Certificate

This is to certify that the Independent project entitled *"Long Term Average Speech Spectrum in Hindi"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 0122).

Mysore
May 2002

Director
All India Institute of
Speech & Hearing
Mysore - 570006.

Certificate

This is to certify that the Independent project entitled "*Long Term Average Speech Spectrum in Hindi*" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

Guide

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Mysore
May 2002

Declaration

I hereby declare that this Independent project entitled *"Long Term Average Speech Spectrum in Hindi"* is the result of my own study under the guidance of Manjula P., Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier or in any other University for the award of any Diploma or Degree.

Mysore

May 2002

Register No. M 0122

Dedicated to

My Beloved Family

ACKNOWLEGEMENT

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CHAPTER 1

INTRODUCTION

The use of hearing aids in rehabilitation of the hearing impaired has been a common practice since ages. If one thinks back in time, it goes back to the hand-cupping behind the ear, the most natural hearing aid ! However, the indigenous human brain has been successful in evolving the hearing aids from the non-electric to electric ; the bulky and huge to light weight and small; the analog to digital and so on. The main goal, whatever may be the technology, is "ease of listening" ! But can we replace the wonder of nature, the sense of hearing ? We can only try !

Of the many models of hearing aids, a systematic approach for hearing aid selection is incorporating one of the prescriptive formulae in the selection of hearing aids. These formulae have been devised to solve the dilemma of selecting the hearing instruments, roughly 3-5 million made in the world each year. The prescriptive procedures provide a consistent and repeatable frame work for selecting an instrument which, on theoretical grounds, is likely to most benefit the instrument wearer. (Upfold, 1988)

The goal of many of these prescriptive procedures is to achieve audibility of amplified speech across a wide range of frequencies (Cox, 1983 ; Pascoe, 1978 ; Popelka and Mason, 1987 ; Seewald, 1992) and at a comfortable listening level (Skinner, 1988). Thus, we need some representation of the speech spectrum which can be used in conjunction with an individual's pure tone thresholds to select frequency-gain characteristics of a hearing aid.

There are a number of different methods by which speech can be analysed spectrally. One such analysis procedure takes a time average of the sound / speech pressure level per cycle across frequency. This measurement commonly referred to as the long term average spectrum of speech (LTASS), provides a means of viewing the average frequency distribution of the energy in a continuous speech sample. The measurement of the long-term average speech spectrum is made by passing the speech energy through a series of contiguous band pass filters and integrating the energy at the output of each filter. These averaged values are then plotted to arrive at the visual representation that is a smoothened plot of the envelope of the power spectrum of the speech sample. The speech power is greatest between 100 to 600 Hz, where the energy of the fundamental frequency of the voice and the first formant overlap. It drops off with increasing frequency above about 600 Hz such that at 10,000 Hz, the level is approximately 50 dB below the peak level measured at the lower frequencies (Denes and Pinson, 1963).

Hearing aid gain prescriptions often incorporate the above i.e., an adjustment to compensate for the fact that normal speech contains more low frequency than high frequency energy. The reasons given for this are that excessive low frequency amplification would tend to mask the lower energy in the high frequency region. This would induce the hearing aid wearer to use a volume control setting which would be too low for optimum reception of higher frequencies. Once the gain is selected and adjusted, the sensation level of the amplified output is determined by the input level of the speech signal.

Hence, it is important that the representation of the long term average speech spectrum (LTASS) used to calculate gain accurately reflects the acoustic characteristics of the speech signal actually received at the hearing aid microphone. (Cornelisse, Gagne and Seewald, 1991)

Two types of multi-talker speech spectra have been employed in hearing aid gain prescription procedures. They are referred to as simultaneous spectra and sequential spectra. A simultaneous spectrum is obtained by measuring the long term RMS spectrum produced by several talkers recorded at one time, talking together. This type of spectrum has been employed in hearing aid gain prescriptions by Cox (1983) and Pascoe (1978). In contrast, a sequential spectrum is defined here as obtained by measuring the long term RMS speech spectrum for each of several individual talkers. This type of spectrum is found in the hearing aid prescription procedure described by Byrne and Tonisson (1976). For purposes of hearing aid gain prescription, sequential type of spectrum seems more appropriate than a simultaneous spectrum because the sequential spectrum accurately represents the average levels in the speech of individual talkers.

Need of the study

LTASS values have been reported by Western investigators and the same values have been used for Indian population. There are reports that differences in LTASS may be attributable to factors that talkers speak different languages and accents (Cox and Moore, 1988). Therefore, by doing this study, we will be able to get values for the Indian population and more efficiently use the prescriptive procedures.

Appropriate amplification for infants and young children with hearing loss is critical because the amplified speech signal will be used for development of speech and language. At present, there is no consensus regarding the optimum amplification characteristics of this population. Some investigators say that present hearing aid fitting algorithms developed and validated on an adult population can be applied to young children (Byrne and Ching, 1988, cited in Stelmachowicz, Hoover, Lewis, Kortekaas and Pittman, 2000. Others say amplification needs of children with prelingual hearing losses may differ substantially from the needs of adults who generally develop hearing loss later in life (Boothroyd, 1997a, 1997b)

Werner, 1992, cited in Stelmachowicz, Hoover, Lewis, Kortekaas and Pittman, 2000, reviewed a number of studies from the developmental psychoacoustic literature and concluded that infants have higher behavioral detection thresholds (by 10-25dB) than do adults. Developmental differences have also been reported using a wide range of speech materials (Nozza, Rossman and Bond, 1991, cited in Stelmachowicz, Hoover, Lewis, Kortekaas and Pittman, 2000). Young children also tend to use slowly changing dynamic or temporal cues, whereas adults rely more on static spectral cues or temporal cues (Morrongiello, Robson, Best and Clifton, 1984, cited in Stelmachowicz, Hoover, Lewis, Kortekaas and Pittman, 2000; Nittrourer and Studdert-Kennedy, 1987; Nittrourer, 1992)

Keeping the above in mind the present study has been carried out taking children as well as adults as subjects.

Aims of the Study

1. To derive the LTASS in Hindi for adults and children.
2. To compare the LTASS between adult males and adult females.
3. To make the comparison of LTASS between boys and girls (among children).
4. To compare the LTASS between adults and children.
5. To bring about a comparison of the LTASS between adult males and children.
6. To compare the LTASS between adult females and children.
7. To make a comparison of the LTASS obtained by western studies and the present study.

CHAPTER 2

REVIEW OF LITERATURE

The long-term average speech spectrum has been investigated by a number of investigators, In the following few pages, the review of literature on the speech spectra got by researchers and their implications in the calculation of prescriptive formulae for hearing aids will be done. The review has been divided into categories as:

1) Studies and their findings on LTASS.

2) Variables affecting LTASS.

3) Hearing aid selection using LTASS.

The first measurements of the LTASS were reported at the Bell Telephone Laboratories almost 60 years ago (Crandall and Mackenzie, 1922, cited in Formby and Monsen, 1982). Since that time, speech spectra have been obtained by researchers for a variety of different reasons and purposes. The earliest investigators were interested in the spectra of continuous speech from a communication-engineering point of view. (Crandall and Mackenzie, 1922; Sivian 1929; Dunn and Fransworth, 1939; Dunn and White, 1940, cited in Formby and Monsen, 1982). During World War II, a measurement of speech spectra was of interest to the military (Stevens, Egan and Miller, 1947, cited in Formby and Monsen, 1982). More recently, the measurements have been obtained by anthropologists and linguists (Tarnoczy, 1956; Winckel, 1968; Bordone-Sacerdote and Sacerdote, 1969; Fant, 1973, cited in Formby and

Monsen, 1982) and by scientists concerned with speech production (Licklider, Hawley, and Walkling, 1955; Brandt, Ruder, and Shipp, 1969; Schwartz, 1970, cited in Formby and Monsen, 1982). Consideration of the speech spectrum appears to be assuming increasing prominence in literature pertaining to hearing aid design, selection and evaluation.

In hearing aid selection, there appears to be rather widespread agreement that, for any given hearing threshold level (HTL) or most comfortable loudness level (MCL), less gain should be provided at the frequencies below 1kHz than at higher frequencies because, the low frequency part of the speech spectrum contains greater energy. Some hearing aid selection procedures such as that given by Shapiro, 1976, include adjustments based on the spectrum and others such as that given by Crouch and Pendry, 1975, cited in Formby and Monsen, 1982, include adjustments, which would have a similar effect. The reasons given for this are that, excessive low frequency amplification would tend to mask the lower energy in high frequencies. This would induce the hearing aid wearer to use a volume control setting, which would be too low for optimum reception of the higher frequencies.

Most scientists prescribe real ear gain keeping in mind the above stated facts. For doing so, though, they first need a speech spectrum. Findings of a few studies of how the speech spectra have been got are as follows:

1) **Dunn and White (1940)** did a classic study in which 11 talkers (6 male and 5 female) were instructed to read a 2.5 minute passage. The sound was picked up by a microphone positioned 30 cm in front of the talker's lips. Samples 125

msec in duration, were taken at the rate of 4 samples/sec, for a total of 600 samples for the entire 2.5 minute passage. For the analysis, the frequency range was divided in to bands, one octave wide, below 500 Hz and ½ octave wide above that frequency. The rms pressure in each band was calculated for each 125 msec interval; these short interval rms values were averaged across talkers, converted to spectrum level and plotted as in Figure 1.

