought to arrive at accurate and valid thresholds. The present study is therefore an attempt to compute hearing thresholds from the stapedial reflex thresholds.

A sample of 100 subjects with an age range of 17.24 years was selected for the study. 14 ears had to be discarded because of the failure in exhibiting a reflex or yielding pure-tone thresholds were in disagreement with speech reception thresholds provided by them. The data obtained on 186 ears were subjected to analysis to arrive at an appropriate multiplication factor so as to find the applicability of the formula proposed by Niemeyer and Sesterhenn (1974) for the Indian population. Different factors have been suggested for each frequency to compute the hearing thresholds of each one of them. A seperate multiplication factor is also suggested for finding the average thresholds at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz to provide an easy means to check the validity of pure-tone thresholds.

The formula thus derived was applied on 30 ears randomly selected from the original sample to verify the efficiency. In 76% of cases the thresholds could be computed within a range of I 15 dB. This method can be used with little care as an objective means to verify the clinically obtained pure-tone thresholds obtained through behavioral audiometry.

Although the pure-tone thresholds provide discrete data, the audiometric results may be affected by variables like acoustic factors, instructions response criteria, environmental factors, threshold finding methodology and stimulus presentation, etc. Hence, the validity of pure tone results have to be validated.

The threshold of sensitivity for speech has been used as an index to validate pure tone thresholds. Though, the speech reception threshold is reported to be a valid estimate of pure tone threshold, it still remains difficult for patients who do not or cannot respond verbally. The response in the speech audiometry is also limited by the verbal repertoine of the patient. Further, in India with multitude of languages. it is still more difficult as we do not have standardized speech materials in all languages. This raises the problem of finding an alternative method to establish the validity of pure tone thresholds.

Audiometry being a procedure and not merely a response, the term objective would be applicable only if the technique as well as the response is objective. So the validation of the

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results obtained on behavioral audiometry should be established using an objective technique, especially at the present era where audiologists are fully aware of diagnostic, treatment and rehabilitative needs of the patient and assessment problems they pose. The development of improved methods for applying advanced electronic instrumentation and human engineering principles to audiologic procedures is the foremost concerned in this contemporary phase. On such sophisticated method is the impedance audiometry which goes far beyond the more presentation of sound and the recording of resulting responses.

The predictability of hearing sensitivity from the stapedins reflex thresholds seem to be one of the most clinically promising and objective method. Young and Estes (1967) first attempted to assess the validity of reflex measurements as a means of establishing auditory thresholds in normals and mentally retarded adults. Recently, Niemeyer and Sesterhenn (1974) devised a formula by which hearing thresholds should be calculated with a fair accuracy from the relationship between reflex thresholds for pure tones and for broad band noise.

A pilot study carried out on 20 normal Indian subjects by the investigator revealed that the formula proposed by Niemeyer and Sesterhenn (1974) did not yield accurate hearing thresholds. This may be because of the racial and tropical differences which are proved to bring significant differences in behavioral studies. Basavaraj (1973) showed that there is a considerable difference in acoustic impedance in Indians. Mythili (1975) reported a difference in the accoustic reflex thresholds of Indians from that of whites.

The present study is therefore proposed to derive a suitable formula by which hearing thresholds could be determined from the reflex thresholds of pure tones and white noise. This can thus be widely in the clinics to verify the pure tone thresholds obtained through behavioral audiometry.

The present study is undertaken with the following objectives: (1) To establish the reflex thresholds for pure tones of 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and for white noise ; (2) To devise and standardize a formula which would enable to compute hearing thresholds from the acoustic reflex thresholds ; (3) to report the possible relationship that exists between the computed thresholds and the real thresholds obtained through the behavioral audiometry and (4) to evaluate the efficiency of this technique of evince the validity of pure tone thresholds.

The following hypotheses were put forward :

1 Using a formula it is possible to compute the hearing sensitivity from the Stapedius reflex thresholds of a subject.

2 There exists no difference between computed hearing sensitivity and the hearing sensitivity obtained through behavioral audiometry.

METHODOLOGY

Subjects

One hundred subjects between the age of 17 to 24 years were selected for the study. Out of them 67 were males and 33 were females. None of them had any previous history of ear aches or any ear complaint. All of them had normal ear structures-otologically and normal hearing audiologically with reference to ANSI, 1969. All of them exhibited 'A' type tympanogram to further assure normal ear structures. They were all unfamiliar to all the above test situations. 14 ears were discarded as they failed either to exhibit reflex threshold or good agreement between puretone average (PTA) and speech reception threshold (SRT).

Equipment and test Environment

A calibrated (ANSI, 1969) dual channel diagnostic audiometer (Madsen OB 70) with TDH-39 earphones and MX 41-AR ear cushion was used to obtain the pure thresholds and speech reception thresholds of the subjects. Talk back system was used to record the response of the subjects during speech audiometry.

An electroacoustic impedance bridge (Madsen ZO 72) with Telex 1470 earphone and MX-41/AR ear cushion calibrated to ANSI 1969 was used to record the stapedius reflex threshold for pure tones of 500 Hz, 1000 Hz, 2000 Hz and white noise.

