A COMPARATIVE STUDY OF LOUDNESS DISCOMFORT LEVELS (LDLs) USING DIFFERENT STIMULI IN HEARING AID USERS

(REGISTER NO. M 0106)

An Independent project submitted in part fulfillment of the First year M.Sc (Speech and Hearing), University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI, MYSORE - 570006

MAY 2002

Dedicated to
My Dearest
Amma, Appa & Suganya

Certificate

This is to certify that the Independent project entitled *"A Comparative Study of Loudness Discomfort Levels (LDLs) Using Different Stimuli in Hearing Aid Users'"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (RegisterNo. MO 106).

Mysore

May 2002

Director

All India Institute of
Speech & Hearing
Mysore - 570006.

Certificate

This is to certify that the Independent project entitled *"A Comparative Study of Loudness Discomfort Levels (LDLs) Using Different Stimuli in Hearing Aid Users"* 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 *"A Comparative Study of Loudness Discomfort Levels (LDLs) Using Different Stimuli in Hearing Aid Users"* is the result of my own study under the guidance of Dr. K. Rajalakshmi, 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 0106

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INTRODUCTION

One of the major features seen in cochlear loss subjects is 'the phenomenon of recruitment'. Recruitment may be defined as the rapid growth of loudness in an ear with sensori neural hearing loss (Roeser and Valente 2000). In these cases there is a decrease in loudness discomfort level (LDL) and narrowing of dynamic range (DR).

As an assessment procedure for recruitment phenomenon, Watson (1944) was the first to use the level at which a tonal or speech stimulus becomes uncomfortable. .

Loudness discomfort level is the sound pressure level at which the stimuli becomes uncomfortably loud (Stach, 1994). This is also called as threshold of discomfort (TD) or tolerance level or uncomfortable loudness level (ULL) (Hawkins, 1980).

The ULL may be defined as the lowest intensity at which a stimulus becomes uncomfortably loud (Hawkins, 1980). The supra threshold auditory measures have been used for both diagnostic and rehabilitative evaluation of patients. From a diagnostic point of view these measures have been essentially concerned with defining whether the patient had a limited dynamic range known as recruitment, and hence were valuable in defining the focus of the patients hearing loss. From a rehabilitative point of view various tests have been used to define gain setting and maximum output level for hearing aid use. The hearing aid user should not experience loudness discomfort while measuring a hearing aid. This is commonly held tenet of hearing aid fitting and has significant clinical importance, when the SSPL 90 (saturation sound pressure level 90) is too high and exceeds the hearing aid users loudness discomfort level.

Davis et al., (1946) and silverman (1947) found that the range of comfortable loudness was not markedly different for hard-of-hearing than for normal subjects. Specifically, the literature shows that persons with cochlear lesions reach loudness discomfort well below the normal level of 120 dB SPL (Beck, 1949; Maspetiol, 1954).

LDL's can be obtained using different stimuli which can be verbal or non verbal. There is little agreement on which stimuli to be used when establishing LDL's. Few authors maintain that speech is more realistic than pure tones (Briskey, 1980; Carhart, 1946; Davis et.al., 1946). Pure tone LDL's are recommended because they can be compared to the manufacturers SSPL 90 curve (ANSI, 1982).

Various authors have established LDLs with discrete stimuli such as pure tones and narrow band noise (Berger, 1980; Hawkins, 1980; Cox, 1981, 1983; Krebs, 1972). These authors comment that pure tones and narrow band noise are frequency specific and thus enable greater precision than speech in SSPL selection.

Although investigations have not established how accurately discrete stimuli (such as pure tone and narrow band noise) LDL's predict speech LDL's. Various investigators compared mean pure tone and speech LDL's.

These results have revealed a high variability in findings. Some authors (Davis et.al., 1946; Dudich, Keiser and Keith, 1975) found that speech LDL's were about 7dB higher than pure tone LDL's where as others (Ritter, Johnson and Northern, 1979; Kamm, Dirks and Mickey, 1978; McCandles and Miller, 1972; McLeod and Green Berg, 1979) reported no LDL difference for these stimuli.

Need for the study

Literature has reported high variability in finding loudness discomfort levels (LDLs) when discrete stimuli and speech are compared. A conclusive statement about which kind of stimuli should be used in determining LDLs has not been given. Hence, there is a need to find out if there is any difference between mean LDLs of discrete stimuli i.e., (narrow band noise and warble tone), white noise, drum beat and speech. The results of this study can be useful in selecting appropriate stimuli for establishing loudness discomfort level.

In view of the above stated findings the present study was carried out with following Aims

- To find out if there is any significant difference in discrete stimuli (NBN, Warble Tone) LDLs across the frequencies.
- To find out if there is any difference between mean LDL for speech and other mean LDLs.
- To find out if there is any difference between mean LDL for narrow band noise and warble tone averages of 500Hz, lOOOHz, 2000Hz.
- To find out if there is any difference between mean LDL for speech and discrete stimuli averages (NBN and warble tone averages of 500Hz, lOOOHz, 2000Hz).

