FREQUENCY SPECIFIC TEMPORAL INTEGRATION IN INDIVIDUALS WITH NORMAL HEARING AND COCHLEAR HEARING LOSS

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“DEDICATED TO AMMA

&

MY GUIDE”

CERTIFICATE

This is to certify that this dissertation entitled **"Frequency Specific Temporal Integration in Individuals with Normal Hearing and Cochlear Hearing Loss"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration No. 11AUD025. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This dissertation entitled **“Frequency Specific Temporal Integration In Individuals With Normal Hearing And Cochlear Hearing Loss”** is the result of my own study under the guidance of Dr. Vijaya Kumar Narne, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

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Chapter-I

INTRODUCTION

The different physical characteristics of the sounds play a crucial role in the perception of the complex sound. One of the important cues is the durational aspects of the speech sound (Moore, 1982). Both absolute thresholds and loudness of sounds depend upon the duration of the stimuli (Moore, 1982). Till duration of around 200 ms, the amount of intensity required to perceive the sound will reduce with increase in stimulus duration (Watson & Gengel, 1969). This integration of sound energy over time is referred to as temporal integration.

In normal hearing subjects temporal integration increases as the stimulus duration decreases, the amount of increment in thresholds averaging at 8 to 10 dB per decade (Hughes, 1946; Plomp & Bouman, 1959; Zwicker & Wright, 1963; Olsen & Carhart, 1966; Watson & Gengel, 1969, Florentine, Fatl, & Buus, 1988). Subjects with cochlear hearing loss, on the other hand, exhibit abnormal amount of temporal integration. (Miskolczy-Fodor, 1953; Harris & Haines, 1958; Elliott, 1963; Simon, 1963; Wright, 1968; Pedersen & Elberling, 1973; Young & Kanofsky, 1973; Olsen & Carhart, 1974; Pedersen, 1975; Stelmachowicz & Seewald, 1977; Chung & Smith, 1980; Chung, 1981; Carlyon & Sloan, 1987; Florentine et al 1988). These subjects show reduced betterment in threshold with increase in duration. Normal hearing individuals need around 6 to 8 dB increase in intensity to detect a 10 ms duration signal whereas individuals with cochlear hearing loss need around 1 to 5dB to detect the signal of 10 ms (Martin & Wofford, 1970). This phenomenon of reduced slope of temporal integration in individuals with cochlear hearing loss is shown in Figure 1.

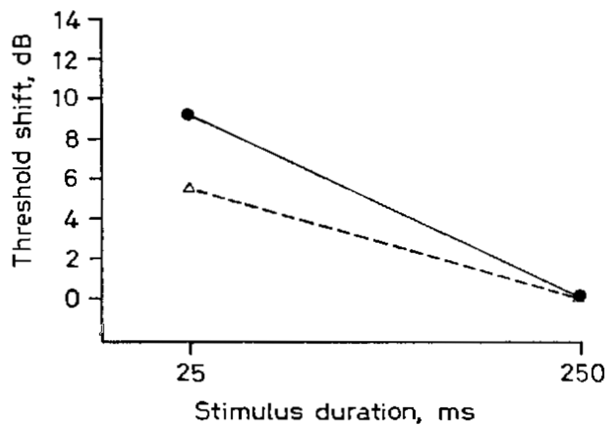

Figure 1.1: The comparison of slope in normal hearing (circle) and cochlear (triangle) hearing loss (Stelmachowicz & Seewald, 1977)

Abnormal temporal integration in cochlear hearing loss subjects there, are several views on it that these subjects may be listening to off frequency energy, produced by switching. When a sinusoid is switched on and off, off frequency energy was produced above and below the primary frequency. The amount of off frequency was dependent on the rise-fall time (Wightman, 1971). As per the Florentine et al, 1988 this diminished temporal integration in cochlear hearing loss could be because of

- The increased signal level used for the impaired listeners`
- Spectral splatter to frequencies where threshold were lower and
- Truly reduced temporal integration in cochlear impairment.

Temporal integration seems to be dependent on frequency in normal hearing individuals. Reduced temporal integration has been reported as the frequency is varied from lower frequency to higher frequency (Gengel & Watson, 1971; Pederson & Elberling, 1972; Stelmachowicz & Seewald, 1977). In contrast, several other investigators have reported essentially similar temporal integration across frequencies (Olsen & Carhat, 1966; Florentine et al, 1988). Similar conflicting findings have also been reported in those with cochlear hearing loss (Florentine et al., 1988; Miskolczy, 1953; Wright, 1968).

Severity of cochlear hearing loss may have an effect on temporal integration. According to some investigators, temporal integration decreases as the degree of hearing loss increases (Florentine et al., 1988), as observed by a negative correlation between the thresholds and amount of integration. In contrast to this Watson & Gengel (1969) reported no significant difference in temporal integration between normal hearing and cochlear hearing loss individuals with sloping hearing loss. Temporal Integration may also vary as a function of the configuration of hearing loss (flat vs sloping) (Fastl, 1977, Florentine et al., 1988). The current study aimed at assessing temporal integration across frequencies in individuals with normal hearing and in individuals with flat and sloping cochlear hearing loss.

1.2. NEED FOR THE STUDY

The spoken language contains many short and complex sounds. Temporal integration plays an important role in the perception of short duration transient cues and in integrating chunks of information arriving one after the other (Nguyen & Hawkins, 2007). Temporal integration abilities of auditory system were studied widely over years in normal hearing and hearing impaired population (Watson & Gengel, 1969; Florentine et al., 1988). This study examines how the threshold changes as function of stimulus duration across different frequencies in normal and cochlear hearing loss with flat and sloping configurations. The previous studies Florentine et al. (1988) studied the temporal integration in normal and cochlear hearing loss with different configuration hearing loss in two subjects. But the number of subjects they took in normal and clinical population was less. A similar lacuna was observed in Garner (1947) Hughes (1946) Wright (1968) and Oxenham, Moore and Vickers (1997), where they assessed temporal integration in normal hearing and hearing impaired group with limited no of participants (<5). Further, not all studies have assessed both normal hearing and cochlear hearing impaired subjects on similar parameters. Hence, there is a need to systematically evaluate temporal integration across a wide range of frequencies in (a relatively large number of) individuals with cochlear hearing loss, after controlling for the effect of degree of hearing loss and configuration of loss.

1.3. AIM OF THE STUDY

The current study aimed at assessing temporal integration across frequencies in individuals with normal hearing and in individuals with flat and sloping cochlear hearing loss.

