CLICK RATE INDUCED FACILITATION OF ACOUSTIC REFLEX IN CHILDREN WITH SENSORINEURAL HEARING LOSS

Rajith, B. N.

Register No: 15AUD022

This Dissertation is submitted as part fullfillment

for the Degree of Master of Science in Audiology

University of Mysore, Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSURU-570 006

May, 2017

CERTIFICATE

This is to certify that this dissertation entitled **"CLICK-RATE INDUCED FACILITATION OF ACOUSTIC REFLEX IN CHILDREN WITH SENSORI NEURAL HEARING LOSS"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: 15AUD022. 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.

Mysuru

May, 2017

Dr. S.R. Savithri
Director
All India Institute of Speech and Hearing
Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that this dissertation entitled "**CLICK-RATE INDUCED FACILITATION OF ACOUSTIC REFLEX IN CHILDREN WITH SENSORI NEURAL HEARING LOSS**" has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Guide

Mysuru

May, 2017

Dr.Rajalakshmi
Professor in Audiology,
All India Institute of Speech and Hearing
Manasagangothri, Mysuru- Mysuru
570006

DECLARATION

This is to certify that this dissertation entitled **"CLICK-RATE INDUCED FACILITATION OF ACOUSTIC REFLEX IN CHILDREN WITH SENSORI NEURAL HEARING LOSS"** is the result of my own study under the guidance of **Dr. Rajalakshmi. K**, Professor in Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru, ***Registration: 15AUD022***

May, 2017

Dedication

To parents, friends and

my

dear guide

Acknowledgment

I would like to express my sincere gratitude to my guide Dr. Rajalakshmi.K for her unconditional guidance and support. Thank you for being wonderful guide and teacher. Thank you ma'am for all your support and patience and also forgiving me for many of my mistakes and giving me another chance. You have always inspired me with your dynamic personality and I feel privileged to have you as my mentor and role-model. Special thanks for the yummy food she makes

My sincere thanks to Dr. S R Savithri, Director, AIISH, Mysuru for providing me a platform and materials to carry out this study.

I thank Dr. Sandeep M, HOD, All India Institute of Speech and Hearing, Mysore for permitting me to use the department.

I would also like to thank all the lecturers and staff of Audiology, All India Institute of Speech and Hearing, for helping and guiding me throughout my Master's course.

I thank Mr. Santosha CD for his help in statistical analysis.

I thank my parents and my sister for their constant support throughout my education.

I would like to thank my seniors, Ms. Padmashree B, Ms. Deepthi M, Ms.Prathiba and Mr. Ishu mittal for their constant support.

A special thanks to special people in my life Mr. Dhanush and Ms. Shanthala SP for their unconditional support and motivation.

I thank my friends Sanjeev, Nikhil J, Manisha, Nayana, Pavana, Shreelakshmi, Amoolya, Jagha charan, Meghana, Archana, Lavanya, Chaitra and ShivaPrasad, Sumanth AV and all my Mighty masters for their support.

I thank all the participants and their parents for their cooperation.

Abstract

Objective: To observe improvement in acoustic reflex threshold when click rates are varied from 50clicks/sec to 300 clicks/sec while presenting constant number of clicks across different repetition rates in children with sensorineural hearing loss.

Introduction: Rate integration is a process of improvement in the threshold with increase in the stimulus rate. Improvement in the acoustic reflex with increase in the click rates can be due to temporal summation and rate integration. Children with immature temporal processing can perform differently for higher rate compared to adults. Presence of sensorineural hearing loss can even reduce the rate integration in children.

Method: 30 ears with normal hearing sensitivity and 30 ears with mild to moderate sensorineural hearing loss within the age range of 5-10 years were included in the study. The acoustic reflex threshold was measured at each repetition rate from 50, 100, 150, 200 and 300 click per second and improvement in the acoustic reflex threshold between 50 clicks/sec and 300/sec was calculated to check for rate induced facilitation.

Result: Improvement in the ART was lesser in children with sensorineural hearing loss compared to children with normal hearing sensitivity. Maximum improvement was seen when the rate was increased from 50/sec to 100/sec compared to higher rates.