REVIEW OF LITERATURE

Loudness discomfort level is the sound pressure level at which the stimuli becomes uncomfortably loud (Stach, 1994). This is also called as threshold of discomfort (TD) or tolerance level or uncomfortable loudness level (ULL).

A major reason for measuring the loudness discomfort level (LDL) is to select the saturation sound pressure level (SSPL) of a hearing aid.

Watson (1944) was the first to introduce the concept of uncomfortable loudness level as a clinical measure, and although, he refers to the (ULL) for speech or tonal stimulation as the point at which the sound becomes painful, it is clear from his results and his later work that he was measuring the point at which it becomes uncomfortable rather than painful in the clinical concept. This point is classified to some extent in the work of Bangs and Mullins (1953).

Silverman et al. (1946) reported that in both normal and hearing-impaired subjects the discomfort threshold was 130 dBSPL.

Stephens (1970) studied the influence of the test procedures and certain personality measures on the determination of the uncomfortable loudness level. The results were not influenced by the mode of presentation; headphone and loudspeaker produced similar results. Monaural-binaural difference were in line with previous studies in this field. Continuous Bekesy techniques resulted in higher values than obtained manually, this being apparently related to a decision mechanism rather than a perceptual phenomenon. Pulsed Bekesy stimuli gave higher values than continuous Bekesy stimuli as has been found in most comfortable loudness level studies.

Stephens and Anderson (1971) investigated a number of experimental determinations of the uncomfortable loudness level (ULL) at 1000Hz which were made on several groups of normal hearing subjects, using various methods of stimulus presentation and applying different personality measures to the subjects. The same mean levels were found for both ear phone and free field presentations. In experienced subjects, monaural-binaural difference was between 2.5dB and 4 dB in different experiments. In two groups of subjects, uncomfortable loudness level was found to be significantly negatively correlated with their test anxiety scores, but this correlation did not hold for the other two groups tested.

Various procedures have been used to find out loudness discomfort levels. Morgan, Wilson, and Dirks (1974) investigated to determine a reliable procedure for obtaining loudness discomfort levels, and to observe the effects of frequency on the loudness discomfort levels. Three psychophysical methods were used. They were constant stimuli method (CS), method of adjustment (ADJ), and tracking method (TRK). The method of constants provides the most reliable judgements over six trials for a lOOOHz stimulus. In the second experiment, pure tones at octave frequencies between 125Hz and 4000Hz, and two bands of noise were selected as stimuli. Their data for the LDL for wide band noise and narrow band noise showed significant difference of 3.8dB between these two stimuli.

Morgan and Dirks (1974) reported from their experiment conducted to determine if the frequency effect could be explained adequately on the basis of differences between conventional and real-ear calibration methods and to extend the loudness discomfort level measurement to free-field conditions. Determination of the sound pressure level (SPL) generated by an earphone and by a loud speaker in the free field was accomplished with a probe tube at the entrance to the ear canal under earphone and free-field conditions and by conventional calibration methods. Psychophysical measurements of loudness discomfort level (LDL) were conducted under earphone and in the free field. Corrections derived from differences between standard calibration procedures and probe tube measurements were applied to the psychophysical measurements. The corrected results lead to the conclusion that there was no intensity level increase in the low frequency LDL under earphone and there was no difference between earphone and free-field LDL judgements.

Cox (1981) studied to describe the empirical basis for a procedure for loudness discomfort level (LDL) measurement, which was specifically designed for use in clinical hearing aid selection. Data have been collected on the repeatability of LDLs measured using two different testing procedures. Both procedures used an ascending approach to measure the LDL to protect clients from serious discomfort. In procedure 'A' the stimulus was produced by a Bekesy audiometer and controlled by the subject who was instructed to allow the signal to automatically increase until the LDL was reached and then to push the button causing the attenuator to reverse the direction. The LDL was taken as the mean peak level reached over three trials. LDLs were measured at four frequencies on each of the five different event days. Procedure 'B' was modeled after Hughson-Westlake procedure for threshold measurement. The stimulus was controlled by the tester and increased in 5dB steps until die subject indicated that the LDL was reached. The level was immediately dropped to 10, 15 or 20dB, again increased in 5dB increments until the subject signaled. This sequence was repeated until no further elevation in LDL response levels occurred. The LDL was taken as the highest level indicated by the subject in two out of three trials. The results showed that, the errors associated with predictions based on procedure 'B' were usually smaller than those associated with procedure 'A'. Until a better procedure for LDL measurement is identified, procedure 'B' is being used.

Beattie and Sheffler (1981) investigated the effect of psychophysical methods (method of adjustment versus method of limits) on speech loudness discomfort level. Twenty normal hearing subjects were tested. The results indicated that the psychophysical method has a marked effect on the LDL for speech. The mean LDLs for the respective methods of adjustment and method of limits were 86.8 dBSPL and 92.9 dBSPL respectively and were statistically significant. Additionally, a significant interaction between the two methods was observed.