1.4. OBJECTIVES OF THE STUDY

- To measure the temporal integration across frequencies in normal hearing subjects
- To measure the temporal integration in cochlear hearing loss, controlling for degree of hearing loss
- Comparison of temporal integration in normal verses cochlear pathology
- To investigate how temporal integration varies with configuration of hearing loss

Chapter-II

Review of literature

The relationship between stimulus duration and stimulus intensity in perception of acoustic energy is generally referred to as temporal integration or temporal summation. Literature in the past indicates that a number of investigations have been carried out on the both normal hearing individuals and those with pathology to study temporal integration. Investigators have also studied the effect of different factors such as frequency and intensity on temporal integration. The studies on temporal integration are reviewed under the following sections:

1. Studies on normal hearing subjects
2. Studies on clinical population.

2.1. Studies on normal hearing subjects

Garner (1947) have reported that when signal duration is doubled, intensity of signal must be decreased by about 3 dB to hear the signal or to remain at threshold. This half duration double formula, works better for signal durations between 10 and 200 ms. This does not explain, for signal durations greater than approximately 200 ms, where detectability is independent of duration (Watson and Gengel, 1969; Gengel and Watson 1971). In addition, temporal integration at durations less than 10 ms is not well understood (Scharf, 1910). At very short durations, some authors report an increase in threshold energy (Plomp and Bouman, 1959), while others report a constant threshold energy (Zwicker and Wright. 1963).

2.1.1. *Effect of frequency on temporal integration*

A number of studies have reported that the slope of temporal integration varies with frequency. Pedersen and Elberling (1972a) found a decrease in the slope of temporal integration as a function of frequency. They found a systematic decrease when the frequency was varied from 500 Hz to 8 kHz with a slope of 11.1dB at 500 Hz and 8.1 dB at 8 KHz. Similar results were also obtained by other investigators (Hattler & Northern, 1970; Sanders, Josey & Kemker, 1971; Gengel & Watson, 1971; Florentine, Fasti & Buus, 1988). However, Barry and Larson (1974) reported no difference in the amount of temporal integration across frequencies. They showed a mean threshold difference of about 10 dB between 20 msec and 500 msec tone, for all the four frequencies tested (500 Hz, 1 KHz, 2 KHz and 4 KHz). The reason for these differences in finding is not clear.

There are several authors who studied procedural influence on frequency. Chamberlain and Zwislocki (1970) investigated the influence of procedure in a study by using six different psychophysical methods. Those were method of adjustment, limits, constant stimuli, tracking, forced choice, and confidence rating. The slope of integration was found to change with frequency for all procedure except for tracking and forced choice. Similar kind of results were observed by Bilger and Feldman (1969), where they also examined the comparison between threshold-duration functions obtained with three different methods those were tracking, forced choice and "yes-no" procedure. Results showed that that for first two procedures there was no change with frequency, while the "yes-no" procedure revealed different functions for different frequencies.

Thus, some investigators report that frequency has an effect on temporal integration whereas others maintain that such frequency effect is not observed in true normal subjects. The difference could be due to procedural difference.

2.1.2. *Effect of intensity on temporal integration*

To study the effect of intensity, temporal integration has been studied at threshold and supra threshold levels. Stelmachowicz and Seewald (1977) studied pure tone thresholds and acoustic reflex thresholds for 500 Hz, 1 kHz and 2 kHz tones of 500, 250 and 25 msec durations with a rise-fall time of 10 msec. Results revealed that supra threshold slopes approximated those obtained at auditory threshold, for subjects with normal hearing.

2.2. Studies on clinical population

A majority of the investigations have focused on temporal integration in subjects with cochlear pathology as temporal integration occurs at the level of cochlea (Wright, 1968). A few researchers have also conducted studies on patients with retro cochlear pathology, conductive hearing loss and temporal lobe dysfunction.

2.2.1. *Retro-cochlear pathology*

Temporal integration is reported to be normal in individuals with affected auditory nerve function, hence, brief tone audiometry has been used in differential diagnosis of cochlear pathology and retrocochlear pathology. Sanders. Josey and Kemker (1971) evaluated temporal integration in three patients with eighth nerve tumors and in patients with cochlear pathology. They used 1 kHz and 4 kHz tones as stimuli which ranged in duration from 150 msec to 10 msec with 5 msec rise-fall time. The results revealed that brief tone audiometry provides a clear distinction between patients with eighth nerve tumor and those with cochlear pathology.

Sanders, Josey and Kemker (1971) conducted yet another study evaluating temporal integration in three individuals with eighth nerve tumor. They found that the amount of temporal integration was similar to that of normal hearing individuals, and increased when compared to those with cochlear pathology. They concluded that the assessment of temporal integration may be an important audiological tool to differentiate between cochlear hearing loss and eight nerve tumor.

2.2.2. *Conductive and mixed hearing loss*

Studies on patients with conductive hearing loss have revealed similar integration functions as normal hearing subjects. This can be expected as cochlea, which is thought to be responsible for temporal integration, is intact in conductive pathology. Wright and Cannella (1969) studied temporal integration in normal hearing individuals with temporarily induced conductive hearing loss of about 40 dB. This was done by inserting a Vaseline gauze plug deeply into the external auditory meatus. Brief tone audiometry was administered before and during the insertion of the gauze plug and also after the removal of it. Stimuli used were of 250 Hz, 1 kHz and 4 kHz frequency and had durations ranging from 500 to 10 msec with a rise-fall time of 10 msec. The results revealed no difference among the three conditions, indicating that conductive hearing loss has no effect on temporal integration. They also verified the results in a subject with mild conductive hearing loss, which also showed no difference in the temporal integration function pre and post treatment.

2.2.3. *Cochlear pathology*

Research on subjects with cochlear pathology have revealed a reduced capacity to integrate energy over time. Hence, the slope of temporal integration will be shallower than that in ears with normal hearing. Sanders and Honig (1967) have observed that brief tone audiometry clearly distinguished an ear with normal hearing from that with cochlear pathology. Also, the degree of abnormality in integration of energy tended to be proportional to the magnitude of hearing loss. But no relationship was found between different etiologies of cochlear pathology (e.g., ototoxicity, Meneier's disease, & presbycusis) and pattern or degree of temporal integration.

Wright (1968), in one of the earliest studies, measured temporal integration at threshold of audibility using Bekesy tracking method. The results obtained from a listener with unilateral moderate sensorineural hearing loss revealed a deviant temporal integration function in the affected ear. The results were attributed to the probable excess adaptation.