Conclusion: Rate induced facilitation of acoustic reflex using clicks can be used as an objective test to verify temporal integration in children with sensorineural hearing loss, however, presence of stapedial reflex is a primary criteria to use this objective test. This objective method can overcome limitations of behavioural assessment to assess temporal processing.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

Temporal integration refers to summation of the acoustic energy of the stimulus that results in the summation of neural activity over time, requiring less sound pressure to detect the auditory signal. Increasing the stimulus rate results in improvement in hearing threshold for tonal and wide band stimulus. Increasing the rate of brief stimulus involves temporal integration in similar manner to increase in the duration of the continuous stimuli.

Normal temporal integration can provide cues for duration discrimination and in turn help in speech perception (Rawool, 2007). Temporal integration at threshold improves due to increase in the duration of the stimulus over time (Pederson and Salomon, 1977). Thus auditory system acts as energy detector.

Temporal integration/ summation also occurs due to increased rate of stimulus presentation (Beattie and Rochverger, 2001). This may be due to the fact that more number of stimuli is presented over a short period of time, thus energy gets added up as a function of time.

There are differences in the process of temporal summation for continuous versus pulsed stimuli. When the duration of clicks are longer then 10ms, the analytic property of inner ear in addition to theory of temporal summation need to be considered while presenting greater than two pulses (Zwislocki et al, 1960).

Darling and Price (1989) reported that click trains presented at faster repetition rates required lower intensities for judgement of equal loudness.

Carlyon et al (1990) defined temporal integration as difference in behavioral threshold between one and ten tone pulses. They found that both number of pulses and repetition rates affect temporal integration in humans.

Yost and Klein (1979) showed that the click-evoked thresholds decrease with an increase in the number of clicks from 5 to 10 and an increase in the repetition rates from 5 to 30 clicks/s. Process of temporal integration has been studied at supra thresholds than at threshold levels (Pollack, 1958). Click trains were presented at higher intensity levels at different repetition rates, establishing the fact that faster repetition rates require lower intensities for judgement of equal loudness. Similarly, improvement is also seen in acoustic reflex threshold apparent with increase in duration of stimuli (Moller, 1962; Cacace, Margolis, and Relkin, 1991).

Acoustic reflex refers to a measurable change in acoustic impedance at the tympanic membrane that results from contraction of stapedial muscle in response to loud sounds. It is a bilateral reflex that is mediated in the brainstem (Borg, 1973). Acoustic reflex for pure tones are usually present at 80-100 dB SPL for normal (Jerger 1970; Silman, popelka and Gelfand., 1978).

Acoustic reflex threshold (ART) refers to intensity of eliciting stimulus at which a pre-specified changes occurs in the baseline admittance. The magnitude of the acoustic reflex depends upon the frequency as well as intensity of the stimulus.

Rate induced facilitation of acoustic reflex threshold refers to improvement in the acoustic reflex threshold apparent with increase in stimulus rate (Fielding & Rawool, 2002; Rawool, 1995). The rate- induced facilitation is reduced in older individuals probably due to slower processing which may lead to lack of processing of some of the stimuli at higher rates (Rawool, 1996).

Ipsilateral click-evoked acoustic reflex thresholds are known to improve by approximately 21 dB with an increase in the click repetition rates from 50/s to 300/s. When click-trains are presented over the same duration (e.g. 1.5 s), the number of clicks presented at the lower rates is less than the number of clicks presented at the higher repetition rates. Thus, there is more total energy at the higher repetition rates. Therefore, Johnsen and Terkildsen (1980) proposed that, number of clicks could be an important factor in threshold advantage at the higher repetition rates. This would predict that if the number of clicks was kept constant, the threshold advantage with the increase in the repetition rates may be reduced or absent.

1.1 Need of the study

Temporal processing in the auditory system is inefficient in infancy and matures till 12 years of age (Irwin et al (1985), Werner et al (1992), Whightman et al (1989)).

The improvement in auditory threshold with increased duration is less in individuals with hearing loss and it is more apparent at frequencies with greater hearing loss. Thus in sensorineural hearing loss, the ability to integrate acoustic energy of brief sounds is reduced. Rate induced improvement of auditory threshold is reduced in the presence of hearing loss (Carlyon et al, 1990). In sensorineural hearing loss, the temporal summation and analytic property of inner ear will be affected.