The loudness discomfort level procedure had its initial roots in a method described by Pascoe (1978) in which, loudness category judgements are made to define the entire dynamic range. This category scaling approach was then employed in a loudness discomfort level (LDL) procedure published by Hawkins, Waiden and Prosek (1987) and further modified by Hawkins, Ball, Beasley and Looper (1992). It can be adopted to include probe-microphone measurements with suggestions from Seewald (1990a), Stelmachowicz (1991), and Stuart, Durieun-smith, and Stentrom (1991). In this procedure, pure tones or narrow bands of noise centered at 500Hz, lOOOHz and 2000Hz are produced by a standard audiometer and delivered through insert earphones coupled to the ear with a foam earplug. Starting at approximately 90dBSPL, an ascending approach using 2.5dB or 5dB steps is employed and the category judgement uncomfortably loud is crossed several times. The intensity at which a consistent judgement of uncomfortably loud is obtained is considered to be the loudness discomfort level.

The integration of probe-microphone measurements is accomplished by inserting the probe tube through the foam earplug and into the ear canal.

There is little agreement on, which stimuli to use when establishing LDLs. Some clinicians use speech to obtain LDLs (Briskey, 1980; Carhart, 1946; Davis et al., 1946; Dirks and Morgan, 1983; Fournier, 1968; Morgan, Dirks, Bower and Kamm, 1979; Staab, 1975). According to them speech is more realistic than pure tones, as pure tones rarely occur in everyday listening and usually are not meaningful. Moreover, the LDL for speech can be obtained in less time than is required to measure LDLs at several pure tone frequencies.

Davis et al., (1946) were amongst the first investigators to report a systematic study of the threshold of discomfort for pure tones and speech. Although, specific experimental methods were not described, these investigators reported that an initial median threshold of discomfort for listeners with normal hearing was 1 lOdBSPL for pure tones and 117 dBSPL for speech. In comparing these levels with data collected on subjects with hearing impairment, Davis et al., (1946) concluded that hard-of-hearing subjects showed consistently higher tolerance levels than normal hearing subjects.

Silverman (1947) found that the LDL for speech was approximately lOdB higher than for pure tones for normal-hearing persons, but not for hearing impaired persons.

Hood and Poole (1966) also investigated LDL as a function of hearing loss in sensor neural listeners. They measured LDL for pure tones for 100 patients with Meniere's disease and 100 patients with unilateral cochlear hearing loss due to other etiologies. Hearing threshold for both the groups of subjects ranged from 0 dBHL to 80 dBHL based on the distribution of points on scatter grams relating LDL and hearing loss for each subject. Hood and Poole (1966) concluded that there was "no discernible upward trend of the LDLs with increasing hearing loss". From this conclusion, it might be assumed that pooling of LDL data across hearing loss would not substantially alter estimates of LDL. However, when median LDLs are computed from the Hood and Poole data, the results suggested a non-linear relationship between LDL and hearing loss.

Hood and Poole (1966) reported LDL's for pure tones to be at significantly lower levels, 90dBSPL to 105 dBSPL, in both normal hearing and cochlear lesion subjects.

Schmitz (1969) used a "running" speech stimulus in the sound field for the measurement of loudness discomfort level. The median LDL for subjects with bilateral cochlear hearing loss was 90 dBSPL, where as almost half of the normal hearing subjects never obtained their LDL within the available 120 dBSPL range. That is, in contrast to the Davis et.al., (1946) results, Schmitz data indicate that the LDL for speech is higher among normal-hearing subjects than among subjects with bilateral cochlear hearing loss.

Olson and Hipskind (1973) compared in 20 normal adults, the relationship among stimulus levels necessary to determine the initial and maximum acoustic reflex (AR) and the loudness discomfort level (LDL) for pure tones and for connected discourse. Normative data were provided. Especially the relations among pure tones and speech were examined. Actual speech elicited the acoustic reflex at levels 15.7 dB to 19 dB weaker than the speech frequencies (0.5 KHz, 1KHz, 2KHz). Though the Pearson's correlation showed strongly positive correlation between the maximum acoustic reflex (AR) and loudness discomfort level (LDL) for pure tones, for actual speech the hearing level to arouse maximum AR was 11.7 dB less than that to arouse LDL.

Morgan, Wilson, and Dirks (1974) have taken pure tones at octave frequencies between 125 Hz and 4000Hz and two bands of noise were selected as stimuli. Their data on LDL for wide band noise, and narrow band noise showed significant difference of 3.8 dB between these two stimuli.

Dudich, Reiser and Keith (1975) found that speech LDLs were about 7dB higher than pure tone (500Hz, 1 OOOHz and 2000Hz) LDLs.