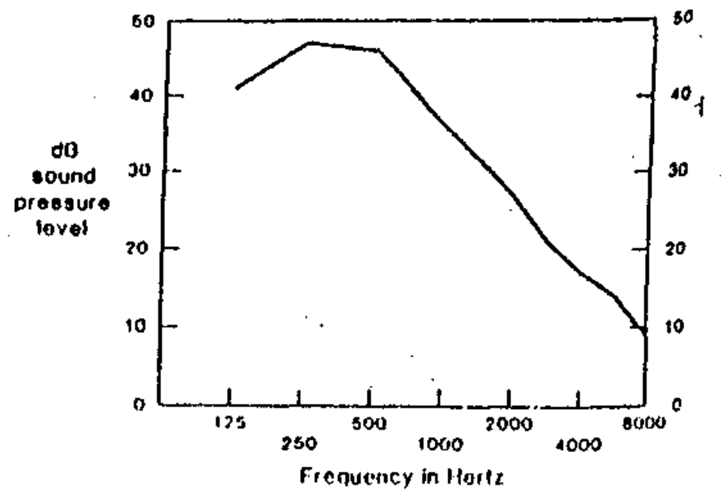


Figure 1: Adapted from Olsen, W.O., Hawkins, D.B. and Tasell (1987), Figure 1, page 100.

The result is the average free field rms pressure per cycle, for an interval equivalent to 1.25 minutes of speech, in each of 12 frequency bands. Figure 1 shows maximum intensity in the vicinity of 500 Hz, i.e., largely the contribution of the first formant of voiced sounds. Above this region, the spectrum rolls off at roughly 9 dB/octave toward high frequency region mainly by the low energy noise of unvoiced and voiced consonants. While this general shape is characteristic of most published estimates of the long-term speech spectrum, the relative levels as a function of frequency, do vary.

2) Byrne (1977) performed a study in which the speech sample of 15 men and 15 women were recorded. The speech material was a passage from a popular magazine, which ranged from around two and a quarter to over two and a half minutes in duration. Speech samples were recorded in a sound treated room with the subject seated, so that his/her mouth was 16 inches from the microphone of the tape recorder. During the reading, the VU meter of the tape recorder was observed to see that the speech level was reasonably steady. The speech samples were then analyzed to obtain an average rms spectrum.

This average spectrum was got for the Australian speakers and the spectrum was found to be similar to that of other studies. They found differences between spectra of males and females in the region of 125 Hz and 1000 Hz where the female level is much lower, although it could not be measured precisely.

3) **Berger, Klich and Millin (1982)** conducted a study with 16 freshmen and sophomores, (eight men and eight women) as subjects. The subjects read a 15 word, 18-syllable second order sentence. The sentence was considered to provide a representative sample of the speech sounds a hearing aid must amplify. The subjects were seated facing the condenser microphone positioned one meter in front of his or her mouth and were asked to read at normal speed and loudness. The subjects were given a practice time and before the speech samples were recorded.The tape-recorded sample and the ambient noise were digitized at 12,000 samples per second with a minicomputer. The digitized samples were then analyzed with a Fast Fourier Transformation (FFT) whose

output was divided in to one-third octave bands. Later one-third octave band spectral analysis of the speech samples was obtained.

The greatest energy in speech was found to be around 500 Hz. This apparently reflects the considerable energy present in vowels at the fundamental frequency and their lower formants. The energy in speech gradually decreased towards the higher frequencies.

4) Byrne et al., (1994) did a study in which the LTASS was determined for 12 languages : English (several dialects), Swedish, Danish, German, French, Japanese, Cantonese, Mandarin, Russian, Welsh, Singhalese, Vietnamese and Arabic. Speech samples (18) were recorded, using standardized equipment and procedures in 15 localities for (usually) ten male and ten female talkers for each language. Eight sets of recording equipment were assembled. These consisted of a high quality (but inexpensive) cassette tape recorder deck and custom made microphones. A passage was selected from a story book, which took about 90 seconds for most talkers to read. The talker read the material, which was enlarged and placed on a chart at least 1 m in front of him or her. The recording microphone was placed on a stand or suspended in front of the talker, 20 cm from the mouth and at an azimuth of 45° incidence. The subjects were instructed to read at a normal speed and level, and were given practice time.

All the analyses were done at National Acoustic Laboratories, Sydney, using a Bruel and Kjaer 2131 analyzer coupled to a Tectronics computer. The overall and third octave band nns levels were derived. It was found that the

LTASS across samples were similar and thus, a Universal LTASS was found to be very similar to that recommended by Cox and Moore (1988).

5) Jha, 1998, performed a study in Hindi in which he took fifteen men and fifteen women as subjects and found the LTASS. Using the software "Vaghmi" ,he analysed the spectra. The general shape of the spectrum was similar to those reported by previous investigators, but significant differences were found between those obtained and the Western studies. At low frequencies, the Western spectra were higher and at high frequencies, they were lower in energy. In the males vs. females spectra , no differences were reported.

Variables Affecting LTASS

Thus, as is evident a plethora of studies to find the LTASS have been done. There is a general spectrum shape, which is characteristic of the LTASS as shown in Figure 1. However, relative levels as a function of frequency do vary. The differences may be attributed to a number of variables related to the way in which estimates were derived.

Variables related to the speech signal may include the *sex, age and vocal effort* of the talker. The *choice of speech material* may include, nonsense syllables, synthetic sentences, passage. The *method of analysis* may be varied in an almost infinite number of ways. One of the most important of these is the *width of the frequency bands* within which each average level will be computed. Also important are the *length of the sampled interval and whether or not the analysis* includes silent intervals between words. The analysis done in terms of *simultaneous or sequential spectra* is also a variable which may affect the LTASS. *The distance and azimuth of the microphone* relative to the talker may have an appreciable effect on the overall level of speech. Finally, the *results* may be reported in spectrum level or in overall levels within the analysis bands.

When the possible effects of these and other variables are considered, it is easy to see how published estimates of the long-term characteristics of speech may vary. Considering that speech spectra vary greatly from one individual to another, it would seem desirable that speech with a known, preferably average, spectrum be used in hearing aid evaluation procedure. For hearing impaired listeners, it is generally accepted that the overall level should be between 65 and 70 dB SPL.

The speech spectra for four prescriptive procedures (that incorporate LTASS into their calculation of real ear gain) are as follows: The speech spectra chosen by Pascoe (1978) and Cox (1983) arc essentially identical, whereas those chosen by Byrne and Tonisson (1976) (note that this is the spectrum published by Byrne in 1977 and incorporated in a revised procedure) and Byrne and Dillon (1986) of National Acoustic Laboratories in Australia are of different configuration. In the speech spectrum used by Byrne and Tonisson, the level from 2000 to 6000 Hz is constant, whereas, for the Pascoe and Cox spectra, the level falls-off 10 dB at higher frequency. In addition, the speech energy at 250 and 500 Hz in the Byrne and Tonisson speech sample is 15 dB higher than at 1000 Hz, whereas for the other two it is only 5 to 10 dB higher.

If the overall level differences were ignored, less real ear gain will be needed at low (250 to 500 Hz) and high (3000 to 6000 Hz) frequencies relative to that in the mid frequency region (1000 and 2000 Hz) for the Byrne and Tonisson speech spectrum than for the Cox and Pascoe spectra. The speech spectrum derived by Byrne and Dillon speech spectrum is intermediate between the others.

Procedures for Describing Real Ear Gain

There are two main categories of procedures

1. Prescriptive Procedures
2. Comparative Procedures

The prescriptive procedures make use of threshold or MCL (most comfortable level) based data. Whereas, the comparative procedures are speech-test based approaches. They differ somewhat in their underlying principles. There is no consensus regarding which of the many procedure is the best.

According to McCandless and Lyregaard (1983), a fitting method should fulfill the following requirements.

1. A high level of hearing aid acceptance and benefit for the user.
2. A prescriptive fitting method, which implies prediction of, required hearing aid characteristics on the basis of audiological information.
3. A simple procedure capable of administration within the time constraints of a busy office or clinic.

4. A procedure based on sound scientific principles, such that it can be expanded, if necessary.
5. The result must be verifiable i.e., it must be possible to document the extent to which the objective has been achieved.
6. A procedure, preferably, not requiring excessive specialized equipment and should be feasible in existing dispensing environments.
7. As far as possible, it should be general i.e., not limited to specific age or ethnic groups.

In most prescriptive procedures, it is assumed that there is a preferred listening level (PLL) within the comfortable loudness range, and that, sound at this level requires less effort to listen than lower or higher levels. The preferred listening level will depend on each hearing impaired individual's growth of loudness and this level will often differ for specific frequencies between 250 and 6000 Hz. For broad band sounds, such as speech, the preferred listening level will also depend on the individual's loudness summation, the frequency content of the speech, the frequency response of the hearing aid and the relation of the amplified signal to the individual's auditory area.

In some prescriptive procedures, measurements of one or more points in the comfortable loudness range are made for frequency specific sounds for each individual. In Pascoe's procedure it is assumed that the preferred listening levels are in relation to the mid point of the comfortable loudness range as described above, and in Cox's procedure it is assumed that they are at the mid point of the range between threshold and the upper limit of comfortable loudness. These measurements are based on the growth of loudness experienced by the individual.

In other prescriptive procedures, no direct measurements of comfortable loudness are obtained. The preferred listening levels (PLLs) are estimated from pure tone thresholds using formulae based on the average of PLLs obtained from large groups of hearing impaired individuals, consisting mainly of those with sensorineural losses. These averages are often the mean of a 20 to 30 dB range. Consequently, an individuals actual preferred listening level may differ by as much as ± 15 dB from the average level. For example, if the average PLL is 80 dB HL for people with a pure tone threshold of 45 dB HL at 2000 Hz, one person may have an actual preferred listening level as low as 65 dB HL and another may have one as high as 95 dB HL.