Sanders, Josey and Kemker (1971) studied temporal integration in individuals with normal hearing and ten individuals with cochlear pathology. They used 1 kHz and 4 kHz pure tones ranging in duration from 10 msec to 150 msec. They found that the slope of integration for individuals with cochlear pathology was shallower when compared to that of normal hearing individuals. The temporal integration values ranged from 1 to 4 dB at 1 kHz and 2 to 4 dB at 4 kHz in individuals with cochlear pathology. These values were lesser when compared to those of normal hearing individuals which had a mean value of 10 dB at 1 kHz and 8.5 dB at 4 kHz.

Pedersen and Elberling (1973) studied the slope of temporal integration as a function of hearing loss. They measured temporal integration at 500 Hz, 1 kHz, 4 kHz and 8 kHz in 46 subjects with Presbycusis. The stimuli were of 10 durations ranging from 2 msec to 1000 msec. It was observed that the slope decreased as the degree of hearing loss increased. Analysis of the data also revealed that among the different expressions of temporal integration, $A^2/2B$ was most relevant.

Gengel in 1972 assessed the temporal integration in normal hearing and in those with simulated hearing loss by masking at frequencies of 500 Hz, 2 kHz and 4 kHz for the stimuli of durations ranging from 10 to 500 ms in octaves. They found that the temporal integration function in those with simulated hearing loss was similar to those in normal hearing individuals. The average temporal integration values found in individuals with simulated hearing loss were 15 dB at 500 Hz, 10 dB at 2000 Hz and 8.5 dB at 4000 Hz.

Temporal integration has been studied in different modalities. Gengle and Watson (1971) evaluated 8 subjects with hearing impairment for temporal integration from 250 Hz to 4 kHz at octave intervals. The durations of the stimuli considered were 512, 64 and 32 msec. For two severely hearing impaired subjects, temporal integration was evaluated in both auditory and tactile mode. The average difference between thresholds for 32 and 64 msec signals relative to threshold for a 512 msec signal was calculated. The results revealed that temporal integration was reduced at frequencies with abnormal threshold. The results were similar for both the modes suggesting that in severely hearing impaired subjects, tactile stimulation may be controlling the threshold response.

The influence of audiometric configuration on temporal integration in individuals with cochlear hearing loss was evaluated by Hattler and Northern (1970). Temporal integration in quiet and ipsilateral masking conditions was examined in 20 subjects with sloping and flat audiometric configuration. Stimulus duration ranged from 10 to 300 msec with rise fall-time of 2.5 msec. Results revealed that there was neither an effect of audiometric configuration nor that of masking on the pattern of temporal integration.

Tyler in 1976 investigated the effect of off frequency energy on temporal integration measurements. They used unfiltered and high-pass filtered sinusoids as stimuli. The duration of the stimuli were 20 and 200 msec with 1 msec rise-fall time. The temporal integration function was obtained from four individuals with normal hearing and four individuals with high frequency cochlear hearing impairment. The individuals with hearing impairment revealed abnormal temporal integration in the unfiltered condition. When forced to listen on frequency, two of the hearing impaired subjects demonstrated normal temporal integration. It was concluded that off frequency energy can confound the measurement of temporal integration.

Pederson and Salomon (1977) compared the amount of temporal integration at threshold and at a higher sensation level in individuals with normal hearing and those with cochlear pathology. It was observed that at higher sensation level, normal hearing subjects exhibited lesser amount of temporal integration, whereas, at threshold level, individuals with cochlear pathology showed reduced temporal integration. Hence it was concluded that temporal integration depends on the sound pressure level reaching the cochlea and not on the degree of hearing loss.

Selmachomicz and Seewald (1977) investigated the temporal integration function at threshold and supra threshold levels in individuals with cochlear impairment at the auditory and acoustic reflex thresholds. The results revealed a steeper temporal integration function at acoustic reflex threshold, whereas, it was flatter at the auditory threshold level. They found similar temporal integration functions for normal hearing and those with cochlear hearing loss at suprathreshold levels.

Florentine et al., (1988) compared temporal integration in normal hearing, in individuals with cochlear hearing impairment with flat and sloping configurations and in individuals with simulated hearing impairment. The hearing loss was simulated by spectrally shaped noise. Sinusoids of frequencies 250 Hz, 1000 Hz and 4000 Hz were used with their durations varying from 20ms to 200ms, 10 to 200ms and 2 ms to 200 ms respectively. For normal hearing individuals, for every ten times increase in duration, the threshold decreased by about 8 to 10 dB. Similar results were obtained for the individuals with simulated hearing loss showing similar amount of temporal integration as normals in quiet condition. Whereas, individuals with hearing impairment showed reduced amount of temporal integration than the other two groups.

Martin and Wofford (1970) measured temporal integration in 12 adults with normal hearing and 12 adults with cochlear impairment using fixed frequency Bekesy tracings. Pure tone pulses were used as stimuli which ranged in frequency from 250 Hz to 8 kHz and in durations from 20 to 500 msec. The stimuli had 10 msec rise-fall time and 500 msec off time. Subjects with cochlear impairment showed lesser temporal integration at higher frequencies with mean values of 1.8 and 1.3 dB at 4 and 8 kHz respectively.

This was attributed to greater loss at higher frequencies. However, the results also indicated overlap between the two groups.

Contrary to the above mentioned studies, Watson and Gengel (1969), reported contradicting results. They assessed the temporal integration in 4 normal hearing individuals and 3 individuals with sloping hearing loss using psychophysical method of adjustment for octave durations from 16 to 1024 ms across the frequencies from 125 Hz to 8000 Hz in octave steps. They found similar results for normal hearing and individuals with sloping hearing loss.

Thus, it can be seen from this review of literature that cochlear impairment has a definite effect on temporal integration, reducing the amount of temporal integration significantly. Results also revealed a correlation between the amounts of hearing loss and temporal integration. However, few studies have contradicted the above findings by stating no difference exists between the temporal integration function seen in normal hearing individuals and those with cochlear hearing loss. Hence, the present study aimed at evaluating the temporal integration function between normal hearing and individuals with hearing loss.

The previous research is also inconsistent in terms of the effect of frequency on the temporal integration function, hence the current study also studied the temporal integration function across different frequencies.

Chapter –III

METHOD

3.1.Participants

Subjects participated in the present study were divided into two groups. Group-1 includes normal hearing listeners and second group includes cochlear hearing.

3.1.1.*Group 1*

The group 1 included of 10 normal hearing subjects in the age range of 20-50 years. All subjects had pure-tone thresholds less than ≤15 dB HL at octave frequencies from 0.25 KHz to 8 kHz for air condition and 0.25 KHz to 4 KHz for bone conduction. Immittance results showed 'A' type tympanogram with ipsi-lateral acoustic reflexes present at 95 dB in both ears indicating normal functioning of middle ear. Structured interview revealed no past or present history of otological or neurological problems.