Shapiro (1976) has reported mean LDLs for pure tones at levels from 112dBSPL to 118 dBSPL in a group of sensory neural listeners with an average hearing loss of approximately 60 dBSPL in the speech frequency range. These intensities are slightly higher than mean LDLs for normal listeners as reported by Hood and Poole (1966).

Wood ford and Holmes (1976) compared loudness discomfort levels for pure tones and wide-band noise for normal listeners and subjects with sensory neural hearing loss. They found significant difference in LDL for pure tones between the two groups, but found relatively little difference between the wide band noise loudness discomfort levels.

Kamm, Dirks and Max (1978) used a simple up down adaptive procedure which was used to estimate the 50% point on the psychometric function for loudness discomfort level (LDL) for listeners with sensor neural hearing impairment LDLs were obtained using pure tones of 500Hz and 2000Hz and Spondaic words. Mean LDLs were observed at relatively constant sound pressure levels (SPLs) for subjects with hearing loss 50dBHL and at progressively higher SPLs with further increase in hearing loss. The analysis verified a statistically significant relationship between LDLs and magnitude of hearing loss. The nonlinear relationship between LDLs and hearing loss together with the large inter subject variability in the data suggested that prediction of LDL from hearing threshold would often be highly inaccurate. These results also demonstrate the averaging LDL data across a group of subjects with a wide range of hearing loss, which may lead to inaccurate conclusions regarding the effects of sensor neural hearing loss on LDL.

Shapiro (1979) studied the relationship between hearing level and loudness discomfort level (LDL) for narrow band noise, which was evaluated in two groups of patients with sensorineural hearing loss. Group I had thresholds ranging from 25 dBSPL to 60 dBSPL and group II had thresholds ranging from 65 to 100 dBSPL.

LDLs were determined for narrow bands of noise centered at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. The LDLs for group II were greater than those for group I and the differences were statistically significant. It is speculated that one reason that others are not finding differences as a function of hearing level may be the absence of severe to profound hearing loss in the test populations.

Morgan and Dirks (1979) investigated loudness discomfort level threshold measurement for selected speech stimuli and noise stimuli. The subjects were eleven individuals with normal hearing sensitivity. The stimuli used were various speech stimuli as well as broadband speech spectrum noise for all the stimuli, the mean values of LDL measurements showed no differences in LDL.

McLeod and Greenberg (1979) studied the relationship between loudness discomfort levels (LDLs) and acoustic reflex threshold (ART). This was determined by comparing the ART to the LDLs obtained by the psychophysical method of constant stimuli. Randomly presented stimuli of 1000Hz, 2000Hz and a multi- talker speech noise were presented to normal and sensor neural hearing-impaired listeners. The listeners task was to judge whether the stimulus was at a level that was ,(1) too loud or uncomfortably loud ,(2) not too loud or not uncomfortably loud. Prior to the judgement of the subject, acoustic reflex threshold was determined. Both LDL and ART were found significantly higher in hearing impairment group. For pure tone stimuli LDL for hearing impairment group was at or below the ART. Significant differences were shown to exist between LDL and ART for each group. Statistical analysis revealed significant correlations between LDL and ART. Both pure tones and speech ART successfully predicted LDL within +_10dB for a high percentage of the subjects.

Ritter, Johnson, and Northern (1979) did another study which showed the relationship between the loudness discomfort levels (LDLs) and acoustic reflex thresholds (ARTs). The subjects were, two groups of ten normal-hearing adult subjects and one group of ten adult subjects with bilateral sensor neural hearing losses. The testing was done under headphones and under sound- field conditions for four different acoustic stimuli; pure tones, warble tones, spondaic words, and speech spectrum noise. The instruction to each groups varied. The results indicated that the LDLs regardless of instructional pattern were reported at consistently higher sound pressure levels (SPLs) than the ARTs for all groups of subjects. The closeness with which the SPLs for LDLs and ARTs occur depends upon the type of instructional pattern used to define the LDL, the type of acoustic stimulus used, and is according to the hearing sensitivity of the subjects, i.e., normal hearing or hard of hearing. While LDLs and ARTs for the hard of hearing subjects with sensor neural hearing loss are reported with in the same range of SPLs as reported for normal hearing subjects, LDL and ART patterns are not necessarily the same.

Hawkins (1980) studied the loudness discomfort level for various stimuli. He has compared LDLs for eighteen different stimuli on a single group of subjects with a psychophysical procedure that has been recently recommended for clinical use, the simple up-down adaptive method. The eighteen stimuli/included 5 pure tones, one-third octave bands of noise, an 8-talker babble filtered in to 5 different one-third-octave bands, wide-band noise, spondaic words and sentences. He has conducted the study on a normal hearing population. The results of LDL for 18 stimuli showed that, there are only small differences among the mean LDLs for pure tones, one-third octave bands of noise and filtered speech. The results for normal hearing subjects are analyzed and found that, the LDLs were not significantly different for these signals than for pure tones or narrow band noise.