Although, further research is needed on more exact ways to determine PLLs, it is assumed that estimates based on direct determination of an individual's comfortable loudness range and a consideration of the normal comfortable loudness level contour will yield a clear approximation of what they actually are than estimates based on threshold data. Some of the procedures are described using the Pascoe speech spectrum to demonstrate how the real ear gain prescribed by several procedures affects the configuration of the amplified speech spectrum. A brief review of a few hearing aid selection procedure; that make use of speech spectrum follows-

I. Prescriptive Procedures for Linear Hearing Aids

   A. Threshold Based Procedures

NAL procedure (1976)

NAL-R procedure (1986)

POGO procedure (1983)

Berger et al. procedure (1984)

B. MCL based procedure

Pascoe procedure (1978)

Cox procedure (1983)

II. Prescriptive Procedure for Non-Linear Hearing Aids

DSL I/O method (2000)

NAL procedure for hearing aid selection

The National Acoustic Laboratories (NAL) procedure applies a formula which utilizes individual puretone thresholds to prescribe both real ear frequency response and overall gain. Of the two parameters, frequency response is considered more critical, as overall gain is usually adjustable by means of volume control of the instrument. The NAL procedure also allows prediction of the 2cc coupler response, which, on average, is most likely to result in the required real ear performance.

The NAL procedure aims to make all parts of the frequency spectrum of speech equally loud when a hearing instrument is worn at preferred listening level. The underlying assumption is that the wearer will obtain optimum speech understanding when the widest possible range of frequencies is heard and this is most easily achieved if no part of the speech is louder than the others. The original Byrne and Tonisson (1976) formula did not achieve this consistently.

Calculations of real ear gain for a person with a moderate sensorineural hearing loss as prescribed by the Byrne and Tonisson procedure are as follows:

Sl.No		250Hz	500Hz	lOOOHz	1500Hz	2000Hz	3000Hz	4000Hz	6000Hz
1.	Thresholds (dBHL) earphones	29	31	39	49	65	58	63	54
2.	Multiply by 0.46	13	14	18	23	30	27	29	25
3.	Correction factor	-15	-15	4	4	3	-2	-2	4
4.	Prescribed real car gain	-2	-1	22	27	33	25	27	29
5.	Unaided field threshold(dB HL)	19	32	43	44	63	56	58	45
6.	Prescribed aided threshold(dB HL)	21	33	21	17	30	31	31	16

Table 1: As taken from Skinner M. W. (1988), Table 6.11, page-166.

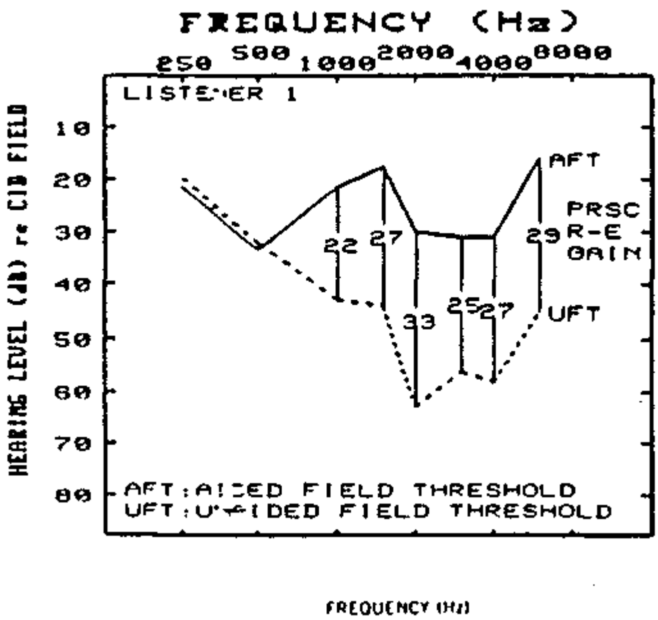


Figure 2: Adapted from Skinner,M.W., Figure 6.11, pagel66. Shows the calculations of real ear gain prescribed by Byrne and Tonisson procedure.

This procedure prescribed gain at each of a number of frequencies from hearing threshold levels (HTL) at those frequencies. Gain was increased at 0.46 times the rate of increase in HTL, this being the value derived from a study of how user-gain increased with HTL. Thus, the gain selection was based on the "half gain rule". On this basis, they devised a graph showing the amount of gain required for each hearing threshold level. The gain at the different frequencies were adjusted to compensate for the differences in loudness observed at the 60 phon equal loudness contour and for the differences observed in the levels of the various frequency components of speech.

NAL-R Procedure

It was realized that although the Byrne and Tonisson procedure aimed to amplify speech so that all frequency bands are equally loud, it was found that this was not being achieved for all individuals. Thus Byrne and Dillon (1986) revised the NAL procedure. It utilized three rules -

1. A half gain rule - applied to three frequency average hearing levels at 0.5, 1.0 and 2.0 kHz.
2. A flat audiogram rule which states that an audiogram with equal audiometric thresholds (HTL) for all frequencies requires a frequency response slow raising at +9 dB/octave up to 1000 Hz and falling at the rate of -2 dB/octave from 1000 to 4000 Hz.
3. A 1/3 slope rule - in which responses slope in each part of the frequency range varied by 31% of the difference between adjacent frequencies' HTLs.

Calculation of real ear gain prescribed by Byrne and Dillon procedure is as follows:

Sl.No		250Hz	500Hz	lOOOHz	1500Hz	2000Hz	3000Hz	4000Hz	6000Hz
1.	Thresholds (dBHL) earphones	29	31	39	49	65	58	63	54
2.	Multiply by 0.31	9.0	9.6	12.1	15.2	20.2	18.0	19.5	16.7
3.	Add overall gain	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
4.	Add frequency specific constant	-17	-8	+1	+1	-1	-2	-2	-2
5.	Prescribed real ear gain (dB)	-1	8	20	23	26	23	24	22

Table 2: As taken from Skinner, M. W. (1988), page- 170.

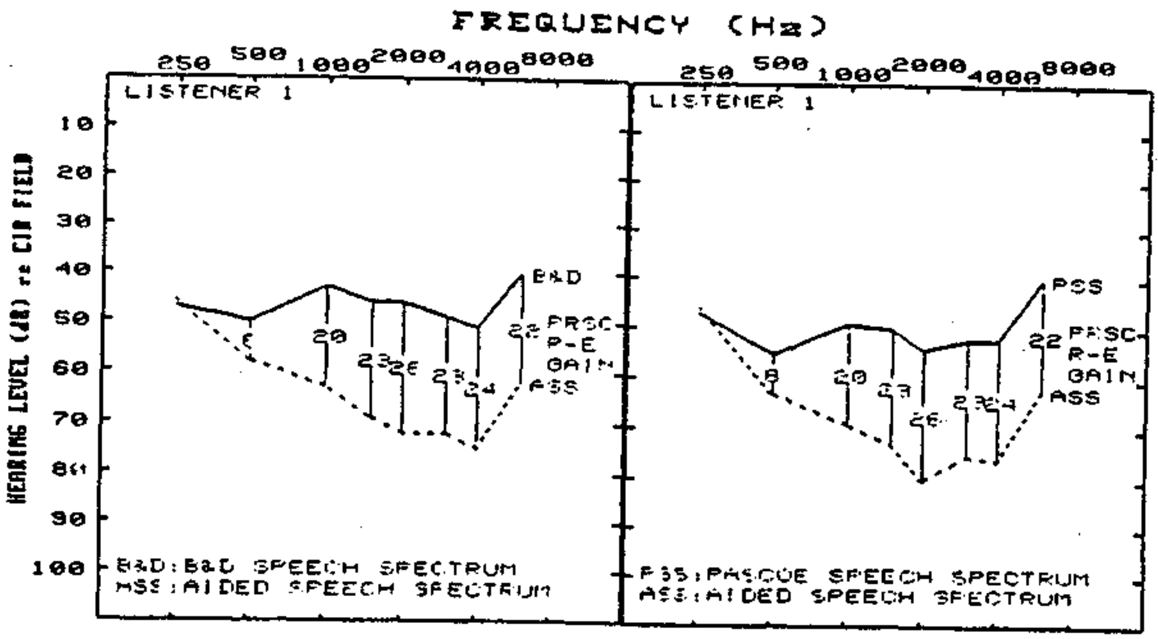


Figure 3: Adapted from Skinner M.W., Figure 6.15,pagel71. Shows the aided speech spectrum prescribed by the Byrne and Dillon procedure \

The gain prescription is prescribed from a combination of rules 1 and 3: and a frequency response is prescribed from a combination of rules 2 and 3. For convenience, the procedure is usually applied using a computer or NAL slide chart but may be simply calculated directly from a table. The formulae derived are based on analysis of the relation between the slope of the audiogram and the slope of the optimal real ear frequency response of a hearing aid. Linear regression analysis indicated that the response slope could be predicted reasonably well (within ± 5 dB/octave; significant at the 0.05 level) from the audiogram slope. Therefore, regression equations from these analysis were used to derive the formulae for prescribing real ear gain from supra-aural-earphone thresholds between 250 and 6000 Hz.

In these formulae, the frequency specific constants give the relative ear gain at each frequency that the procedure predicts is optimal for some one with the same hearing threshold levels at all frequencies (dB HL). Note that the gain is maximal at 1000 and 1500 Hz and that the gain at low frequencies especially at 500 Hz, is significantly more than the Byrne and Tonisson procedure.

POGO (Prescription of Gain and Output) Procedure for Hearing aid Selection

In this procedure, which was devised by McCandless and Lyregaard (1983), the half gain rule is modified so that the gain at 500 and 250 Hz is reduced by 5 dB and 10 dB respectively. This provides less amplification of low frequency room noise. The POGO fitting method is restricted to predominantly sensory hearing losses, with thresholds no greater than 80 dB

HL. Gain and output for conductive hearing losses can be calculated but additional gain is required.

Using POGO method

It contains three basic steps

Stepl : Calculation of the required characteristic, gain and MPO (maximum power output) based on audiometric information.

Step2 : Implementation of the required gain and MPO. This step entails selection and adjustment among the hearing aids available to the dispenser and often is the step, which causes the greatest practical difficulties.

Step3 : Verification of acoustical performance. This step implies a check of the extent to which the objectives in step 1 have been achieved.