The hearing thresholds and speech reception thresholds of the subjects determined at the sound treated suit of the All India Institute of Spcech and Hearing, Mysore, and the reflexometry was performed in a fairly quiet room.

Test Procedure :

All the subjects were first tested to establish the thresholds at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Hughsan Westlake (1944) ascending procedure was used to establish the pure tone thresholds. The thresholds obtained at each frequency were recorded on the audiogram sheet. After obtaining air-conduction thresholds the puretone average (PTA) of 500 Hz, 1000 Hz and 2000 Hz was estimated for every subject and recorded.

The English Spondee words developed and standardized by Swarnalatha (1972) used to establish the SRT. The method described by Chaiklin and Ventry (1964) was used for the purpose. Maritored live voice was used to present the stimulus. The SRT thus obtained for a subject is compared with the PTA to validate the pure tone thresholds. Subjects whose SRT was not in agreement with PTA by 17 dB were discarded from further testing.

Following a period of five minutes rest after speech audiometry, the reflexometry was done on all the subjects to record stapedins, reflex thresholds for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, and white noise.

The procedure followed to obtain the reflex, thresholds for pure tones and white noise was the same as given in the Manual of Madsen ZO 72. The manometer was set to middle ear pressure. The sensitivity control knob was set at 13' position and the balance meter was nulled. Pure tones were presented to the contralateral ear (the ear opposite to the one to which the probe tip is fitted), through a Telex 1470 ear phone. The duration of the stimulus was maintained always as 1.5 seconds The intensity of the tone was increased in 5 dB steps till a noticeable deflection was observed on the balance meter. Thus the reflex thresholds were recorded for 500 Hz, 1000 Hz, 2000 Hz and 4000Hz tones. The same procedure was followed to obtain reflex threshold for white noise.

To ensure test-retest-reliability, twenty ears were selected randomly from the experimental group and tested after the relapse of a week.

Formula to predict hearing sensitivity

The proposed formula by Niemeyer and Sesterhenn (1974) did not hold good to predict the pure tone thresholds for Indians as revealed in a pilot study carried out by this investigator, This could probably be because of the reasons discussed elsewhere. The application of the original formula in predicting the hearing threshold always showed a positive error indicating a different multiplication factor to be used in the formula. This new factor was derived mathematically using the test results yielded by the experimental subjects.

The computation of the multiplication factor at each individual frequency is as follows :

The difference between the mean stapedius reflex threshold for a particular frequency and that of the white noise was found out. This was considered as dZ.

That is, $d_Z = ART_T \quad ART_{WN}$

The difference between the mean stapedius reflex threshold (ART_{T1}) and the mean hearing threshold ($HTLT_1$) for the same frequency obtained through behavioral audiometry was established. This was called d_1.

That is, $d_1 = ART_{T1} \quad HTI_{T1}$

The relationship between d_1 and d_2 was determined as follows ;

$d = f (d_2)$ (function of d_2)

$d_1 = K \, d_2$ where 'K' is constant

The value for the 'K' factor was computed applying the data collected by the investigator.

The final formula thus derived is given below :

$$HTL_{T1} = ART_{T1} - K \; (ART_{T1} - ART_{WN})$$

Similarly the value of 'K',factor for other test frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz was derived.

The above formula was then employed to predict the hearing sensitivity for 30 subjects who were randomly selected from the original data.

The computed hearing thresholds were compared with the actual thresholds of the above subjects and the results were treated statistically to assess the significance of difference and also the efficiency of this method in validating the pure-tone thresholds.

Results and Discussion

The results of the present study were treated statistically using parametric statistics. The statistical means (M) of pure-tone thresholds at individual test frequencies were computed. To find the individul variability within the group, the standard deviation (S.D.) was computed seperately at each test frequencies and the values are shown in Table I (a). Inspection of this table readily thows that the pure-tone thresholds are equally variable at all test frequencies.

Table Ia Showing the mean and S.D. for pure tone thresholds and ART thresholds at various test frequencies.

Pure tone thresholds

	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average
Mean	25.95	17.47	16.38	16.95	19.45
S. D.	5.55	5.71	4.76	5.02	3.80

The validity of pure tone thresholds obtained on 186 ears was established by comparing the SRT yielded by them. The PTA of 186 ears were in agreement with their SRT.

Table Ib : ART Thresholds.

	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average	White Noise
Mean	103.70	98.67	97.65	99.65	100.35	76.96
S D.	5.70	5.10	4.55	5.25	4.30	7.40

The mean (M) values and the values of standard deviation for reflex thresholds of various stimuli are given in Table I (b). The table reveals that the reflex thresholds for white noise is comparitivily more variable than that of the pure tones. There was a difference of 23 dB between the average reflex thresholds of tones of 0.5 to 4 KHz and that of the noise. Normally less intensity was required for the wide band stimuli than for pure tones to elicit acoustic reflex. This can be explained on the basis of critical band hypothesis (Jerger, 1974).