Edgerton and Beattie (1980) had undertaken study to investigate the effects of speech materials on the loudness discomfort level (LDL), to assess the intra - session stability among three LDL trials, and to examine the relationship between the speech LDL, pure tone and spondee thresholds. Ninety- six adults with mild to moderate sensorineural hearing loss were tested. Five commercially available speech materials were used. Their findings showed little or no difference among the speech materials. Thus, it was concluded that the differences in speech materials do not comprise a major source of variability among studies when comparing mean LDL data group which may, however, observe significant individual variation in LDLs that result from differing speech materials. Considerable LDL variability among listeners with similar threshold was found suggesting an intolerably high error rate for predictive purposes.

Cox (1981) reports that none of the readily calibrated test stimuli such as pure tones or noise bands have high face validity for the loudness discomfort level (LDL) measurement task. The relationship between an LDL measured, using one of these stimuli and an LDL for a stimulus, which has a peak factor, and a temporal course more typical of real word stimuli is not obvious. In an attempt to explore this relationship an investigation was performed in which LDLs at 500Hz, 1000Hz, and 2000Hz were measured for pulsed one-third octave bands of thermal noise and for one-third-octave bands multi-talker speech babble. The results revealed that the mean speech-band LDLs were 2 to 3 dB higher than the mean noise band LDLs. He also investigated to determine whether an individual speech-band LDL could be accurately predicted from this noise-band LDL. The results indicated that if the speech-band LDL is predicted from the noise-band LDL, the predicted LDL will be within 3 to 4dB of the true LDL, 68 % of the time.

Christen (1984) reported that hearing-impaired subjects demonstrated an average increase in UCLs to a pink noise stimulus of about 8dB across sessions, a few days apart, although they found some individual subjects who demonstrated no change.

Beattie and Boyd (1986) investigated how accurately pure tone (250 Hz to 6000 Hz) loudness discomfort levels (LDLs) predict speech LDLs. Fifty elderly subjects with mild to moderate sensorineural hearing loss were studied. The results revealed, poor to fair correlations and large standard errors of estimate. So, they have concluded that pure tone LDLs are not accurate versus that of the speech LDL.

Bentler and Pavlovic (1989) investigated the relationship between threshold of discomfort (TD) estimates and the number of components in a complex signal. The threshold of discomfort were first obtained for 16 pure tones located at the center frequency of critical bands from 250Hz to 4000Hz, subsequently, threshold of discomfort were obtained for 2,4,8 and 16 tone complexes. The pure tones components of the complexes were systematically selected from the same 16 pure tones. For each subject, the relative intensities of the components in the four complexes were determined in such a way, so as to parallel the pure tone TD contour obtained for that subject. Data were obtained for 15 normal and 15 hearing impaired adults. The individuals in the latter group, all had mild to moderate sensorineural hearing loss. Summation of discomfort (S) was defined as the difference between the threshold of discomfort for a pure tone presented in isolation and within the complex signal. The two groups demonstrated different summation values.

METHODOLOGY

The present investigation aimed to study the following,

- To find out if there is any significant difference in discrete stimuli (narrow band noise and warble tone) LDLs across the frequencies.
- To find out if there is any difference between mean LDL for speech and other mean (white noise and drum beats) LDLs.
- To find out if there is any difference between mean LDL for narrow band noise and warble tone averages of 500Hz, lOOOHz, and 2000Hz.
- To find out if there is any difference between mean LDL for speech and discrete stimuli averages (narrow band noise and warble tone averages of 500Hz, lOOOHz, 2000Hz).

Subjects

A total of 20 hearing aid users in the age range of 18 to 75 years served as subjects for this study. All the subjects met the following criteria,

- The subjects with "Bilateral moderate to moderately severe sensorineural hearing loss with flat audiometric configuration'.'
- No history of other otological problems.

Instrumentation

A calibrated two channel Madsen Orbiter 822 clinical audiometer with power amplifier (PA 5010), and free field compatible loudspeaker (Madsen) was used for the present study. The loud speaker was placed at a distance of one meter from where the subject is seated at an azimuth of 45°.

Test Environment

Testing was carried out in an acoustically sound treated, air conditioned two room situation, the ambient noise level of which were premissible within normal limits (ANSI, 1991).

Stimuli

A total of five different stimuli were used. They were as follows,

- Warble tone, Narrow band noise and White noise were generated by a clinical audiometer (Madsen OB 822) and directed to a loud speaker and presented through loudspeaker (Madsen).
- Drumbeats were presented through the microphone and directed to the loud speaker (Madsen), and were monitored through the VU meter deflection.
- Monitored live voice (MLU) was used as speech stimuli. The stimuli through monitored live voice consisted of utterances like the following,

1. Can you tolerate this loudness?
2. Is it too loud or too soft ?
3. Does the sound hurt you ?

Instructions

To establish loudness discomfort level (LDL), the subjects were instructed as follows " I am going to present a stimuli. You have to indicate, the moment you feel or find it uncomfortably loud"

Procedure

All the subjects were instructed to wear on their hearing aids at the recommended volume control setting. The modified Hughson-Westlake

(Carhart and Jerger, 1959) procedure was used, which was carried out in two steps.