Required characteristics

Gain : The required insertion gain is calculated as follows

Frequency (Hz)	Insertion Gain (dB)
250	½ HTL-10
500	½ HTL-5
1000	½ HTL
2000	½ HTL
3000	½ HTL
4000	½ HTL

Table 6: *Calculation of Insertion gain by POGO procedure.*

Maximum Power ***Output*** *(MPO)*

The required maximum output is equal to the average UCL (in dB HL) at 500, 1000 and 2000 Hz.

$$MPO = \frac{UCL_{500} + UCL_{1000} + UCL_{2000}}{3}$$

To convert to dB SPL in a 2 cc coupler, add 4 dB.

The calculation of prescribed real ear gain and aided field thresholds for some one with a moderate sensory neural hearing loss is shown as follows:

Sl.No		250Hz	500Hz	lOOOHz	2000Hz	3000Hz	4000Hz	6000Hz
1.	Thresholds (dBHL)	29	31	39	65	58	63	54
2.	½ gain (Steplx0.5)	14.5	15.5	19.5	32.5	29	31.5	27
3.	Correction for noise	-10	-5	0	0	0	0	0
4.	Prescribed real ear gain	4.5	10.5	19.5	32.5	29	31.5	27
5.	Prescribed aided field thresholds (Stepl-step4)	24.5	20.5	19.5	32.5	29	31.5	27

Table 3: As taken from Skinner, M. W, (1988), page -158.

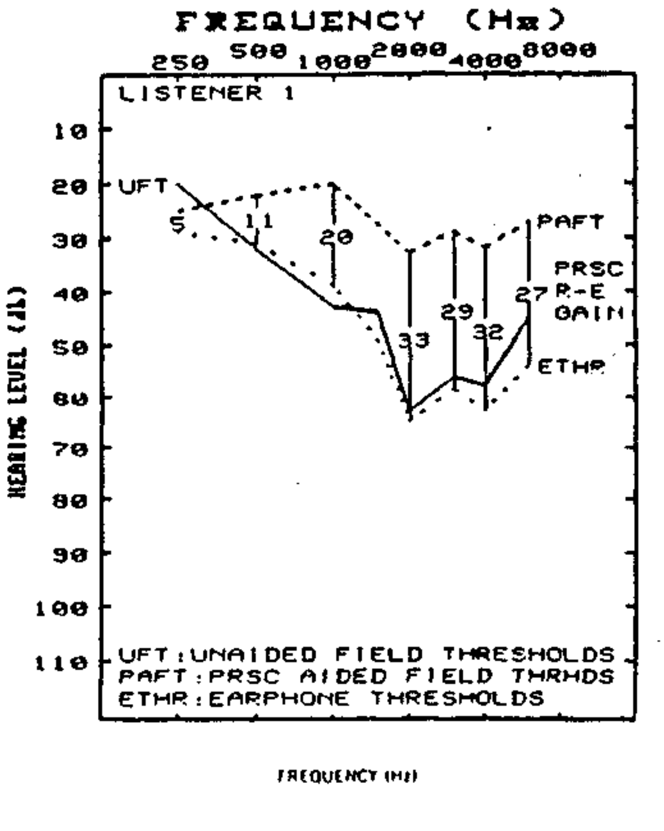


Figure 4: Adapted from Skinner,M.W., 1988,Figure 6.*,page-lS<l. Shows the aided speech spectrum as calculated by the POGO procedure.

Berger, Hagberg and Rane procedure for hearing aid selection

Berger, Hagberg and Rane (1984) recommended using the ^{l}A gain rule (multiplying by 0.5) at 500, 4000 and 6000 Hz and more gain than this (0.59 to 0.67) between 1000 and 3000 Hz. This is called the "prescribed operating gain", however, the calculation of prescribed aided thresholds suggests that operating gain is real ear gain. Although the speech spectrum is not specified, these criteria for prescribing real ear gain are intended to cause the amplified speech energy to be equally loud between 500 and 2000 Hz. Less gain is recommended at 4000 and 6000 Hz to prevent driving the damaged cochlea with high SPLs that may cause further distortion and reduce intelligibility. For individuals with thresholds lower than 50 dB HL, they recommend less gain at 500 Hz (0.3 instead of 0.5). In noisy or reverberant environments they have found that these individuals prefer even lesser gain at 500 Hz (6 dB) and 1000 Hz (3 dB). Calculation of gain at 250 Hz is omitted in the formula because earphones thresholds are often an inaccurate indication of the field threshold and room noise is often high at this frequency. Although the authors note that calculations of real ear gain are more accurate if they are based on unaided field thresholds (dB HL), the earphone thresholds (dB HL) are often used because they have already been obtained as a part of routine hearing test.

Berger, Hagberg and Rane further recommended that additional gain (0.2 multiplied by the difference between the air and bone conduction thresholds, but not more than 3dB) be added for individuals with conductive hearing loss.

Calculations of real ear gain for a person with moderately severe SN hearing loss is as follows:

Sl.No		500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz
1.	Thresholds (dBHL) (field)	32	43	63	56	58	45
2.	Multiply by	0.3	0.63	0.67	0.59	0.53	0.5
3.	Prescribed real ear gain (steplxstep2)	10	27	42	33	31	23
4.	Aided field thresholds (Stepl-step3)	22	16	21	23	27	22

Table 4: As taken from Skinner. M.W. (1988), page-161.

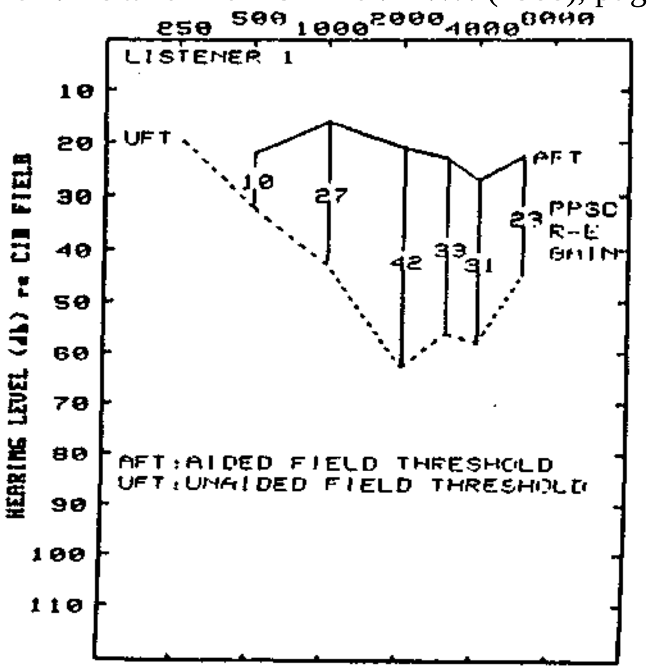


Figure 5: Adapted from Skinner, M.W., Figure 6.8, page-161. Shows the calculations of the real ear gain and aided field thresholds as prescribed by Berger, Hagberg, Rane (1984).

Procedures based on MCL and ULCL data

1. **Cox procedure for hearing aid selection**

Cox (1983) described a procedure for selecting gain based on ULCL (upper limit of comfortable loudness) measures. The MCL (most comfortable loudness) measures have face validity but poor repeatability. The LDL measures have more repeatability, but test instructions are difficult and time consuming. Thus since ULCL exists on the boundary between comfortable loudness and uncomfortable loudness level, it can be used as a basis for selecting both frequency / gain and frequency / SSPL 90 functions.

The Hughson-Westlake procedure for threshold measurement with the modification of approach to ULCL has been used.

Specification of frequency / gain function

The one-third octave band levels for the LTASS were derived from multivoice babbles recorded in both anechoic and sound treated audiometric rooms. When an overall level of 70 dB SPL is assumed, one third octave band levels are 250 Hz = 60 dB; 500 Hz = 66.5 dB; 800 Hz = 60 dB; 1000 Hz = 55 dB; 1600 Hz = 58 dB; 2500 Hz = 53 dB; 4000 Hz = 49 dB. The preferred listening levels for speech are calculated as the midpoint between the thresholds for individuals.

Using the (SPHL) sound pressure hearing levels (thresholds for noise bands), ULCLs and the speech spectrum, the target level of amplified speech spectrum is plotted.

Specification of frequency /$SSPL_{90}$ function

It is reasonable to assume that a hearing aid wearer will not choose to employ an amount of amplification, which allows the rms level of speech to exceed the ULCL. Thus, the SSPL90 can be specified at a level, which will permit an acceptable amount of clipping of speech peaks, so that the volume control can be adjusted by the client to allow the rms level of speech to approach the ULCL.

Since it is conventionally accepted that only 1% of the peaks of speech exceed the long term rms level by more than 12 dB, specifying SSPL90 at each frequency as equal to ULCL + 12 dB should result in acceptable levels of speech peak clipping under all likely conditions. The SSPL90 specification may be summarized as follows:

SSPL 90 (250, 500, 800, 1600 and 4000 Hz) = ULCL + 12 dB

SSPL 90 (1000 Hz) = ULCL + 10 dB

SSPL 90 (2500 Hz) = ULCL + 17dB.

Pascoe Procedure for hearing aid selection

In this procedure (Pascoe, 1978; Skinner, Pascoe, Miller and Popelka, 1982, cited in Skinner, M.W.1988) a hearing impaired individual's preferred listening levels for speech are assumed to be a certain percentage of the difference between 500 and 4000 Hz. These preferred listening levels are the prescribed aided speech spectrum

The estimate where the aided speech spectrum should fall within the auditory area is shown in the left panel.

Note that at 250 Hz and 6000 Hz, the prescribed aided speech levels are 50 percent of the distance between an individual's threshold and MCL (Most

Comfortable Level). At 250 Hz, this means that room noise is not amplified as much and therefore causes less upward spread of masking. At 6000 Hz, where the relevant acoustic cues for speech are often brief and levels are higher than the average speech level, the speech energy is audible.

