LOUDNESS PERCEIVED BY NORAMAL AND ABNORMAL EARS AS MEASUED BY STAPEDIAL REFLEX THRESHOLD

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Stapedial Reflex threshold has gained wide currency in the measurement of loudness experience. (Ewertsenef *al,* 1967; Flottorp, Djupesland and Wither, 1971 : Moller, 1961; Thomsen, 1955) of an acoustic stimulus.

Result of Jerger's (1969) study using acousti c stapedial reflex in sensorineural (S.N.) loss cases shows that the reflex SL decline as a function of increasing hearing loss in patients with loudness recruitment. As S.N. loss increases the SL decreases in regular one to one fashion. The relationship is linear and of unit dope.

Alberti and Kristensen (1970) stated that in the presence of recruitment the intensity level required to stimulate the reflex may be unchanged, or even lowered, while the puretone threshold is markedly elevated.,

Investigations of the acoustic reflex reveal a very consistent finding: hearing impaired patients who manifest recruitment of loudness yield acoustic reflex thresholds at lower sensation levels than do normal hearing subjects who show an absence of loudness recruitment (Ewertsen, *et ah,* 1967; Jerger, 1969; Feldman, 1963; Jepsen, 1963; Lamb, Petersen and Homse, 1968; Metz, 1946, 1952; Thomsen; 1955).

Liden (1970) exposed a few cats to broad band noise at a sound pressure level of 115 dB for 8 hours and measured the reflex thresholds. He concluded that the induced sensorineural hearing loss did not change the intra-aural reflex thresholds.

Petersen and Liden (1972) studied sixty seven normals in the age range of 19-43 years and thirty two S.N. loss cases of varying degree of Cochlear involvement . The only major difference in reflex thresholds between normals and S.N. loss cases was found at 4 KHz where, in general, the greatest degree of hearing loss was noted for the subjects in the sensorineural group.

Beedle and Harford (1973) compared acoustic reflex growth and loudness growth at 500,1000 and 2000 Hz. Results indicated that the acoustic reflex growth is essentially the same for the impaired ears and the good ears of the subjects with a unilateral hearing loss.

Basavaraj (1973) established reflex threshold norms for Indian population. His study also included a few cases with S.N. hearing loss of varying degree of severity. The frequencies 1 KHz, 2KHz, and 4 KHz were common for both population. The normal and S.N. hearing loss ears' stapedial reflex thresholds were respectively as follows: 82,94.42; 80, 86.43; 83,91.25 dBHL. The sensorineural hearing loss group consisted of cases with no tone decay.

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The present paper is an investigation of the observed 'Consistent findings' of several investigators,

Methodology

Experiment I: This part consisted of finding the difference in the acoustic stapedial reflex threshold obtained before and after inducing temporary hearing loss (Cochlear) in normal hearing (-10 to 15 dBHL, I SO 1966) subjects.

Subjects: Ten College students (9M-J-1F) in the age range of 17-25 years were chosen for participation in this study. The subjects selected were only those with bilateral normal hearing (according to ISO 1964 specifications) and whose acoustic stapedial reflex thresholds were less than 95 dBHL at test frequencies, i.e., 1 KHz and 2 KHz. In order to measure the reflex threshold (elevated reflex threshold) after fatiguing the ear, subjects with low reflex thresholds were selected.

Procedure: The following measures were obtained for each subjects:

(a) Pure tone thresholds and acoustic stapedial Reflex thresholds of both ears at test frequencies, i.e., 1 KHz and 2 KHz.

(b) The ear fulfilling the reflex threshold criteria as specified earlier (hereafter known as test ear) was subjected for a continuous 1 KHz tone at 110 dBHL for a period of 30 minutes. Atthe end of 30 minutes, pure tone threshold at 1KHz and 2 KHz were obtained for that ear.

(c) Acoustic stapedial reflex thresholds were once again obtained in the test ear for the test frequencies.

(d) After obtaining the acoustic stapedial reflex thresholds, pure tone AC thresholds were once again measured in the test ear for test frequencies.

The post stimulatory measures were obtained within the first 2 minutes after cessation of the fatiguing stimulus, i.e., 1 KHz tone at 110 dBHL for 30 minutes.

Pure tone thresholds were obtained by using the modified Hughson-Westlake (Jerger and Carhart, 1959) method for all the subjects. Madsen (Model 4251) audiometer with TDH-39 ear phones calibrated to ISO (1964) standards was used for all purposes of this experiment. The calibration was checked using artificial ears (Bruel and Kjaer Model 4152) with condensor microphone (Brucl and Kjaer Model 4144) and A. F. Analyser (Bruel and Kjaer Model 2106). The acoustic reflex measurements were made using Madsen Z070 Electro acoustic Impedance Bridge (calibrated using Bruel and Kjaer equipment). The experiment was conducted in a sound treated room.