Step I

The stimuli that is, narrow band noise (NBN) and warble tones (WT) were presented at frequencies 250Hz, 500Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz and 6000Hz and then white noise, speech stimuli and drumbeats were all presented at subject's most comfortable level. Loudness discomfort levels were obtained for each stimulus separately.

Step II

The second trial was obtained by starting at 5-10dB above the LDL obtained on the first trial. Different starting levels were used to minimize starting level bias and to encourage subjects to search thoroughly around their LDL before making a final decision.

Statistical analysis

The obtained data was subjected to statistical measures of mean and standard deviation. The significance of difference of mean LDLs of different stimuli were measured by t- test.

RESULTS AND DISCUSSION

The loudness discomfort level data was obtained from 20 hearing aid users, for different stimuli such as, narrow band noise, warble tone, white noise, drumbeats and speech. The obtained data were statistically analyzed by using paired 't' test to find out is there any significant differences between,

- Discrete stimuli (narrow band noise and warble tone) LDLs across the frequencies.
- Mean LDLs for speech and mean LDLs for other stimuli (such as white noise and drum beats).
- Mean LDLs for narrow band noise and warble tone averages of 500Hz, 1000Hz and 2000Hz.
- Mean LDLs for speech and LDLs for discrete stimuli (narrow band noise and warble tone) averages of 500Hz, lOOOHz and 2000Hz .

The statistical analysis reveals the following:

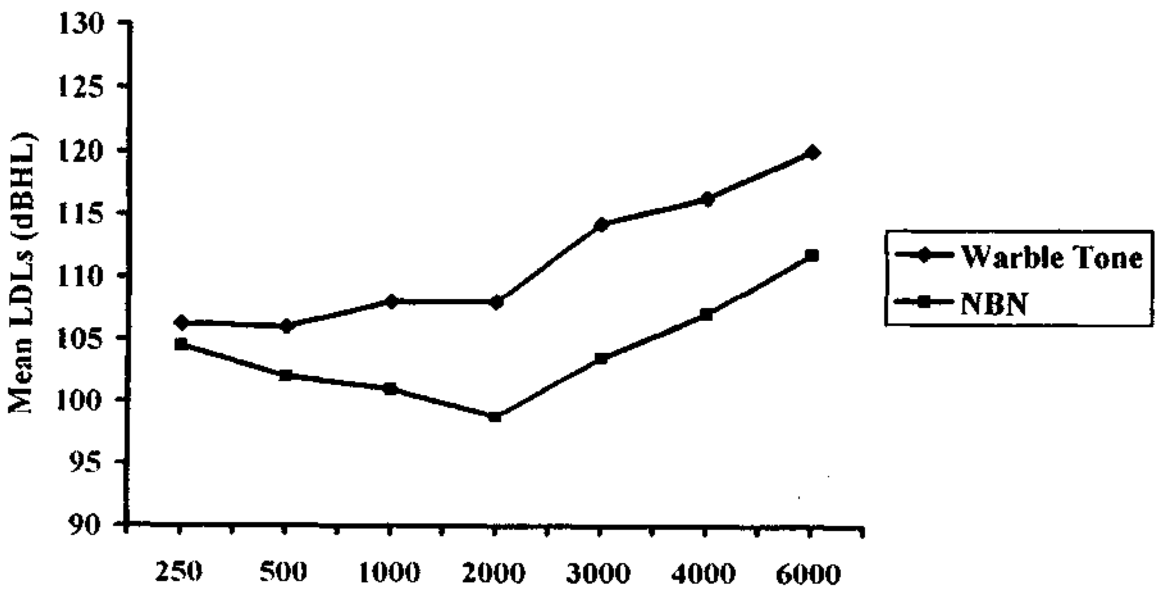
Table 1, depicted below reveals that at lower frequencies (250Hz and 500Hz) there is no significant difference. But, in the mid frequencies (lOOOHz and 2000Hz) significant difference was observed ($p<0.05$) and at high frequencies (3000HZ, 4000Hz and 6000Hz) very high significant difference was observed ($p< 0.001$).

Table 1: The Mean, standard deviation (SD) and t- values of discrete stimuli (narrow band noise (NBN), warble tone (WT) LDLs across frequencies.