Sl.No		250Hz	500Hz	1000Hz	1500Hz	2000Hz	3000Hz	4000Hz	6000Hz
1.	MCL(dBHL)	70	75	84	83	85	86	89	78
2.	Thresholds (dBHL)	19	32	43	44	63	56	58	45
3.	MCL(dBSL) (Stepl-Step2)	51	43	41	39	22	30	31	33
4.	Weighting	0.5	1.0	0.9	0.9	0.9	0.8	0.8	0.5
5.	Aided Speech (Step3xStep4)	26	43	37	35	20	24	25	17
6.	Aided Speech (dBHL) (Step+Step2)	45	75	80	99	83	80	83	62
7.	Unaided Speech	47	55	49	50	54	52	52	40
8.	Prescribed real ear gain (Step6-step7)	-2	20	31	29	29	28	31	22

Table 5 : Calculation of the prescribed real ear gain is described. As adapted from Skinner, M.W. (1988), Figure 6.18, page 174-175.

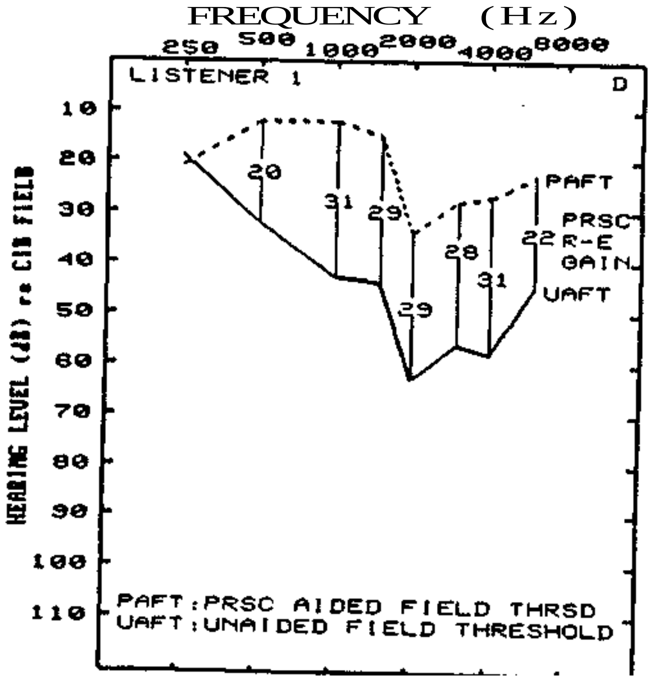


Figure 6: Adapted from Skinner, M.W., 1988, Figure 6.18, page-17 5. Shows the prescribed real ear gain as described in Table-5.

In Figure 6, the real ear gain, shown by the numbers on the vertical lines, represent the amount of gain needed to amplify the Pascoe speech spectrum to the aided speech spectrum. In the right panel, the prescribed aided thresholds are derived by subtracting the real ear gain at each frequency from the unaided field thresholds. Clinically, all this information can be plotted on the same audiogram form as in Table 5.

Desired Sensation Level Input / Output (DSL I/O) Procedure

This procedure by Seewald (2000) provides information on the input - output characteristics of a hearing aid, position of knee point and compression ratio. Thus, it is helpful in hearing aids which involve AGC (Automatic Gain Control).

The persons thresholds and real ear to coupler difference are fed in to the DSL I/O software to calculate the targets. The targets are calculated using the LTASS which is already stored in the computer. The targets include user gain, full on gain and maximum output. Using the manufacturers specifications, a hearing instrument which has a fitting range that will accommodate the target values can be chosen. The behavioral thresholds can then be calculated.

Thus, even with non-linear hearing aids, the LTASS can be used.

CHAPTER 3

METHOD

A number of studies have been done to find out the long-term average speech spectrum in different languages. In this study, an effort has been made to find out the LTASS in Hindi and explore its applications in hearing aid prescriptive procedures.

Selection of subjects

The present study comprised of two main groups (I & II)

Group I

This group comprised of thirty adults including fifteen males and fifteen females in the age range of eighteen to forty-five years.

Group II

This group comprised of fifteen children, out of whom seven were boys and eight were girls.

The criteriae for selection of subjects were as follows:

1. Should be native speakers of Hindi
2. Should be able to read and write in Hindi
3. Should have normal speech and language
4. Should possess no otological history

Speech material

A passage consisting of 147 words was developed in the following way: A Hindi chapter from a fourth standard CBSE (Central Board of Secondary Education) textbook was selected. This chapter was concised and made in such a way that it represented all the speech sounds present in Hindi, an Indo-Aryan language. The duration of the passage varied among the speakers and ranged between 1 to 1½ minutes, varying from individual to individual. The reading material was printed on a white sheet of paper with font size 22 and then given to the subjects to read.

Equipment

A Sony (mini-disc) digital tape recorder MZR70 was used to record the speech sample through a unidirectional microphone mounted on a stand. A computer with Audiolab software for analyzing LTASS was also used.

Test Environment

The recording of all children and 15 adults (males and females) was done in a sound treated suite with ambient noise within permissible limits (ANSI, 1991 Standards, cited in Wilber, 1994) for audio metric testing. The recording of the rest of the 15 adults was done in a quiet environment at the subjects' home, as they were unable to come for the recording.

Procedure

The subjects were informed regarding the nature of the experiment. They were seated comfortably. The adults were asked to first read the passage silently and then part of it aloud. On the other hand, the children were asked to read the passage aloud two times prior to the recording. All subjects were asked to read with normal vocal effort and normal rate. They were also asked to continue reading, even if they realized, they had made an error.

The microphone was placed at around 9-10 inches away from the speaker's mouth at an azimuth of 0°. The subjects were indicated gesturally by the raise of the hand to start reading. The VU meter reading of the digital tape recorder was monitored and it was taken care that it did not exceed 3 units. If the reading exceeded, then the subjects were asked to stop reading and then asked to read more softly and the recording was done again.

Analysis

The computer software "Audiolab" which was developed by the department of Audiology (All India Institute of Speech and Hearing) in collaboration with "Voice and Speech Systems", Bangalore was used for the analysis of recorded materials. The recorded speech samples of each subject were fed in to the computer and each was saved as a file.

The editing was done using the "Creative Mixer- Sound Blaster" 16-bit computer software. Each sample was edited for maximal pauses and repetitions. Once the sample was edited, the LTASS was obtained and the intensities (in dB SPL) at the nearest mid octaves were noted down. The LTASS of different groups of samples (i.e.,females, males, boys and girls) was averaged across the speakers and then used for comparison with each other.

CHAPTER 4

RESULTS AND DISCUSSION

In the present study, the aim was to obtain the long term average speech spectrum in Hindi language for thirty adults (fifteen males and fifteen females) and fifteen children (seven boys and eight girls).

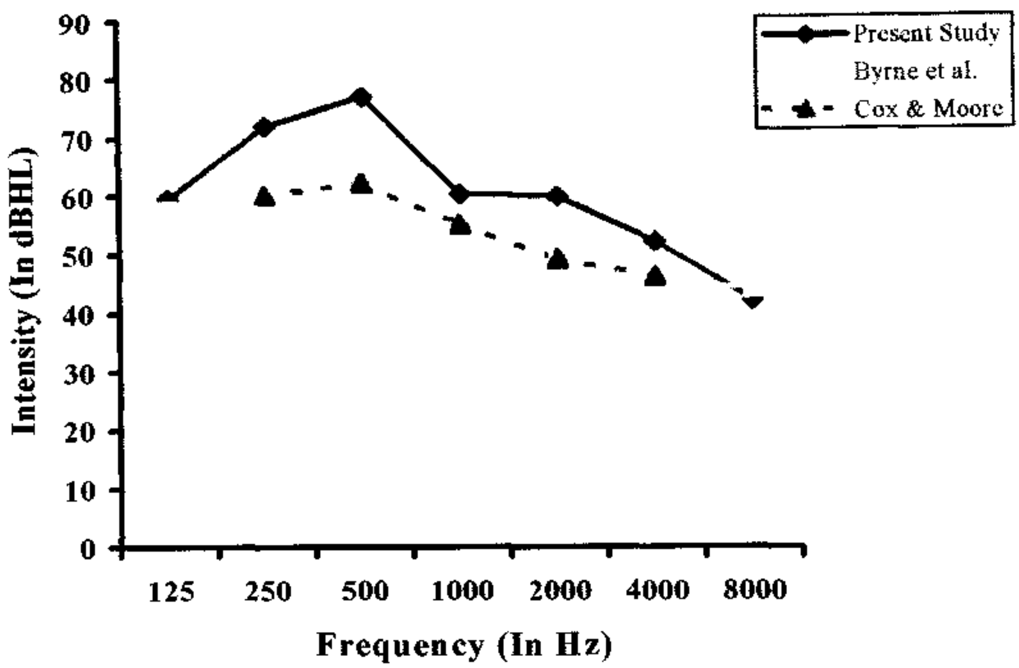
The individual energy levels at different frequencies were obtained. Also, each of the groups' means were obtained and compared.

A. Comparison of LTASS between the present study and Western studies:

The mean energy levels at different frequencies for 45 subjects (including adults and children) are given in Table-7 along with the mean levels obtained by Byrne et al. (1994) and Cox and Moore (1988).

SI. No	Frequency in Hz	Present Study	Byrne et aL (1994)	Cox and Moore (1988)
1	125	59.95	57.7	-
2	250	71.18	60.3	60
3	500	76.8	62.1	62
4	1000	60.1	53.7	55
5	1500	59.17	52	52
6	2000	56.64	48.7	49
7	3000	55.69	-	48
8	4000	51.86	45.6	46
9	6000	45.5	-	44
10	8000	41.97	43.7	-
11	10000	37.3	-	-

Table 7: Comparison of the mean energy levels between the present study and two Western studies.