The earphone of the Madsen (Model 4251) audiometer was connected to the head band of the Madsen Z070 Electro-Acoustic Impedance Bridge. Thus at a stretch puretone and reflex thresholds were obtained at 1 KHz and 2 KHz for a particular ear. Similar findings were recorded for the other ear. The ear fulfilling less than 95 dBHL reflex criteria was chosen for inducing hearing loss.

The procedure given in the Manual (Manual of Madsen Electro-Acoustic Impedance Bridge Model Z070) published by Madsen Electronics was followed with a slight modification for obtaining the acoustic reflex threshold.

As air tight sealing was not possible, reflex thresholds were measured in the absence of air tight sealing. The difference in reflex threshold was about 5-10 dB in a pilot study conducted with and without air tight sealing.

Difference Method (Garrett, 1971) was used as a test of significance between the mean values of pre and post stimulatory reflex thresholds. Four subjects of the original sample were tested once again to check the test-retest reliability after a period of eight days.

Experiment II: Acoustic stapedial reflex threshold measurement in moderate sensorineural hearing loss ears (40-70 dBHL ISO 1964) with no tone decay.

Subjects: All subjects with moderate sensorineural hearing loss reported (between Sept. 1974 to Feb. 1975) at the AIISH, Mysore were included for this study.

Procedure: The following measures were obtained for each subject.

(a) AC and BC thresholds at audiometric frequencies ranging from 250 Hz to 4000 Hz.

(b) Complete tone decay test measurements (Carhart, 1957).

(c) Acoustic stapedial reflex threshold for frequencies showing moderate sensorineural hearing loss.

Five subjects of the original sample were tested again to check the test-retest reliability.

Results and Discussion

Experiment I: At 1 KHz, the mean pure tone threshold is 7dB. Poststimulatorily, stimulation thresholds had goneup to 53.5 dB, exhibiting a mean threshold shift of 46.5 dBHL. The mean acoustic stapedial reflex threshold (ART) of 87.5 dB is elevated to 101 dB, by a mean shift of 13.5 dB.

At 2 KHz the mean pure tone threshold of 3 dB is raised to 51.5 dB post stimulatorily (mean shift of 48.5 dB). The mean reflex threshold of 86.5 dB is elevated to 97 dB (mean shift of 10.5 dB).

The mean pure tone thresholds obtained, after measuring the elevated reflex thresholds, are 46 dB and 43.5 dB respectively at 1 KHz and 2 KHz. The obtained mean pure tone thresholds show, that for all experimental purposes the subjects had moderate hearing loss (40-70 dB).

There is significant difference between the mean pre and post stimulatory reflex thresholds, at .05 level and .01 level, at 1 KHz and 2 KHz.

Observation of the Temporary Threshold Shift (TTS) and the shift in Acoustic Reflex Threshold (ART) in the present study and in the previous study

(Vyasamurthy, *et al.*, 1975) shows that the shift in acoustic reflex threshold (ART) is about 10-15 dB, irrespective of the amount of TTS. Table 1 gives the relation between TTS and shift in Acoustic Reflex Threshold (ART) for 10 subjects.

TABLE 1. Showing the Amount of TTS and Subsequent shift in Acoustic Reflex Threshold

Number	1 KHz		2 KHz	
	TTS in dB	Shift in ART dB	TTS in dB	Shift in ART dB
1.	55	10	55	5
2.	55	15	45	15
3.	45	10	35	5
4.	50	20	60	10
S.	55	20	50	15
6.	50	15	55	20
7.	25	10	45	15
8.	45	15	45	5
9.	40	10	45	5
10.	45	10	50	10
Mean	46.5	13.5	48.5	10.5

Constant shift in Acoustic Reflex Threshold (ART), irrespective of the amount of TTS, can be well understood if we look into the following examples and the Table 2 and 3.

Examples (fromTable 2):

	ART in dBHL	ART in Sones	Elevated pure tone THS in dBHL	Post Stimulatory ART in dBHL	Post Stimulatory ART in Sones
1.	85	32	60(4)	95	32
2.	85	32	50(2)	95	32

Note:—The number in parentheses are approximate Sone Values.

TABLE 2: Showing the relationship between the Normal Acoustic Reflex Threshold (ART) and the Post Stimulatory ART (i.e., after inducing temporary hearing loss of S. N. type) in terms of perceived loudness among 10 normal hearing subjects at 1 KHz.

No.	ART dBHL	ART in Sones	Elevated Pure tone THS dBHL	Post Stimulatory ART in dBHL	Post Stimulator' ART in Sones'
1	85	32	60(4)	95	32
2	85	32	65 (8)	100	64
3	85	32	50(2)	95	32
4	80	22	55 (4)	100	64
5	85	32	50 (2)	105	64
6	90	47	55(4)	105	64
7	95	69	40(1)	105	64
8	80	22	55 (4)	95	32
9	95	69	50(2)	105	64
10	95	69	55 (4)	105	64

Note:—The number in parentheses equals to the loudness in Sones.