Variable	N	Mean	SD	t-Values
NBN-250Hz WT-250Hz	20 20	104.5 106.25	10.37 10.87	9.41
NBN-500Hz WT-500Hz	20 20	102 106	12.9 12.6	1.651
NBN-lOOOHz WT-lOOOHz	20 20	101 108	13.72 16	2.126*
NBN-2000Hz WT-2000Hz	20 20	98.75 108	13.76 14.9	3.340 *
NBN-3000Hz WT-3000Hz	20 20	103.5 114.25	11.4 13.7	4.099 * *
NBN-4000Hz WT-4000Hz	20 20	107 116.25	10.4 11.3	4.635 * *
NBN-6000Hz WT-6000Hz	20 20	111.75 120	7.9 8.7	4.616**

$p < 0.05$ ** $p < 0.001$

***Graph** 1: Mean LDLs for NBN and WT across the frequencies.*



Frequency (Hz)

The graphical representation (Graph 1) of mean LDLs using narrow band noise (NBN) and warble tone (WT) shows that, LDLs systematically increased as frequency increased from 3000 Hz to 6000 Hz for both warble tone and NBN.

It was observed that when the frequency of the warble tone was increased from 250 Hz to 6000 Hz, there was an increase in the magnitude of the LDLs. Whereas, for narrow band noise it was observed that mean LDLs decreased from 250 Hz to 2000 Hz, from low to mid frequencies and increased with the higher frequencies.

The results of the present study are in accordance with the study of Beattie and Boyd (1986). Their results revealed that with the increase in frequency, pure tone LDLs also increased from 1000 Hz to 6000 Hz.

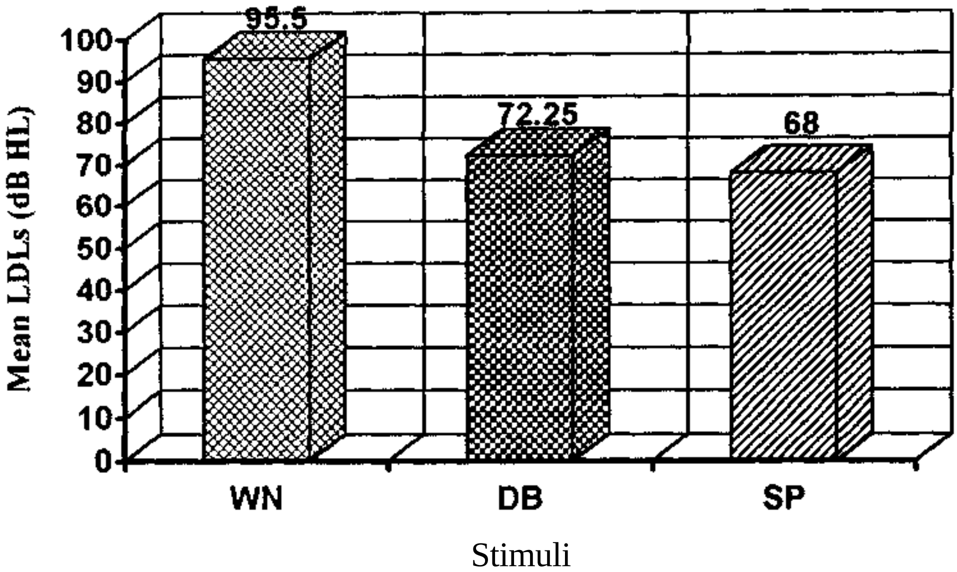
Table 2: The mean, SD, t- Values of speech and other LDLs (white noise and drum beats)

Variable	**N**	**Mean**	**SD**	**t-Values**
Drum Beats White Noise	20 20	72.25 95.5	8.8 9.58	8.256 * *
Drum Beats Speech	20 20	72.25 68	8.8 8.64	3.847 * *
White Noise Speech	20 20	95.5 68	9.58 8.64	10.564 * *

* *p< 0.001

Table 2, shows mean and SD for speech (SP), white noise (WN) and drumbeats (DB). The mean LDLs of the drumbeats, white noise and speech were compared. The results revealed very high significant difference in means (p<0.001).

Graph 2: Mean LDLs for White noise (WN), Drumbeats (DB) and speech (SP).



From above the graph 2, it can be observed that, the mean of LDL using speech stimuli (68 dBHL) was comparatively less than, that of drumbeats (72.25 dBHL) and white noise (95.5 dBHL). So, from this it can be assumed that speech is a better predictor of LDLs in hearing aid users, when compared to other stimuli, as it is able to predict LDL at a lower level.

Table 3: The mean, SD and t-Values for averages (of 500Hz, 1000Hz, 2000 Hz) of narrow band noise and warble tone.

Variable	N	Mean	SD	t-value
NBN average	20	100.63	11.56	3.357*
WT average	20	107.5	13.54	

* $p<0.05$

The mean for the averages of (500Hz, 1000Hz, 2000 Hz) narrow band noise and warble tone were compared. The results revealed that there was a significant difference ($p < 0.05$) between the mean for the averages of NBN and warble tone.

From the graph 2, it is seen that, speech is a better predictor of LDL when compared to mean LDLs of other stimuli. An effort eas made to see if there is any significant difference in the mean LDLs of speech and mean LDLs of discrete stimuli averages of 500Hz, 1000Hz and 2000Hz, which is shown in the table-4.