***Graph** 1: Comparison of LTASS between the present study and two Western studies*

In the present study, the energy has been found to be much more than the two studies it has been compared with, although no statistical analysis has been done. The probable reason for higher energy at low frequencies could be that Indian languages are vowel-based languages and also because of procedural variations. A common speech spectrum needs to be considered in spite of the differences as it is impractical to have different target gains for different languages. Since the shape of the spectrum is the same, this can be compensated by adjusting the volume.

B. Spectra of Individual Speakers

The spectra of individual subjects differed considerably in their general shape. No analysis was made of these differences but an indication of these differences was found. This result is in conformity with other studies such as those done by Byrne, 1977; Cox and Moore, 1988; Byrne et al., 1994.

C. **Speech Spectra of Males**

For males, the maximum speech energy was concentrated between 250 Hz and 500 Hz. The range of the mean intensity levels was around 38.13 (from 79.6 dB at 500 Hz to 41.47dB at 8000 Hz). In the study by Byrne et al., 1994, the range was 20.2 (between 62.6 dB at 500 Hz and 42.4 dB at 8000 Hz).

D. Speech Spectra of Females

In the speech spectra of females, the maximum speech energy was concentrated between 250 Hz and 500 Hz. The range of the mean intensity levels was 34.02 (between 77.03 dB at 500 Hz and 43.07dB at 8000 Hz). In comparison, the Byrne et al. study in 1994, found a range of 16.8 (between 61.7 dB at 500 Hz and 44.9 dB at 8000 Hz).

E. **Speech Spectra of Children**

For children, the maximum speech energy was concentrated between 250 Hz and 500 Hz. The mean intensity levels ranged from 73.7 dB (at 500 Hz) to 41.43 dB (at 8000 Hz). Thus, the range was 32.27.

A very limited number of studies have been done using children as speakers. A study has been done by Niemoller, Mc Cormick and Miller, 1974. In the present study, the speech spectra of adults and children were combined and peaks and valleys were found when analyzed in 1/3 octave band. Their results were in agreement with previously published literature. Stelmachowicz, Mace, Kopun and Carney (1993) took children aged 2 $^{l}/_{2}$ months to 3½years for their study. They found that typical levels (of their parents) at input to a child's hearing aid microphone may be 20 dB higher than those found in face-to-face adult configuration.

Further, comparison of LTASS of each of the groups will be discussed as follows:

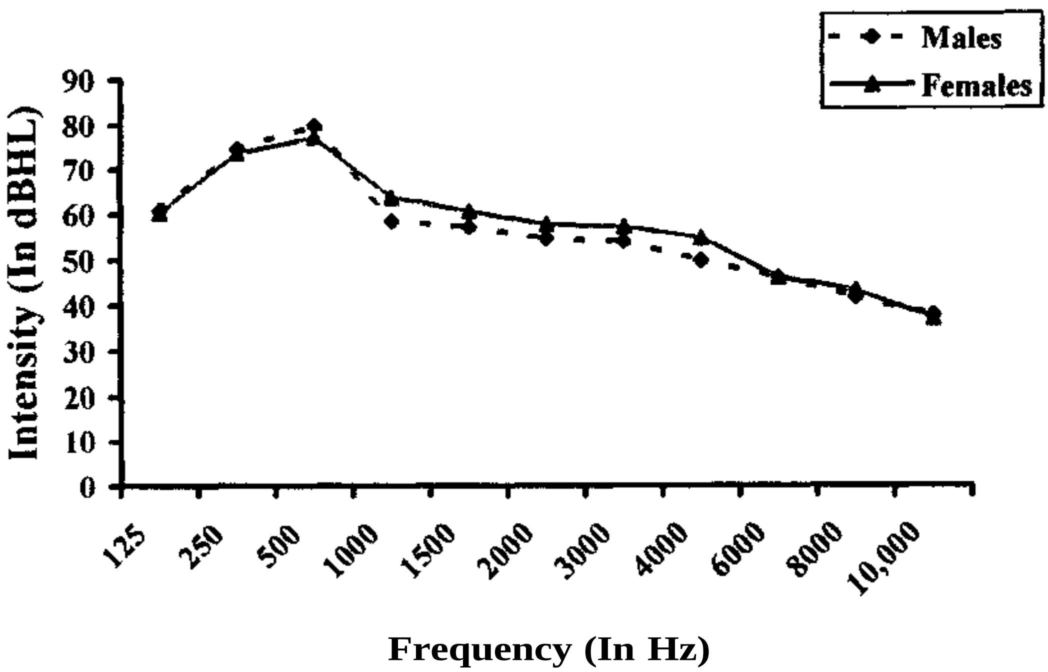
1. Males vs Females
2. Boys vs Girls
3. Adults vs Children
4. Females vs Children
5. Males vs Children

1. Comparison of the LTASS between adult males and females:

SI. No.	Frequency in Hz	Males		Females		't' Value	Significance
		Mean	SD	Mean	SD		
1	125	60.78	5.83	60.12	6.78	0.284	NS
2	250	74.5	3.21	73.52	4.44	0.749	NS
3	500	79.6	2.85	77.03	5.55	1.636	NS
4	1000	58.39	3.39	63.53	6.73	2.63*	S
5	1500	57.10	2.46	60.48	4.13	2.72*	**S**
6	2000	54.45	5.02	57.58	4.14	1.85	NS
7	3000	53.79	4.97	56.89	4.45	1.802	NS
8	4000	49.60	4.72	54.45	5.24	2.63*	**S**
9	6000	45.84	4.40	45.84	5.36	0.006	NS
10	8000	41.47	4.15	43.01	5.99	0.82	NS
11	10000	37.86	2.98	36.87	5.94	0.579	NS

* $p < 0.05$ NS : Non Significant S : Significant

***Table** 8: Shows the means, Standard Deviations (SD) and 't'values of the males and females at different frequencies.*



Graph 2: Comparison ofLTASS between males and females

There was a significant difference between males' aiid females' speech spectra at 1 kHz, 1.5 kHz and 4 kHz (at 0.05 level). Females were found to have greater energy than males by 8 dB at 1 kHz and 4-5 dB at 1.5 kHz and 4 kHz.

In a study done by Byrne et al., 1994, a universal LTASS was found. However, there were differences in results among a few languages:

i) Memphis female speech was high by 3-4 dB from 1250 Hz to 2000 Hz

ii) Mandarin female speech was high by 3-4 dB from 2500 Hz to 4000 Hz.

The combined (for all the 12 languages) difference between male and female spectra showed no significant differences between 250 Hz to 5000 Hz.

For frequencies below 160 Hz, the male levels greatly exceeded the female levels, whereas above 6300 Hz, the female levels were found to exceed male levels. These findings were consistent with those of Benson and Hirsch, 1953; Tarnoczy and Fant, 1964; Taraoczy, 1971, cited in Byrne et al., 1994; Niemoller, McCormick and Miller, 1974; Byrne, 1977; Pearsons, Benett and Fidell, 1977, cited in Byrne et al., 1994; Cox and Moore, 1988.

Cox and Moore, 1988, compared the male and female spectra and found significant differences at 800 Hz and 1000 Hz. male and female differences were also statistically significant for 315 Hz 1/3 octave band and for all 1/3 octave bands below 250 Hz and 6.3 kHz.

Although male talkers produce significantly higher levels than female talkers at 315 Hz 1/3 octave band, this frequency is not typically included in hearing aid gain prescription and thus the difference was ignored. In addition, the differences at 800 Hz and 1000 Hz were only 2-3 dB and hence, an average spectrum of males and females was considered.

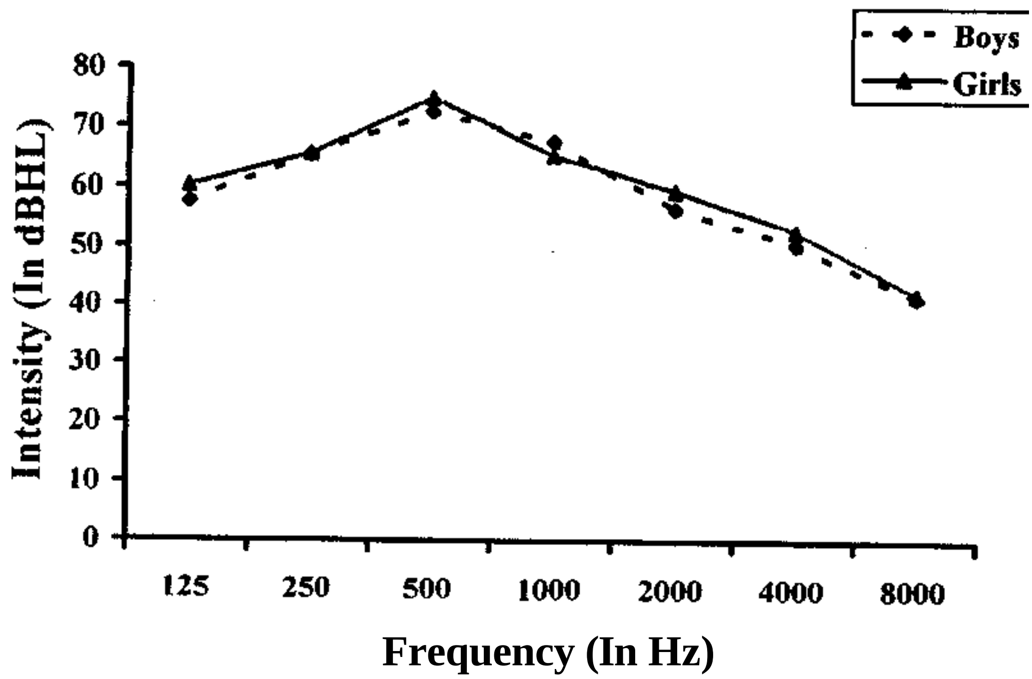
In the present study, the differences between males and females at 1 kHz, 1.5 kHz and 4 kHz are around 3-4 dB which are in conformity with the study by Byrne et al., 1994. Thus the males and females can be considered as one group as in most frequencies, there was no significant difference.