3.1.2.*Group 2*

Group-2 is divided into two sub groups (flat hearing loss and sloping hearing loss), each group was consisted of 10 subjects who were clinically diagnosed as having moderate to moderately severe cochlear hearing loss in the age range of 20 to 50 years. Pure tone average of all the subjects was within 40 to 70 dB HL and air-bone gap not greater than 15dB at any of the octave frequencies from 250 Hz to 4 KHz. Immitance results showed 'A' type tympanogram with reflexes appropriate for hearing loss at 500Hz, 1000 Hz, 2000Hz and 4000 Hz. Absent Transient Evoked Oto-Acoustic Emissions. ABRs with good morphology and indicative of a peripheral pathology. No past or present history of neurological problems.

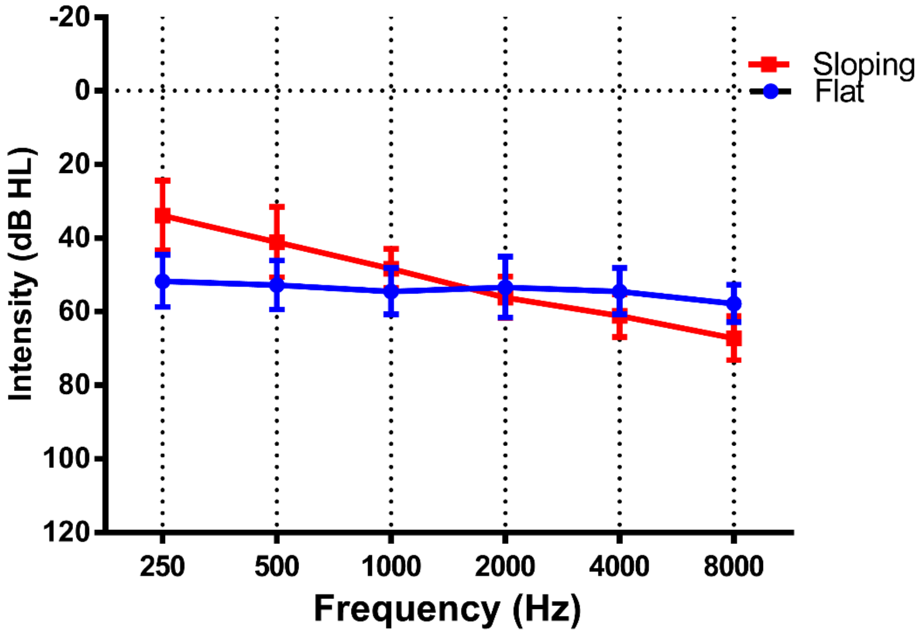

Figure 2.1. Average pure-tone thresholds as a function of frequency. The error bar indicate the standard deviation. Blue line is individuals with flat audiometric configuration and red line is individuals with sloping configuration.

Instrumentation

The following instruments were used:

- A two channel Madsen OB922 clinical audiometer calibrated according to ANSI S3.6 1996 standards 1996, with Telephonics TDH39 earphones and Radio ear B71 Bone vibrator was used for pure tone audiometry.
- A calibrated Grason Stadler Tympstar Immittance instrument was used to assess middle ear function and the acoustic reflex
- ILO292 USB2 Version 6 was used to elicit and measure the Oto-acoustic emissions
- Intelligent Hearing Systems (IHS) Smart EP version 3.95USBeZ was used for recording ABR
- Psycon version 2.18 software was used for presentation of stimuli (Kown, 2008).

3.2Stimulus

A sinusoidal stimulus of three different frequencies 250 Hz, 1000 Hz and 4000 Hz with duration varying from 20ms to 200ms, 10 to 200ms and 2 ms to 200 ms respectively. The stimulus was generated by using Psycon 2.18 software. Ramp was used to avoid spectrum splatter which will smoothen the beginning and ending points of the stimulus. The ramping was 10ms at the beginning and ending of the stimulus for each durations, where as in previous literature different rise and fall time are used to avoid frequency spread (Pedersen & Elberling, 1972; Wright, 1968). The inter stimulus interval was 500ms for all the durations. The intensity level was varied to identify the threshold of the participants at each duration across frequencies.

3.3. Procedure

Tone detection thresholds were obtained using three-interval, three-alternative forced-choice procedure (Levitt, 1971). The stimuli were generated by Psycon-2.18 software installed on a personal computer and routed to the HDA-200 headphones. On each trial, two continuous noises and a tone with ramp will be presented randomly with an inter stimulus interval of 500 msec. The participant's task was to identify the block containing stimulus. The step size will be 5 dB initially and will be reduced to 2 dB after first reversal. Two-down one-up procedure was used to arrive near the threshold. The mean of last eight reversals in a block of 12 was taken as threshold. This procedure can provide the value of threshold necessary for 70.7% correct responses.

Chapter-IV

RESULTS AND DISCUSSION

The present study was intended to measure the temporal integration in normal hearing and different configuration of cochlear hearing loss for three different frequencies. The thresholds obtained across durations and frequencies for above mentioned groups was tabulated and following analysis was performed on the data using SPSS and MATLAB. All the statistical analyses in the study were performed using the SPSS v17 software package.

1. To emphasize the effect of temporal integration, the data were normalized by subtracting the threshold at 200ms from the absolute threshold at other durations. These thresholds will be termed as Difference Thresholds and all the evaluations will be performed on this data.
2. To assess effect of duration and frequency on difference threshold in normal hearing and cochlear hearing loss listeners a two way repeated measure of ANOVA was administered.
3. Slope was obtained for all the listeners by a least square fit to the data across different durations. The fitting was performed using custom made program in MATLAB.
4. One way ANOVA was performed to see effect of frequency on slope across three different frequencies.

   A one way ANOVA was performed to assess the slope in normal hearing and Cochlear hearing loss.

Temporal Integration in normal hearing

Figure 4.1 shows the mean difference threshold for normal hearing listeners at different durations across three different frequencies (250Hz, 1000 Hz and 4000 Hz). It is noted from the figure that for all frequencies the threshold increased as the duration of the stimulus decreased. The decrease in threshold is approximately 3 dB for every doubling of the duration. But for 4 kHz, there was only 2.2 dB reduction in threshold for every doubling of duration.