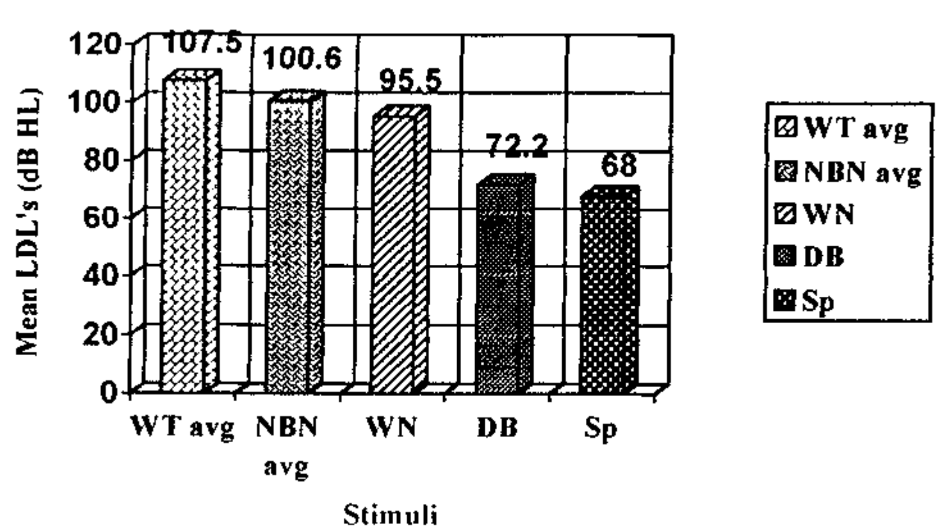
Table 4: The mean, SD snd t-values of speech and discrete stimuli average (NBN and WT of 500Hz, 1000Hz, 2000Hz).

Variable	N	Mean	SD	t-value
NBN average Speech	20 20	100.63 68	11.56 8.6	14.192**
WT average Speech	20 20	107.5 68	13.5 8.6	13.125**

**p< 0.001

It can be observed from table 4, that there is significant difference between mean LDLs of speech and NBN average (p<0.001) and also between mean LDLs of warble tone average and speech (p<0.001).

Graph 3: Mean LDLs for different stimuli.



Graph 3, represents mean LDLs for different stimuli such as warble tone, narrow band noise (discrete stimuli) averages, and white noise, drumbeats and speech. From the graph it can be clearly observed that speech mean LDLs occur at lower levels than that of other mean LDLs.

Briskey (1980) and Dirks and Morgan (1983), reported that speech is more realistic stimuli to determine LDLs rather than pure tones, as pure tones rarely occur in every day listening situation, usually are not meaningful. More over, the LDL using speech stimuli can be obtained in less time than is required to measure LDLs at several pure tone frequencies. The results of the present study showed that LDLs could be determined at lower levels using speech stimuli, which are in consonance with the results of Briskey (1980).

The result of present study shows that, it is easier to establish LDLs using speech as stimuli when compared to other stimuli. Moreover, LDLs can be converged at lower levels using speech when compared to other stimuli, (such as warble tone, narrow band noise, white noise, and drumbeat).

SUMMARY AND CONCLUSION

From rehabilitation point of view tests have been used to define gain setting and maximum output level for hearing aid use. The hearing aid user should not experience loudness discomfort while wearing a hearing aid. This is commonly held tenet of hearing aid fitting and has significant clinical importance.

The studies have shown high variability for loudness discomfort level (LDL) measurements when discrete stimuli and speech are compared. Hence, the present study was taken up with an aim, of finding out if there is any difference between loudness discomfort levels (LDLs) for discrete stimuli (narrow band noise and warble tone), white noise, drum beats and speech.

The data were obtained from 20 hearing aid users in the age range of 18-75 years. The subjects had moderate to moderately severe sensorineural hearing loss with flat audiometric configuration, **initially,** stimuli such as (narrow band noise, warble tone, white noise, drum beats and speech) were presented at subject's most comfortable level and modified Hughson-Westlake method (Carhart and Jerger, 1959) were used to establish LDLs.

The results of the present study showed that, when the narrow band noise and warble tone were compared across frequencies it was found that LDLs systematically increased as frequency increased. Again, when the speech stimuli LDLs were compared with other stimuli mean LDLs (such as white noise, and drum beats), it was found that speech is a better predictor of LDL, than other stimuli LDLs. Also, when the averages of (500Hz, 1000Hz,and 2000Hz) narrow band noise and warble tone were compared, the results showed significant difference between these two stimuli averages.

Finally, the comparison between the speech stimuli and the averages of narrow band noise (NBN), and warble tone (WT), showed significant difference between the mean LDLs for speech, narrow band noise average and warble tone average.

From the results of the present study, it can be inferred that using speech as stimuli, loudness discomfort levels (LDLs) can be reached at lower levels when compared to other stimuli (such as drumbeats, white noise, warble tone, and narrow band noise).

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