Effect of repetition rate on click evoked acoustic reflex, an objective test to evaluate temporal integration in clinical paediatric population can be included in the test battery to overcome limitations of behavioural procedures.

1.2 Aim of the study

To verify temporal integration in children with sensorineural hearing loss using click rate induced facilitation of acoustic reflex.

1.3 Objective of the study

- To check effect of click rates on Acoustic reflex threshold in normal hearing children and children with sensorineural hearing loss.
- Pair wise Comparison between different click rates.
- Comparison of improved ART from 50 clicks/sec to 300 clicks/sec across groups.

Chapter 2

Review Of Literature

The measurement of variation in mechanical input impedance were studied by stimulating auditory system using different stimulus at various intensity levels. Studies have shown that acoustic reflex activity results in an increase in magnitude and decrease in phase lag of ear's input impedance. The auditory system behaves differently for different auditory stimuli. The transient stimuli like click provide complex information like temporal integration and temporal resolution etc.

Zwislocki (1969) developed a quantitative psychophysiological theory based on psychophysical and neurological evidence for loudness level and loudness as a function of stimulus duration where he demonstrated direct relationship between loudness level and stimulus duration attributing to phenomenon of temporal integration. Improvement of threshold intensity by approximately 10dB when duration of pure tone is increased by ten times. There is improvement in threshold by 10-15 dB when the stimulus duration increased from 10 to 500ms.

According to Wright (1968) there is abnormal rapid decay in neural output of the cochlea due to cochlear hearing loss indicating lesser spike discharge by centrally located neural integrator.

Zwislocki (1960) reported that temporal integration involves change in the central integrator and is supported by psychophysical studies using power function model by Gerkan (1990).

Garner (1948) studied the rate of temporal integration in short tones. The bandwidth of energy is reciprocal of duration of the stimulus. Thus intensity of the signal to be increased when duration is reduced. The width of the band necessary for maximum integration is also related to frequency and the width of critical band.

Cacase (1990) studied the threshold and supra threshold temporal integration in crossed and uncrossed human acoustic stapedius reflex and found lower reflex threshold for uncrossed longer duration stimuli.

Gelfand (1998) reported that, acoustic reflex require greater amount of intensity change to counteract a given decrease in stimulus duration compared to psycho acoustic phenomenon.

Temporal processing in the auditory system is inefficient in infancy and continues to develop until the age of 12 years (Irwin et al., 1985; Werner et al., 1992; Whightman et al., 1989).

According to Morrongiello et al. (1987) infants and 5 year children show poor discrimination of signal and silence discrimination.

2.1 Effect of rate on temporal integration

Garner (1947) reported improvement in the auditory threshold due to increase in the rate of stimulus presentation associated with increased temporal integration at rapid rate.

Temporal integration also occurs due to increased rate of stimulus presentation (Beattie and Rochverger, 2001). This may be due to the fact that more number of stimuli is presented over a short period of time, thus energy gets added up as a function of time.

Berliner, Durlach and Braida (1997) studied the behavioural measures associated with improved auditory discrimination due to increase in repetition rate of the stimuli.

Darling and price (1989) use click trains presented at 11, 31, 51 and 91 clicks/sec and found that clicks presented at faster repetition rate required lower intensity for the judgements of equal loudness sensation.

Yost and Klein (1979) varied repetition rate from 5 to 30 clicks/sec and found that improvement in click evoked threshold when the rate is increased and also when the number of click is increased from 5 to 10 clicks.

According to Jerger, Mauldin and Lewis (1977) the slope of the acoustic reflex amplitude-intensity function becomes steeper with an increase in the duration of reflex eliciting stimulus.

A study on effect of stimulus rate on Auditory brainstem response and behavioural thresholds by Gorga et al (1984) found that behavioural threshold improves as stimulus rate is increased but Auditory brainstem response becomes less well defined when rate is increased.

Johnsen and Terkildsen (1980) proposed that an important factor contributing to the threshold advantage at the higher repetition rates could be the number of clicks. This would predict that if the number of clicks was kept constant, the threshold advantage with the increase in the repetition rates may be reduced or absent.