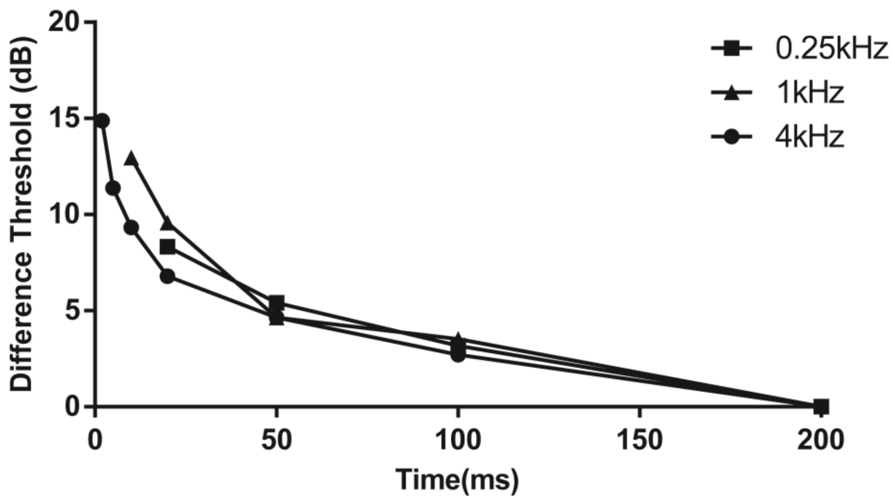

Figure 4.1. Mean difference threshold as a function of duration for 3 different frequencies in normal hearing individuals

To see the affect of frequency and duration on difference threshold in normal hearing, a two way repeated measure ANOVA was performed with frequency and duration as within subject factor. The test was performed on the data for the durations of 200 ms to 20 ms. Durations less than 20 ms was not included, as 250Hz did not any data less than 20 ms. Results of the ANOVA revealed a significant main effect of duration [$F_{(2,\ 12)}$ = 210, P<0.01], but effect frequency showed no significant [$F_{(2,\ 14)}$ = 2.30, P=0.075]. The interaction between duration and frequency [$F_{(6,\ 33)}$ = p<0.03] is significant. These indicate that difference threshold change with increase in duration is not same across different frequencies. Bonferroni Paired wise comparison revealed that for 4 kHz change in threshold is significantly lesser than 0.25 kHz and 1 kHz.

Further to explore the effect of frequency on temporal integration a slope was derived. The slope was derived by fitting the data of all listeners using equation 1.

$$I_t/I_\infty = \left(1 - e^{\frac{-t}{\tau}}\right) \text{----- Eq.1}$$

I_t is the threshold at stimulus duration t and I_∞ is threshold at longest duration of the stimulus. In the present study 200 ms is considered as I_∞. The t is the stimulus duration, and τ is the time constant this indicates the slope. The equation was proposed by Plomp and Bouman (1959). The data of each individual was fitted with equation 1 and which allowed derive slope. A one way ANOVA was performed on the slopes and the results showed a significant main effect of frequency [$F_{(2, 5)}$ =3.25, $P<0.01$]. The slope is shallow at 4 kHz compared to 0.25 and 1 kHz.

Temporal integration in cochlear hearing loss

a. Flat Hearing loss

The mean threshold for flat hearing participants at different durations across three different frequencies (250Hz, 1000 Hz and 4000 Hz) was depicted in Figure 4.2. It can be noted from the figure that decreasing duration increases the threshold. The change in threshold with doubling of duration is approximately 2 dB across all the frequencies. This indicates that temporal integration is slightly reduced in flat hearing loss participants than normal hearing participants. Further, it is noted that some listeners showed poor temporal integration whereas other showed temporal integration in normal range.

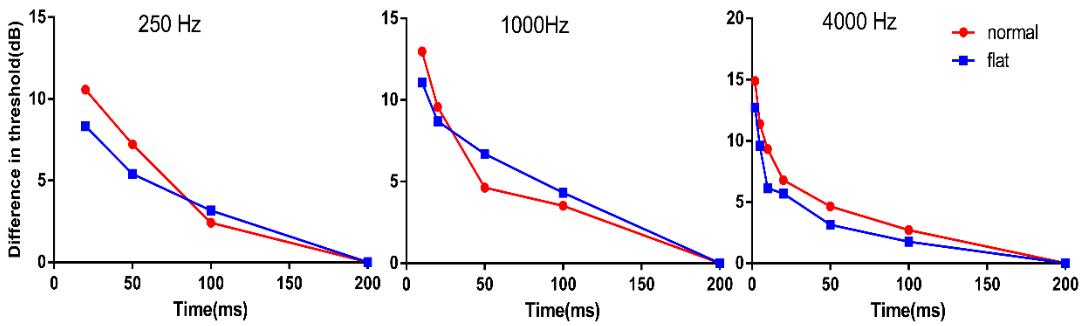

Figure 4.2. Mean difference as function of duration in normal hearing (red) and flat-cochlear hearing loss subjects (blue)

To check the affect of duration and frequency on temporal integration in flat hearing individuals a two way repeated measure ANOVA was performed with frequency and duration as within subject factor. Here also the test was performed on the data for the durations of 200 ms to20 ms for reasons explained above. ANOVA revealed a significant main effect of duration [F (1, 5) = 32.859, P<0.01]. Whereas there is no significant main effect of frequency [F (1, 5) =6.742, P>0.48] and further there was no significant main effect of interaction [F(1,5) = 2.85, P>0.28] indicating that decrement in the threshold was same across the frequencies.

b. Sloping Loss

From Figure 4.3 it is noted that the mean threshold decreased with increasing duration for sloping hearing loss participants at different durations across three different frequencies (250Hz, 1000 Hz and 4000 Hz). The change in threshold as the duration increases was approximately 2 dB at 250 Hz, while the change in threshold at 1 kHz and 4 kHz was approximately 1 dB. This shows that temporal integration reduces more drastically in individuals with sloping hearing loss than normal hearing and flat hearing participants.

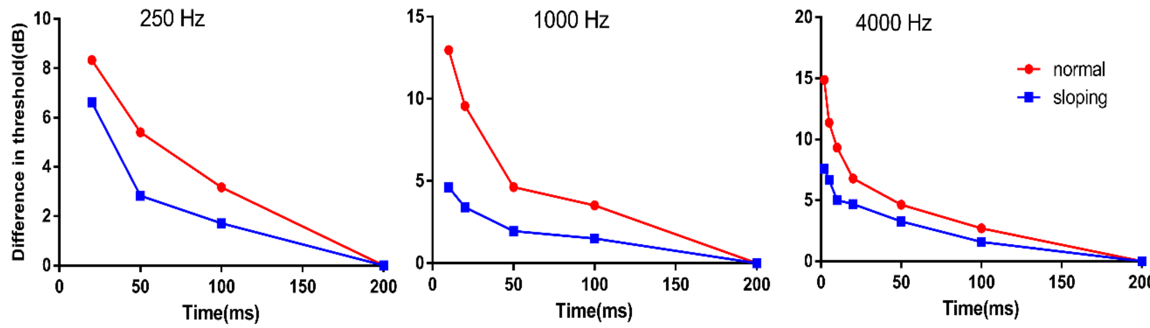

Figure. 4.3. Mean difference as function of duration in normal hearing (red) and sloping-cochlear hearing loss subjects (blue).