In normal hearing subjects, Neimeyer and Sesterhenn (1974) have reported that stapedius reflex thresholds for pure tones was measured at 73 to 105 dB SPL above the normal hearing threshold in a free sound field whereas that of noise at 68.5 dB SPL. Reflex thresholds in present study for pure tones varied from 85 dB to 110 dB SPL with an average of 100.35 dB SPL. This is in good agreement with the results of Niemeyer and Sesterhenn (1974). But the average reflex threshold for white noise, in the present study, was found to be 76.98 dB SPL, which was significantly higher than the reported threshold for white population.

The need for the change of the formula proposed by Neimeyer and Sesterhenn (1974) was felt when it was applied by the present investigator in a pilot study on 20 normal Indians. Subjects yielded a positive error in predicting hearing thresholds. Miller et al., (1976) have also reported a positive error in predicted thresholds when the formula was applied to their subjects in London. Coles (1974) suggested a factor of 2.7 as the muitiplication constant in the place of 2.5. This led the present investigator to derive an appropriate multiplication factor to be applied to the proposed formula to suit to Indian conditions.

The derived multiplication factors at each frequency are shown in Table II. The correlation co-eficient obtained was significant both at 0.05 level for individual frequencies and significant at 0.05 level for the average values of above frequencies thereby indicating a roughly linear relationship betweeen d_1 and d_2. Neimeyer and Sesterhenn (1974) also reported on linear relationship between these two.

Table II showing the Mean and S. D. for d_1 and d_2 at different frequencies (a) Mean and standard deviation of d_2 at different frequencies

Frequency	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average
Mean	26.80	21.60	20.85	22.65	23.35
S. D.	8.75	8.15	8.30	9.05	8.20

(b) Mean and standard deviation of d_1 at different frequencies.

Mean	76.50	81.05	83.25	85.70	81.80
S. D.	6.70	6.15	6.25	6.45	4.75

By knowing the values of d_1 and d_2 the constant 'K' could be derived for all test frequencies and also average of all the test frequencies. The values are shown in table III.

Table III : The correlation between the d_1 and d_2 and 'K-factors' derived for various test frequencies.

	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average
Correlation	0.36	0.22	0.21	0.33	0.18
Multiplication factor	2.8	3.6	3.8	3.8	3.5

Critical Values :

0.05 significance level = 0.138

0.01 significance level = 0.18

With the newly derived factor the formula suggested for the computation of the hearing threshold is as follows :

$$HTL_{T1} = ART_{T1} - K\ (ART_{T1} - ART_{WN})$$

'K' value vary depending upon the test frequency.

After deriving the formula or the basic of the data obtained on 186 ears, it was applied to thirty ears which were randomly selected from the original data to assess the efficiency. The thresholds were calculated for every frequency using appropriate values of 'K'

In 76% of the total 30 ears the thresholds could be predicted using the above formula with an accuracy of ± 15 dB. Neimeyer and Sesterhenn (1974) also reported in 73% of their cases the thresholds could be predicted with an accuracy of ± 10 dB. But Miller et al., (1976 reported they could predict the hearing thresholds in 90% of cases with a wider range of -15 dB to +25 dB. Only 7 of the 30 ears, in the present study, showed greater than I 15 dB difference.

Table IV Showing the difference between the Mean of the pure tone thresholds obtained through behavioral audiometry and the Mean of the computed hearing thresholds at various test frequencies and their significance of difference

	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average
Real hearing threshold Mean	27.13	17.66	16.16	19.43	20.0
Predicted hearing threshold Mean	22.52	18.25	17.79	18.65	17.0
Difference of Means	4.61	-0.59	-1.63	0.78	3.00
t-value	1.99	0.76	0.73	0.31	1.36

Critical values :

0.05 significance level = 2.02

0.01 significance level = 2.69

For the convenience of reference, the Table IV shows the mean hearing thresholds of three ears at various frequencies and also the Mean of the predicted thresholds at the same frequencies. The t–test was applied to find out the significance of difference between two means at all the test frequencies. The t-values obtained are also given in Table IV. All the t-values obtained were much lower than the critical values at 0.05 and 0.01 level indicating 'no significant difference' between the two thresholds.

Thus, the results of this study clearly convince that the first hypothesis 'it is possible to compute the hearing sensitivity from the stapedius reflex thresholds of a subject through a formula can be readily accepted.

The second hypothesis that there exists no difference between computed hearing threshold and the hearing threshold obtained through behavioral audiometry may also be accepted partially as the hearing thresholds could be predicted within a range of + 15 dB using the formula in 76 per cent of cases. It was also proved true when the mean difference between the actual hearing thresholds and the predicted hearing thresholds was treated statistically for the difference. There was no signi- ficant difference either at 0.05 level or 0.01 level. Hence, in majority of cases this proves asa valid means of checking the validity of pure tone thresholds obtained through behavioral audiometry.

The test proved not only valid but also reliable when 10 subjects of the original samples were randomly selected and tested after a relapse of 2 weeks yielded no significant difference in the thresholds.

As the present study did not include the behavior of the clinical population and the children, the standardization of this formula has to be established. The exploration as this line will in future provide definite contributions towards this issue.

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