2) Comparison of the LTASS between boys and girls (children):

SI. No.	Frequency in Hz	Boys		Girls		't' Value	Significance
		Mean	SD	Mean	SD		
1	125	57.54	7.17	60.21	3.52	0.936	NS
2	250	65.38	5.99	65.48	3.81	0.041	**NS**
3	500	72.48	3.64	74.77	5.81	0.895	NS
4	1000	67.53	2.05	65.18	3.67	0.297	NS
5	1500	59.13	3.15	60.6	5.43	0.629	NS
6	2000	56.35	4.2	59.26	5.51	1.136	NS
7	3000	55.82	4.23	55.73	3.79	0.173	NS
8	4000	48.06	3.59	47.97	4.04	1.159	NS
9	6000	42.96	5.36	46.43	3.4	1.159	NS
10	8000	41.24	6.17	41.79	3.69	0.139	NS
11	10000	35.57	5.81	38.58	4.15	1.169	NS

NS : Non Significant

***Table** 9: Shows the means, Standard Deviations and 't' values of boys and girls.*



***Graph** 3 : Comparison of LTASS between boys and girls.*

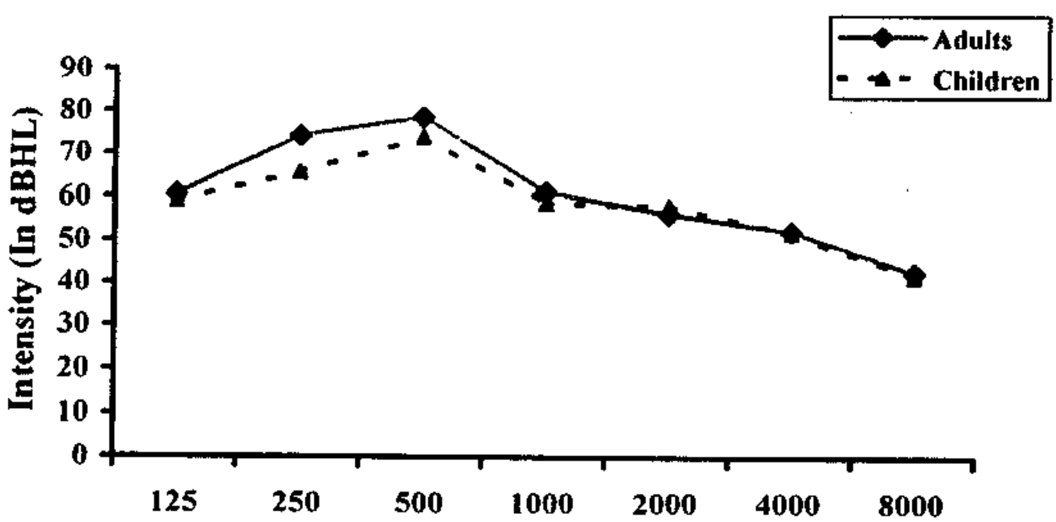
No significant differences were found between the speech spectra of boys and girls. A probable reason could be that, before puberty boys and girls, possess approximately same vocal ranges. (Luchsinger and Arnold, 1965). As discussed earlier very few studies have been done using children as subjects.

3) LTASS comparison between adults and children :

SI. No.	Frequency in Hz	Adults		Children		't' Value	Significance
		Mean	SD	Mean	SD		
1	125	60.45	6.22	58.96	5.49	0.735	NS
2	250	74.05	3.82	65.43	4.76	6.542**	S
3	500	73.35	4.54	73.7	4.89	3.153**	**S**
4	1000	60.96	5.85	66.27	3.39	1.566	NS
5	1500	58.79	3.76	59.91	4.42	0.890	NS
6	2000	56.02	4.79	57.9	5.0	1.226	NS
7	3000	55.34	4.9	56.39	3.58	0.733	NS
8	4000	52.02	5.49	51.55	3.70	0.361	NS
9	6000	45.84	4.82	44.81	4.61	0.688	NS
10	8000	42.24	5.12	41.43	4.81	0.513	NS
11	10000	37.37	4.67	37.18	5.05	0.126	NS

** $p < 0.01$ NS : Non Significant S : Significant

***Table** 10 : Shows the means, standard deviations and 't' values of adults and children.*



Frequency (In Hz)

***Graph** 4 : Comparison of LTASS between Adults and Children.*

Significant differences were found at 0.01 level at 250 Hz and 500 Hz. Adults were found to have greater energy than children at both the frequencies. The difference at 250 Hz was 9 dB and that at 500 Hz was 5 dB. This difference could be seen because of the difference in Fundamental Frequency(Fo) and formant frequencies between adults and children. A limited number of studies have been done taking children as speakers and comparing the LTASS between them. According to Kent and Read, 1995,the fundamental and formant frequencies of children and adults are as follows:

	Children	Adults
F_o	400 Hz	500 Hz
F1	1000 Hz	1500 Hz
F_2	3000 Hz	2500 Hz

In a report by Samuel, 1973, it was found that there was a significant difference in F_o of adults between 20 - 25 years and children below 15 years of age. In adults, the F_o remained constant till around 60 years under normal conditions of health, nutrition and exercise (Titze, 1994).

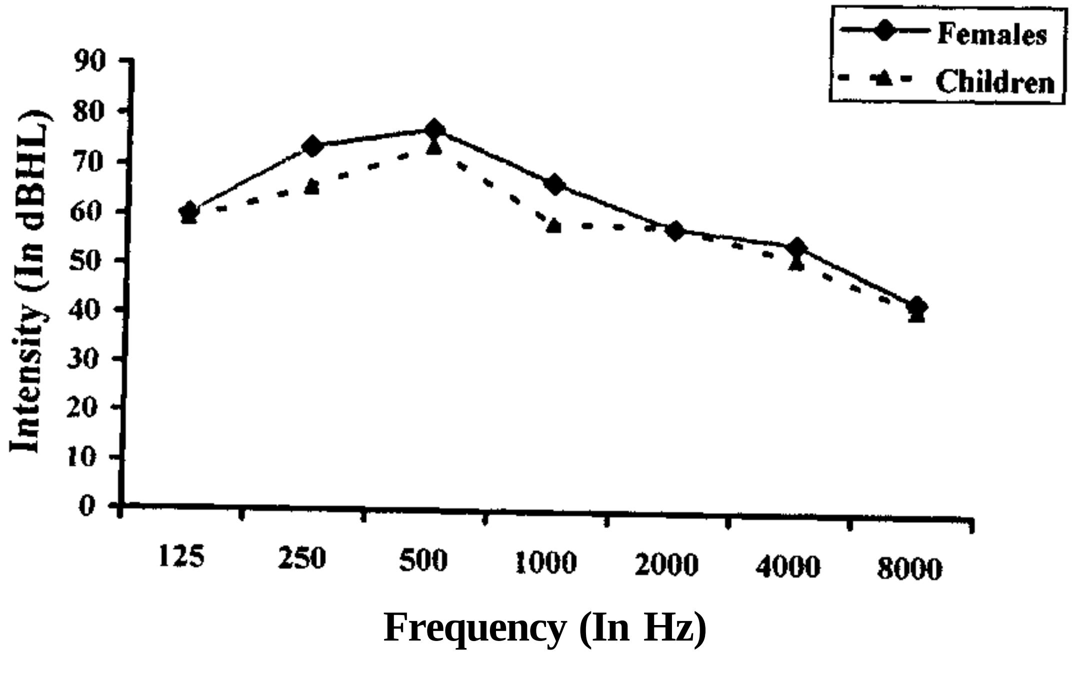
Nittrourer, McCormick and Miller, 1974, stated that peaks in the speech spectra are found at F_o, F_1, F_2, and F_3 for the children and adults. This is probably the reason to find the differences between the two groups around these frequencies.

4) Comparison between females and children:

SI. No.	Frequency in Hz	Females		Children		't' Value	Significance
		Mean	SD	Mean	SD		
1	125	66.12	6.78	58.96	5.49	0.514	NS
2	250	73.52	4.44	65.43	4.76	4.81**	S
3	500	77.03	5.55	73.57	4.89	1.74	NS
4	1000	63.53	6.73	66.27	3.17	1.428	NS
5	1500	60.48	4.13	59.91	4.42	0.365	NS
6	2000	57.58	4.14	57.90	5.0	0.194	NS
7	3000	56.89	4.45	56.39	3.58	0.734	NS
8	4000	54.45	5.24	51.55	3.79	1.737	NS
9	6000	45.84	5.36	44.81	4.61	0.564	NS
10	8000	43.01	5.99	41.43	4.81	0.80	NS
11	10000	36.87	5.94	37.18	5.05	0.152	NS

** $p < 0.01$ NS : Non Significant S : Significant

Table 11 : Shows the means, standard deviations and 't' values of the females and children.



***Graph** 5: Comparison ofLTASS between Females and Children.*

Significant differences were noted at 0.01 level of significance at 250 Hz. Females were found to have greater energy than children by around 9 dB at 250 Hz.