Veimeister and Wakefield (1991) reported that there is improvement in the threshold when the number of pulses within the stimulus is increased even though energy is kept constant across the stimulus by varying the duration suggesting temporal integration occurring for higher repetition rate.

Rawool (1995) varied the click rate from 50clicks/sec up to 300clicks/sec to find acoustic reflex threshold at each rate .i.e. 50, 100, 150, 200, 250 and 300/sec. Result obtained was improvement in the ipsilateral click Acoustic reflex threshold when repetition rate increased from 50 to 300clicks/sec.

2.2 Effect of rate on temporal integration in hearing impaired

In an unpublished dissertation, Tyagi (2001) studied the effect of repetition rate on acoustic reflex threshold with the click stimuli in subjects with mild to moderate sensorineural hearing loss with age range of 17-40 years. Results showed that an improvement of >8.3 dB in acoustic reflex when rate increased from 50 to 300clicks/sec in cochlear pathology.

2.3 Acoustic reflex threshold in children

The maturation of morphology and functional characteristics of conductive mechanism takes place from birth to puberty (Abdala & Keefe, 2012; Obake, Tanaka, Hamada, Miura & Funai, 1988). When compared to adults, both ear canal volume and static compliance are smaller in children (Abdala & Keefe, 2012; Barlow et al., 1988;

Jerger et al., 1978; Obake et al., 1988) and this would influence the measurement and interpretation of reflex thresholds when results were compared between children and adults.

Age-related differences in static compliance could also impact estimates of children's acoustic reflex thresholds. Static compliance represents an estimate of the ease with which sound energy flows through the middle ear. Static compliance values are often lower in children than in adults (Jerger et al., 1972; Obake, et al., 1979). Near threshold, the reflex causes only a small change in the compliance of the middle ear. Smaller static compliance values could possibly make it difficult to measure this very small change. At higher stimulus levels the contraction of the stapedius muscle is stronger resulting in a larger change in compliance that may be easier to measure. This measurement parameter, which may vary developmentally, could lead to a higher estimate of reflex thresholds in children.

2.4 Temporal integration in children

Temporal processing in the auditory system is known to be inefficient in infancy and may continue to develop until the age of 5–10 years (Irwin et al., 1985; Morrongiello et al., 1987; Werner et al., 1992; Wightman et al., 1989).

According to Morrongiello et al (1987), performance for discrimination of duration changes were poor in infants and children compared to adults due to common mechanism contributing to age-related changes in the processing of monaural- and binaural-temporal information.

There is a variability in the maturation of central auditory nervous system which is represented through asymmetry of responses between the ears.

An improvement in left ear scores and approaching those of adults for dichotic digit and sentence identification test with increasing age indicating myelination of corpus callosum that completes with the age.

R.W.Keith in 1986 reported an ear asymmetry on the competing word subtest of the Screening Test for Auditory Processing Disorders (SCAN) up to age 9 years.

Fielding and Rawool (2002) studied rate induced effect on acoustic reflex for click stimuli in 30 children in the age range of 6 to 10 years. Results indicated that the average improvement in reflex threshold is 10.5 dB when rate is increased from 50 to 300 clicks/sec.

The purpose of present study is to evaluate Click-Rate induced facilitation of acoustic reflex in children with sensorineural hearing loss.

Chapter 3

Method

3.1 Participants

Participants were divided in to two groups: Control group and experimental group

3.1.1 Control group: 30 typically developing children between the age range of 5 to 10 years were included in control group based on following inclusion criteria:

Inclusion criteria:

- Auditory sensitivity within 15 dB HL in the frequency range of 250 Hz and 8kHz
- Presence of acoustic reflex for 500, 1000 and 2000 Hz
- Normal tympanogram and static admittance results for 226 probe tone ranging from 0.3ml to 1.75ml.

3.1.2 Experimental group: Consisted of 30 ears age ranging from 5-10 years

Inclusion criteria

- Auditory sensitivity 26-55 dB HL in the frequency range of 250Hz and 8kHz
- Air-bone gap of less than 10 dB HL
- Presence or elevated acoustic reflex for 500, 1000 and 2000 Hz
- Normal tympanogram and static admittance results for 226 Hz probe tone ranging from 0.3ml to 1.75ml.