A two way repeated measure ANOVA was performed with in frequency and duration as within subject factor to see the affect of frequency and duration on temporal integration. The test was performed on the data for the durations of 200 ms to 20ms. ANOVA revealed a significant main effect of duration [$F_{(2, 5)}$ = 36.36 $P<0.01$]. Whereas there is no significant main effect of frequency [$F_{(2, 5)}$ =12.75, $P>0.05$] and further no significant main effect of interaction [$F_{(2, 7)}$ =6.82, $P<0.56$]. Thus, the decrement in the threshold was approximately same across the frequencies.

Comparison between normal hearing and Cochlear Hearing loss

Figure 4.4. Illustrates the mean group data of normal hearing participants, flat hearing participants and sloping hearing participants. The mean data of 0.25 and 1 kHz showed that the amount of temporal integration was similar for normal hearing and flat hearing loss, whereas it was reduced for individuals with sloping hearing loss. For 4 kHz normal hearing and flat hearing individuals showed similar amount of temporal integration that is decrease in threshold is almost similar across durations. Whereas, individuals with

sloping hearing loss showed steeper temporal integration till a duration of 50 ms but after 50 ms the slope became about to shallow.

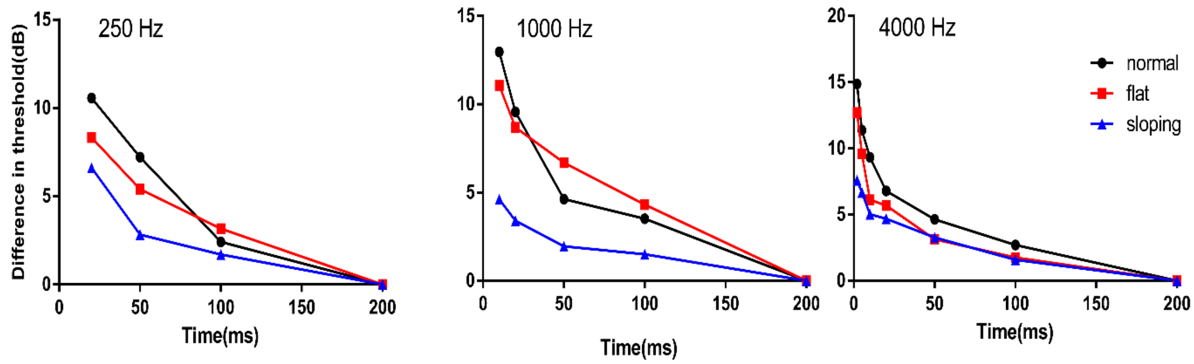

Figure 4.4. Mean difference threshold as function of duration in normal hearing (black), flat- cochlear hearing loss (red) and sloping-cochlear hearing loss subjects (blue)

To avoid the threshold difference across the groups, slope was measured for normal hearing, flat hearing loss and sloping hearing loss individuals. The estimated slope was compared using Kruskal–Wallis test, a non-parametric reciprocal of ANOVA, was performed on the slopes to see the affect of frequency across the groups. ANOVA revealed there was no significant affect of frequency at 250 Hz (H (2, N=20) = 4.4, P>0.1). Both 1 kHz (H (2, N= 21) -12.69, P<0.017) and 4 kHz (H (2, N=24) =6.4, P<0.03) had shown significant effect of frequency. Following this Manwitny U test was performed for multiple comparisons. Results showed no significant difference across groups at 250 Hz. At 1 kHz and 4 kHz slope values were significantly lower for sloping hearing loss participants compared to normal hearing participants.

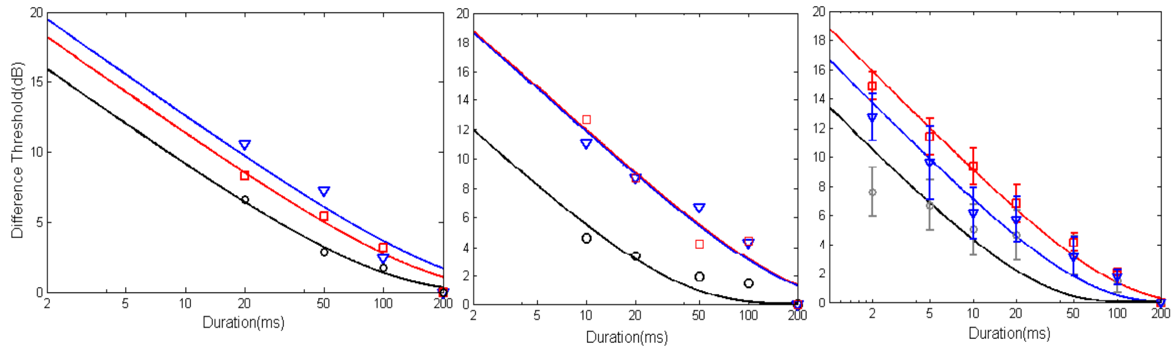

Figure 4.5. Fitted function plotted for derived threshold as function of duration in three different groups of lithers, normal (red), flat hearing loss (blue) and sloping hearing loss (black). The symbols indicate the mean difference threshold at each specific duration. The fitted function is described earlier

Discussion

Normal Hearing

The results of the present study showed that for every doubling of duration threshold decreased by approximately 3 dB. These results were in accordance with previous literature (Sanders and Honig, 1967; Martinet & Wofford, 1970; Pederson & Elberling, 1972a, Florentine et al., 1988, 1999). Analysis of the slope shows that amount of integration was shallower at high frequencies whereas it was steeper at low frequencies which show that the amount of integration was more for low frequencies than the high frequencies. That is reduction in threshold with increasing duration is small at higher frequency (4 kHz) compared to low frequency (0.25 kHz). Some investigators have reported similar results that observed in the present data (Pederson et al., 1972, Watson et al., 1969). In contrary, others showed that there no effect of frequency on temporal integration (Garner, 1947; Miskolczy & Fodor, 1953; Zwicker & Wright, 1963, George., 1990). The probable reason for these differences between these studies may be due to procedural differences. Those studies showing no effect of frequency on temporal integration were assessed temporal integration with ipsi-lateral masking. Whereas those studies which have shown effect of frequency on temporal integration were performed without masking noise.