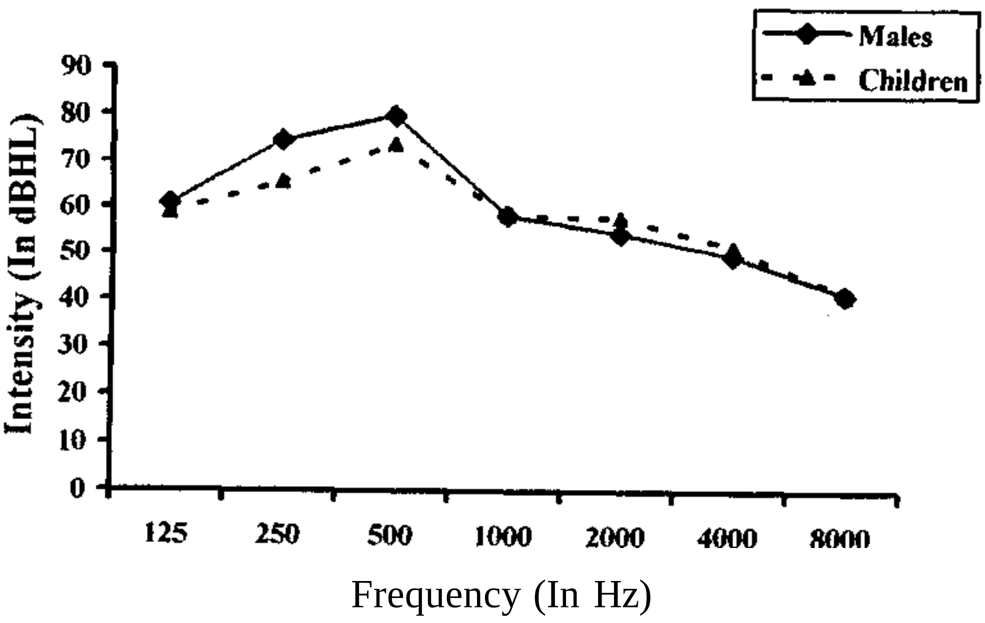
The differences between females and children are similar to those found between adults (as a group) and children. Thus the same reasons can hold good for the comparison between females and children.

5) Comparison between Males and Children:

SI. No.	Frequency in Hz	Males		Children		't' Value	Significance
		Mean	SD	Mean	SD		
1	125	60.78	5.83	58.96	5.49	0.878	NS
2	250	74.5	3.21	65.43	4.76	6.172**	S
3	500	79.6	2.85	73.57	4.89	4.076**	**S**
4	1000	58.39	3.39	66.27	3.17	6.569**	**S**
5	1500	57.10	2.46	59.91	4.42	2.153*	**S**
6	2000	54.45	5.02	57.90	5.0	1.884	NS
7	3000	53.79	4.97	56.39	3.58	1.642	NS
8	4000	49.60	4.72	51.55	3.79	1.246	NS
9	6000	45.84	4.40	44.81	4.61	0.631	NS
10	8000	41.47	4.15	41.43	4.81	0.026	**NS**
11	10000	37.86	2.98	37.18	5.05	0.453	**NS**

* $p < 0.05$ ** $p < 0.01$ NS : Non Significant S : Significant

Table 12: Shows the means, standard deviations and 't' values of males and children.



***Graph** 6 : Comparison of LTASS between Males and Children.*

At 250 Hz, 500 Hz and 1000 Hz, significant differences (at 0.01 level) ant at 1500 Hz (at 0.05 level) were found between males and children. While, males had higher energy at 250 Hz (around 9 dB) and 500 Hz (around 6 dB), the children had higher energy at 1000 Hz (around 7 dB) and 1500 Hz (around 3dB).

The probable reason for the differences as discussed earlier could be that the F_o and F1 of adults being 250 Hz and 500 Hz respectively, more energy is seen at those frequencies. Whereas the F1 for Children being 1000 Hz more energy is seen for children around 1000 Hz.

Males and children have been found to exhibit more differences than do females and children, because of more differences in their fundamental frequencies.

CHAPTER 5

SUMMARY AND CONCLUSION

The primary goal of most modern aural rehabilitation and amplification methods is to maximize the use of residual hearing for speech. For a given hearing impaired individual, the clinician needs to assess, as accurately as possible, the audibility of speech signal throughout the frequency region that contains information necessary for speech recognition. Such an assessment usually is an integral part of the hearing aid selection process, and the results help the clinician to set reasonable communication goals for the patient and to select appropriate rehabilitation procedures. (Olsen, Hawkins and Tasell, 1987).

A number of investigators have made an effort to obtain the speech spectra. Most studies agree with the shape of the spectrum. The speech power is greatest between 100 to 600 Hz, where the energy of the fundamental frequency and the first formant overlap (Formby and Monsen, 1982). Thus, in principle, in most hearing aid selection procedures, amplification at low frequencies is given less importance, as low frequencies will tend to mask the high frequency sounds.

Different procedures of obtaining the long term RMS speech spectrum result in different gain prescriptions. This is not because the procedures are fundamentally different but because they make different assumptions about the speech spectrum (Cox and Moore, 1988). Since different studies lead to different results, a study performed in the Indian context, India being multilingual, would not be uncalled for.

The present study incorporated a total of 45 subjects (30 adults and 15 children). The adults were in the age range of 18-45 years (15 males and 15 females) and children were in the age range of 8-10 years (7 Boys and 8 Girls). A speech sample in Hindi, with all speech sounds of the language, was developed. The samples read by the subject were recorded, edited and LTASS noted down using the "Audiolab" software.

The LTASS obtained has been found to be quite different from the ones proposed in the Western literature. Thus a different speech spectrum can be considered in the context of the Indian population.

The spectra of males and females have been found to have statistically significant differences at 1 kHz, 1.5 kHz and 4 kHz, whereas among children (boys and girls), no statistically significant differences have been found. Between the spectra of adults and children; and females and children differences at 250 Hz and 500 Hz have been obtained. Between the spectra of males and children, differences at 250 Hz, 500 Hz, 1000 Hz, and 1500 Hz were found. The differences in the speech spectra can be attributed to the differences in the fundamental frequencies and formant frequencies between the groups.

Implications of **the Study**

The long term average speech spectrum can be used in calculation of gain and saturation sound pressure level in the selection and evaluation of hearing aids. A number of prescriptive formulae such as POGO (Prescription of Gain and Output), NAL (National Acoustic Laboratories) procedures etc. have used the LTASS to derive the formulae. Some of the examples have been given in the previous chapters.

The speech spectrum is especially useful in children to find the user satisfaction. This is because, unlike adults, children are not able to judge performance with hearing aids. Moreover, the choice of hearing aid electroacoustic characteristics that result in a less than optimal amplified speech signal may have a more significant effect on children than adults.

Thus an accurate and consistent representation of the speech signal may be more critical for children with hearing impairment who are in the process of developing speech and language (Stelmachowicz, Mace, Kopun and Carney, 1993). Some prescriptive procedures like DSL (Desired Sensation Level) incorporate the LTASS and are used especially for children. These are thus useful in non-verbal subjects (adults and children).

The speech spectrum is a handy visual aid in counseling the client. The LTASS placed on an audiogram format can be quite useful to the clinical audiologist. A plot of speech spectrum on an audiogram and sound field threshold obtained with the patients wearing a given hearing aid can demonstrate the portion of the speech spectrum made audible by the hearing aid. The patient can also see and understand better, some of the communication difficulties associated with hearing losses of various degrees and configurations.

The LTASS is a basis for the calculation of Articulation Index (AT). Speech intelligibility predictors available with hearing aid are largely based on the AI. The advantage of these procedures in hearing aid selection is that the calculated index describes the available speech information without requiring word recognition testing (Pavlovic, 1989).

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ha:tʰi

dʒəb ha:tʰijõ ka jʰuṇḍ, dʒəngal se guzərta hɛi, to, adʒi:b - adʒi:b tərəh ki a:va:zẽ, dʒəngal ki ʃa:nti bʰang kar de:ti hɛ̃ us jʰuṇḍ mɛ̃ ek ja do vərʃ ke cʰhote batʃtʃe bʰi ho:te hɛ̃. ve dʒəgəh - dʒəgəh jʰa:ḍijã kutʃal de:te hɛ̃ ɔ:r pe:dõ ki tehnijã: bʰi ṭu:ṭi pəḍi ho:ti hɛ̃.

din nikəlne se pehle hi: ha:tʰijõ ke jʰuṇḍ gʰa:s ke maida:n ki o:r tʃəl dete hɛ̃, dopeher ho:te - ho:te, ve səb ha:tʰi gʰa:s kʰa:kər əpna pe:ṭ bʰər tʃuke ho:te hɛ̃. fir, ve pa:ni pi:kər, pe:ḍõ ki gʰəni ɔ:r ṭʰəndi cʰa:ja mɛ̃ a:ra:m kərte hɛ̃.

dʰərti pər is se bəḍa ɔ:r ko:i paʃu nəhĩ pa:ja dʒa:ta. mənuʃja ne əpne buddʰi bəl se ise bʰi: pa:ltu bəna lija hɛi, ɔ:r is se kai prəka:r ke ka:m le:ta hɛi. ha:tʰi bəḍa buddʰima:n paʃu hɛi, ise dʒo sikʰa:ja dza:ta hɛi, dʒəldi hi: si:kʰ leta hɛ̃. is dʒi:v ki surəkʃa kərna həmara kərtavja hɛi.

हाथी

जब हाथियों का झुंड जंगल से गुज़रता है, तो अजीब अजीब तरह की आवाज़ें, जंगल की शाँती भंग कर देती हैं। उस झुंड में एक या दो वर्ष के छोटे बच्चे भी होते हैं। वे जगह-जगह झाड़ियाँ कुचल देते हैं और पेड़ों की टहनियाँ भी टूटी पड़ी होती हैं।

दिन निकलने से पहले ही, हाथियों के झुंड, घास के मैदान की ओर चल देते हैं। दोपहर होते-होते, वे सब हाथी घास खाकर, अपना पेट भर चुके होते हैं। फिर, वे पानी पी कर, पेड़ों की घनी और ठण्डी छाया में आराम करते हैं।

धरती पर इससे बड़ा और कोई पशु नहीं पाया जाता। मनुष्य ने अपने बुद्धिबल से इसे भी पालतू बना लिया है और इससे कई प्रकार के काम लेता है। हाथी बड़ा बुद्धिमान पशु है। उसे जो सिखाया जाता है, जल्दी ही सीख लेता है। इस जीव की सुरक्षा करना हमारा कर्तव्य है।