3.2 Instrumentation

The commercially available Grason-Stadler GSI tympstar version 2 middle ear analyzer was used to generate and control stimuli and to record the reflexes. This system uses multiplexed stimulus approach (alternate presentation of click-trains and probe tone at regular intervals) in the ipsilateral mode to minimize stimulus artifacts. Such stimulus artifacts may result from inadequate frequency separation of the reflex-eliciting stimulus and the probe tone, or from intermodulation distortion. Multiplexed stimulus approach is successful in minimizing stimulus artifacts (Lutman and Leis, 1980).

3.3 Stimulus

The total envelop for the multiplexed approach in the GSI tympstar, version 2, is 115ms; clicks will be on for 44ms and off for 53ms (the probe tone will be on during these 53ms for measuring the acoustic reflex). The total rise and fall time is 18ms. The Duration of click is 100μs with condensation polarity. Frequency range of delivered click as described in GSI 33 is 50-4000Hz.

For clicks the stimulus intensity levels are calibrated in peSPLs using procedures that are similar to those used for insert earphones. The 226Hz probe tone at 85dB sound pressure level (SPL) will be used for the study. The GSI tympstar yields data in terms of maximum change in the admittance from the baseline within the time frame of the measurement. The clicks were delivered ipsilaterally to the ear of each subject at the repetition rates of 50, 100, 150, 200, 250 and 300/s.

3.4 Test environment

Testing was conducted in an audiometric room with the noise levels within the permissible limits as specified by ANSI S3.1-1991.

3.5 Procedure

The auditory sensitivity of all the subjects were evaluated through pure tone audiometry along with immittance measurement to check for middle ear status. Acoustic reflex thresholds were obtained from the ear using fixed-duration stimuli but varying the number of clicks. The number of clicks were constant for each presentation while the duration of click trains were varied. The minimum duration possible is 1s with highest possible repetition rate of 300 clicks per second. The click train duration at other repetition rates were adjusted to yield approximately 300 clicks. Thus the click-train duration was 6sec for the 50/s rate while 2sec for the 150/s rate.

The lowest intensity value at which minimum change of 0.03-ml in admittance for at least two trials was considered as acoustic reflex threshold. The initial presentation level would be 70dB peSPL. The intensity level was decreased in 5dB steps until the reflex threshold was found. If the reflex is absent at 70dB peSPL then increase the intensity level in 5dB steps until a reflex is present. The stimulus presentation was repeated at a 5dB lower level in order to ensure absence of reflex whenever the change in amplitude of the acoustic reflex was greater than 0.03ml. Subjects were instructed not to move, swallow or talk during presentation of the stimulus.

3.6 Statistical Analyses

The responses obtained were analyzed using the IBM Statistical Package for the Social Sciences (version 21) software. Descriptive and inferential analyses were carried out. A Shapiro-Wilk test indicated that the data were not normally distributed. Hence, nonparametric statistics were used. Mann Whitney-U test was carried out to determine differences across the groups of individuals with normal hearing and individuals with mild and moderate sensorineural hearing loss and also to see gender effect within the normal group. Wilcoxon Signed rank test was done to check difference between right and left ears. Since there was no significant difference between two ears. Response of both ears were combined and then continued for further analyses. In order to compare difference in acoustic reflex threshold for different click rates from 50 to 300clicks/sec, Friedman's test was carried out. There was a significant difference for different click rates. Further Wilcoxon signed rank test was used to see pair wise significant difference. This procedure was carried out irrespective of groups and with respect to groups.

Chapter 4

Results and Discussion

The study aimed at verifying temporal integration in children with sensorineural hearing loss click rate induced facilitation of acoustic reflex. Improvement in acoustic reflex threshold were checked when click rates were increased from 50 clicks/sec to 300 clicks/sec. Total number of clicks were kept constant across each presentation.

The results of this study were examined under the following sections:

4.1 Effect of click rates on Acoustic reflex threshold in normal hearing children and children with sensorineural hearing loss.