There was no clear explanation provided for the effect of frequency on temporal integration (Pedersen & Elberling, 1972). Investigators have argued that the reduced temporal integration at higher frequencies may be due to spectral splatter, where threshold is contributed by energy at other frequencies. They have employed masking to reduce the contribution of spectral splatter in threshold estimation. However, Zwicker et al (1963) have shown that noise may have nullified the effect frequency on temporal integration.

Further, we argues that there was no effect of spectral splatter on threshold. To show that we have plotted spectrum of the lowest duration stimulus at each frequency along the threshold in dB SPL for longer duration (500 ms). Figure .4.9. Shows the spectral energy for 4 kHz signal with 2 ms duration at every one third octave along with pure-tone threshold at octave frequencies (in dB SPL). It would seem that there is insufficient energy from splatter from 4 kHz signal from 2ms to exceed threshold in any frequency other than of vicinity of 4 kHz. Thus there was little concern about need for detection energy outside the critical band of 4 kHz. These results suggests that for short duration signals, (<2 ms for 4 kHz), contribution of spectral splatter is negligible, suggests that show slope in temporal integration is due to frequency effect rather than spectral splatter. In addition studies have also shown that rise- fall time of the stimulus shows effect no effect on temporal integration (wright et al.,1967) but the duration of plateau effects the temporal integration (Pederson et al., 1972b).

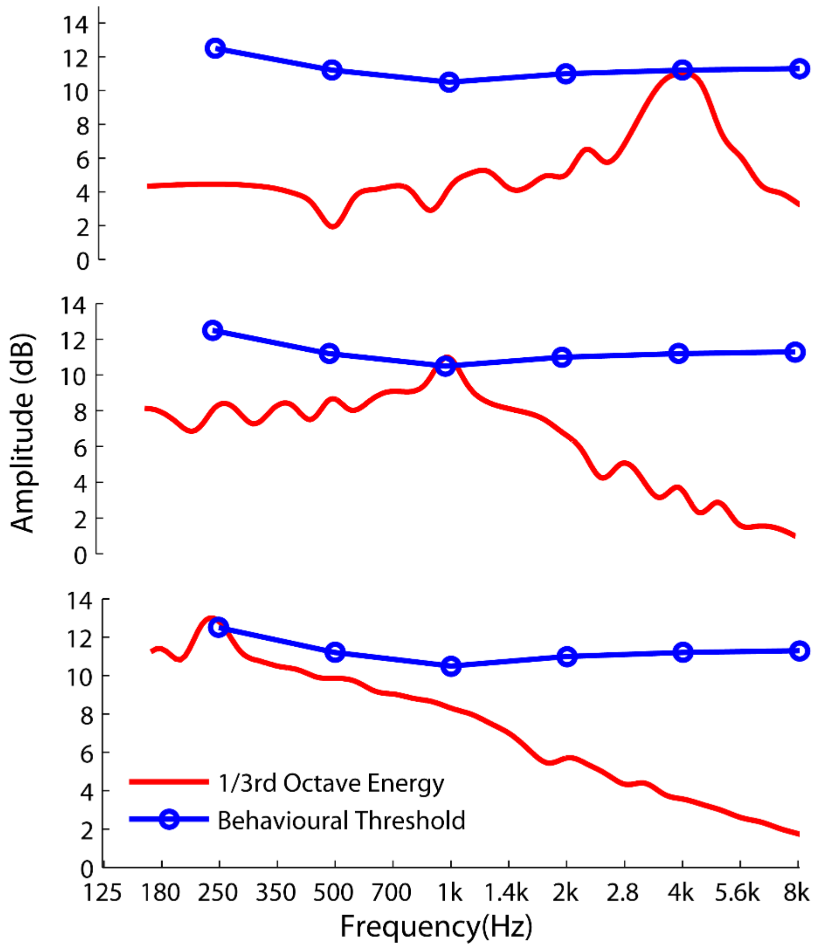

Figure. 4. 6. Spectrum (red) for three different frequencies along with average normal hearing thresholds (blue) in SPL are plotted. For each frequency, the spectrum was derived for lowest duration signal used in the present study. It is noted the spectrum levels are lower than thresholds at side bands.

Cochlear hearing loss

In the present study, the individuals with cochlear hearing loss (i.e including both groups) showed an abnormal temporal integration. That is in these individuals when duration is decreased reduced by 10 folds, an intensity change of 1-5 dB is required, whereas in normal hearing individuals 8-10 dB is required to maintain threshold responses. These results are in agreement with the previous literature (Martin et al., 1970; Gengel et al., 1971; Wright, 1968; Pedersen et al., 1973, Florentine et al., 1988).

In addition, the amount of temporal integration (i.e. difference between 200 ms with 20 ms) was calculated and plotted against the degree hearing loss in Figure 4.7. It can be noted that mean temporal integration reduces as the degree of hearing loss increases. These results are in close agreement with that reported by Chung (1981). However, they noted temporal integration reduces slowly after 50 dB HL of hearing loss, but in the present study there was linear decrease till 55 dB of hearing loss. The discrepancy in the results may be because, the maximum degree of hearing loss in the present is only 55 dB HL. As there was no data noted after 55 dB in the present study similar trend was not noted.

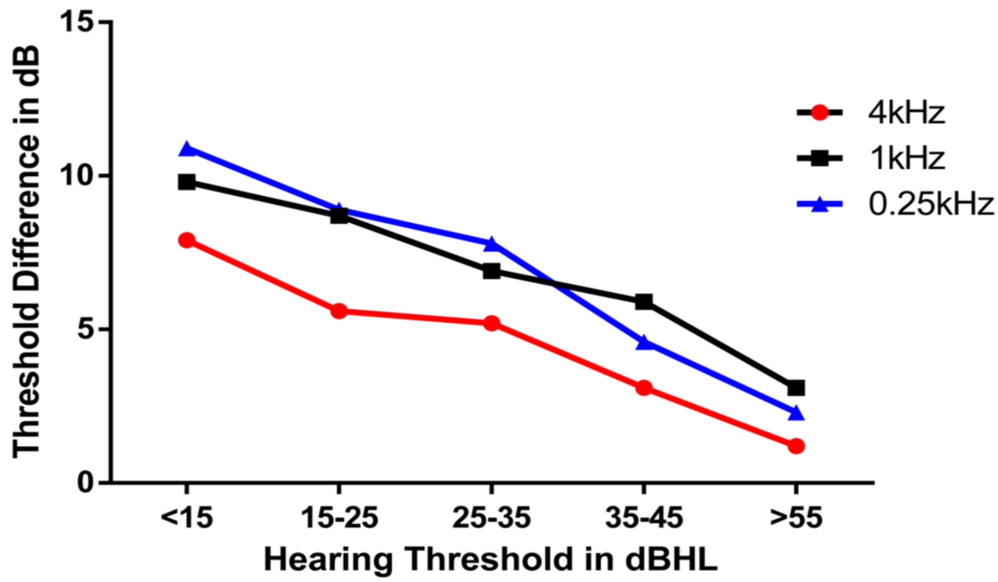

Figure 4.7. Temporal integration as function of degree of hearing loss for 3 different frequencies.