Table 3: showing the relationship between the Normal Acoustic Reflex Threshold (ART) and the Post Stimulatory ART (ie., after including temporary hearing loss of S.N. type) in terms of perceived loudness among 10 Normal hearing subjects at 2KHz.

NO.	ART dBHL	ART in Sones	Elevated Pure tone THS dBHL	Post Stimulatory ART in dBHL	Post Stimulatory ART in Sones
1.	80	22	55(4)	85	16
2.	85	32	50(2)	90	32
3.	90	47	45(2)	95	32
4.	95	69	60(4)	105	64
5.	80	22	50(2)	95	32
6.	85	32	55(4)	105	32
7.	95	69	50(2)	110	128
8.	75	15	50(2)	90	16
9.	95	69	50(2)	100	64
10.	85	32	50(2)	95	32

Note : the number in parentheses equals to the loudness loss in Sones.

The Acoustic reflex threshold (ART) is converted into Sone value using Fletcher's (1953) formula. The following table shows the growth of loudness in sones with increase in intensity, in normal hearing subjects.

dB HL	Loudness in Sones
40	1
49	2
58	4
67	8
76	16
85	32
94	64
103	128

According to this table an ear with 60dB loss incures a loudness loss, approximately of 4 sones. It is explained as follows

$$\text{Loudness in Sones} = 2\left\{\frac{L-40}{9}\right\}$$

$$= 2\left\{\frac{60-40}{9}\right\} = 2^{2.22}$$

2.22log = 2.22x0.301= 0.66822

Antilog of 0.66822 = 4.68 Sones

Thus, the subject loses, approximately, 4 sones, if the loss is 60dB. B for every 9dB increase the above threshold he perceives half the loudness of what

TABLE 4: Comparision of the normal acoustic reflex thresholds (ART; obtained from Basavaraj, 1973) with the ART obtained in typical moderate S.N.hearing loss cases in terms of perceived loudness at 1,2, and 4 KHz.

Freq. in Hz	Mean Normal ART dBHL	Mean Normal ART in Sones	Mean Mod. S. N. hearing loss dBHL	Mean ART in Mod. S. N. loss dBHL	Mean ART in Mod. S.N.los in Sones
1000	82	25	54.81 (4)	96.66	*32*
2000	80	22	5X57 (4)	92.72	*32*
4000	83	27	43.75 *(1)*	91.66	*32*

Note: The number in parentheses equals to the loudness loss in Sones.

normals would perceive. Therefore, the difference between the impaired ear and the normal ear is just about 10 dB. In this particular example (1), it is 10 dB above the normal acoustic reflex threshold.

Such observations have been reported in table 2 and 3. However, the above explanation does not hold good for all subjects, because, some extreme variations are observed in few subjects. This may be because of the inherent limitation of the audiometric dial calibration (in 5 dB steps) or due to the 'Subjective' judgement of the Balance Meter needle movement of the Impedance Bridge (Madsen Z070), to ascertain the reflex.

Test-Retest reliability has been established on four subjects. In one subject, the obtained retest score differed by 10 dB. Otherwise, audiologically acceptable scores are obtained. Reliability was statistically computed by using the 'Rulon Method' as given by Guilford (1965).

Experiment II: Table 4 shows the comparison of the normal acoustic reflex thresholds (Basavaraj, 1973) with the ART obtained in typical moderate sensori-neural hearing loss cases in terms of perceived loudness at 1 KHz, 2 KHz and 4 KHz. (At 2 KHz and 4 KHz the HL itself is considered as L Value, i.e., loudness level in phone, as there is negligible difference between 1, 2, and 4 KHz in the equal loudness contours—Stevens and Davis, 1938). The findings show that the loudness (determined by elicitation of reflex) perceived by sensorineural hearing loss ears without tone decay, is diminished by half the normal loudness (equipment to about 10-15 dB loss in intensity).

In other words the difference in hearing level needed for stapedius reflex threshold for SN loss ear is negligible as diminition by half the normal loudness is just 9 dB loss in terms of intensity. (However, the observation extends upto a loss of 15 dB. This could be due to factors explained earlier in Experiment I).

Test-Retest Reliability: has been established on 5 cases. Reliability was statistically computed by using the 'Rulon Method' as given by Guilford (1965).

Conclusions

(1) The normal and the SN loss cases (including induced hearing loss) exhibit stapedius reflex at almost equal perceived loudness.

(2) A seemingly constant shift of 10-15 dB above the normal acoustic reflex threshold is needed in cases with sensorineural hearing loss. This shift is explained on the reasoning that it is to overcome the peripheral threshold level loudness loss. This concept ultimately questions the phenomenon of 'abnormal growth of loudness' in sensorineural hearing loss ears as the abnormality is not with respect to the growth of loudness but only with respect to the hearing level.

The present conclusions warrant further considerations.

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