The reduction in the temporal integration can't be predicted from pure-tone threshold alone. For example the temporal integration of listeners FA and FH with flat hearing loss, both the individuals had similar degree of hearing loss. But their amount of temporal integration was varied across frequencies. At 1 kHz and 4 kHz listener FH had shown steeper pattern of temporal integration, whereas listener FA had shown shallow pattern of temporal integration. These results are depicted in Figure 4.8. Despite these individuals' differences, overall there was good agreement between degree of hearing loss and amount of temporal integration (Chung & Smith, 1980; Chung, 1981; Florentine et al., 1988).

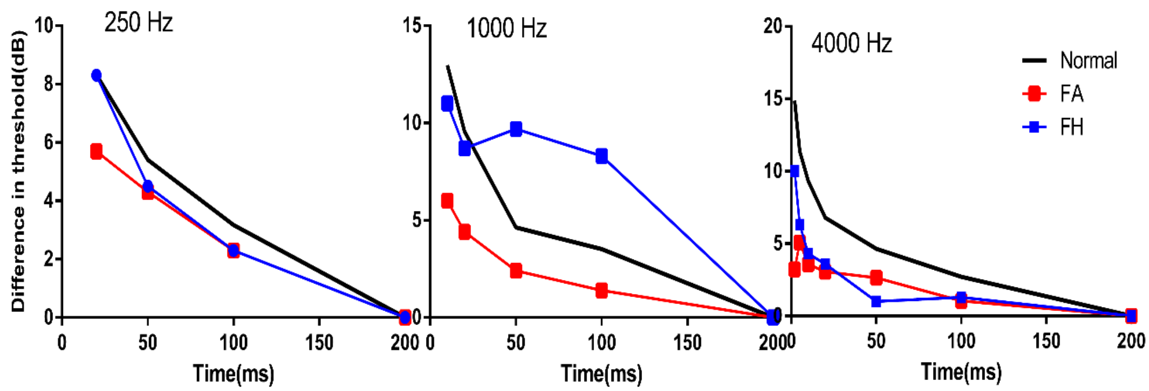

Figure 4.8. Threshold difference as a function of duration. The black line shows threshold average threshold for normal hearing subjects. The blue line for subjects FA and red line for subject FB.

Among the cochlear hearing loss individuals, temporal integration is lower individuals with sloping configuration compared to flat configuration. The close observation revealed that the temporal integration is reduced more significantly at 1 kHz and 4 kHz compared to 0.25 kHz. This difference may be attributed to degree of hearing loss. That is sloping hearing loss individuals have greater degree of hearing loss at higher frequencies, which would have caused the difference in temporal integration (Miskolczy et al., 1953; Simon, 1963; Wright, 1968; Florentine et al, 1988).

In individual with cochlear hearing loss of flat and sloping configuration showed reduced temporal integration than normal hearing individuals. The reduction in temporal integration at 0.25 kHz was smaller than compared to that noted at 4 kHz. Similar results were reported in two subjects of cochlear hearing loss with flat and sloping configuration by Florentine et al., (1988). The good temporal integration at 250 Hz compared to 4 kHz may be attributed to use of “off frequency listening” which is caused by spectral splatter (Tyler, 1976; Florentine et al., 1988). The short duration signals with less rise time (1 ms) used in the present study would cause the spectral splatter which aids in off-frequency listening. Due to less number of cycles in 250 Hz compared to 4 kHz, the amount of spectral splatter which in-turn cause's increased off-frequency listening (Tyler, 1976; Florentine et al., 1988).

In summary, results of the present study shows that intensity reduces by 3 dB for every doubling of duration to maintain threshold in normal hearing listeners. Further, the change in threshold with increasing duration reduces as frequency increases. Cochlear hearing loss subjects requires lesser change in intensity with reducing duration to maintain threshold. The change intensity required reduces with increasing threshold. No clear frequency effect was reported by statistical analysis, but the mean data shows that majority of cochlear hearing loss subjects perform better at 250 Hz compared to other frequencies.

Chapter- V

Summary and Conclusion

The current study aimed at assessing temporal integration across frequencies in individuals with normal hearing and in individuals with flat and sloping cochlear hearing loss. To achieve the above mentioned aim, 2 groups of listeners participated in the study: group-1 consisting of 10 normal hearing participants and group-II consisting of 20 cochlear hearing loss participants (10 flat hearing loss and 10 sloping hearing loss participants). Age range of all the participants were between 20-50yrs. Tone detection threshold was measured in both the groups using sinusoidal stimulus of three different frequencies 250 Hz, 1000 Hz and 4000 Hz with duration varying from 2ms to 200ms, 10 to 200ms and 2 ms to 200 ms respectively. Data obtained from the participants in the two groups were tabulated and subjected to appropriate statistical analysis. The results revealed that,

- In normal hearing participants for every doubling of duration threshold decreased by approximately 3dB at 250 Hz and 1000Hz whereas at 4kHz was 2.2 dB.
- In cochlear hearing loss participants shown an abnormal pattern of temporal integration. Participants with flat hearing loss showed a small reduction in temporal integration than normal hearing participants. Whereas participants with sloping hearing loss showed reduced amount of temporal integration than normal hearing and flat hearing loss participants.
- At lower frequency majority of listeners showed similar performance as normal hearing listeners. But as frequency increases performed worsened.

The results of the present study shows that, all cochlear hearing subjects had reduced temporal integration compared to normal hearing listeners. In general majority of cochlear hearing performed better at 250 Hz, because of use of spectral splatter cues at other frequencies. Finally, we suggests that understanding of this phenomena and others related to it, clinicians will be better able to assess the characteristics of hearing impairment and thereby make more confident judgment of degree of benefit these subjects can expect from hearing aids.

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