4.2 Pair wise Comparison between different click rates.

4.3 Comparison of improved ART from 50 clicks/sec to 300 clicks/sec across groups

4.1 Effect of click rates on Acoustic reflex threshold:

The effect of different click rates on the recorded acoustic reflex thresholds was analysed for both the control and experimental group.

4.1.1 In Normal hearing children : Acoustic reflex thresholds were obtained at repetition of 50, 100, 150, 200 and 300clicks/sec for normal hearing children. Mean, Standard Deviation (SD) and median are in Table 4.1.

Table 4.1; *Mean, Standard Deviation and Median of Acoustic reflex threshold (dB peSPL) at different click rates for control group***.**

Repetition Rate (/sec)	N	Mean	SD	Median
50	28	101.43	5.587	100.00
100	30	93.83	7.154	95.00
150	30	89.67	8.503	90.00
200	30	87.67	7.958	90.00
300	30	86.00	7.589	85.00

The maximum intensity that could be presented for clicks using instrument was at 110dB peSPL. The acoustic reflex threshold for 50clicks/sec was present at or below 110 dB peSPL in 28 ears out of 30 ears.

The mean improvement in the acoustic reflex threshold was 7.60dB when repetition rate was increased from 50/sec to 100/sec (2 ears did not show any measurable ART at maximum intensity limit). When the repetition rate was increased from 100/sec to 150/sec, improvement was 4.16dB. The improvement was 2dB when rate was increased from 150/sec to 200/sec. Further increase in rate from 200/sec to 300/sec resulted in an improvement of 1.67dB. A mean improvement in the acoustic reflex threshold was 15.43 dB from repetition rate of 50/sec to 300/sec.

Since data does not follow Normal distribution (p>0.05) based on Shapiro-Wilk test, ART obtained from the subjects were subjected to Friedman's test to examine the effect of click rates on ART. Analysis showed repetition rate had significant effect on ART. Wilcoxon signed rank test was used to see pair wise significant difference among different click rates within the group.

Table 4.2; *Significance of difference between different click rates in control group.*

Repetition rate (/sec)	**/Z/**	**p**
50-100	4.818	.000*
100-150	4.017	.000*
150-200	3.464	.001*
200-300	2.887	.004*
50-300	4.738	.000*

Note: *= p<0.05

As shown in the above Table 4.2, there is a significant difference in ART when click rate was increased from 50 to 300/sec.

4.1.2 In Hearing impaired: Acoustic reflex threshold was obtained at repetition rates of 50, 100, 150, 200 and 300 clicks/sec for children with sensorineural hearing loss. Mean, Standard Deviation (SD) and median are shown in Table 4.3.

Table 4.3; *Mean, Standard Deviation and Median of Acoustic reflex threshold (dB peSPL) at different clicks rate for experimental group.*

Repetiton rate (/sec)	N	Mean	SD	Median
50	18	106.67	4.537	110.00
100	26	102.50	6.205	105.00
150	28	101.07	5.669	100.00
200	30	100.33	5.862	100.00
300	30	99.33	5.979	100.00

ART was absent in 12 out of 30 ears for click rate of 50/sec at 110dB peSPL.

Above table shows an improvement in ART of 4.17dB when repetition rate was increased from 50/sec to 100/sec. When the rate was increased from 100 clicks to 150 clicks per second, the ART improved by 1.43dB. Mean improvement in ART were o.74dB and 1 dB when the repetition was increased from 150/sec to 200/sec and 200/sec to 300/sec respectively.

An overall 7.34dB improvement in the acoustic reflex threshold was seen between repetition rate of 50clicks/sec and 300clicks/sec.Since data obtained does not follow Normal distribution ($p>0.05$) based on Shapiro-Wilk test, ART obtained from the subjects were subjected to Friedman's test to examine the effect of click rates on ART. Analysis showed repetition rate had significant effect on ART. Wilcoxon signed rank test was used to see pair wise significant difference among different click rates within the group.

Table 4.4; *Significance of difference between different click rates in experimental group.*

Repetition Rate (/sec)	**/Z/**	**p**
50-100	3.416	.000*
100-150	3.317	.001*
150-200	2.646	.008*
200-300	2.249	.014*
50-300	3.792	.000*

Note:*= $p<0.05$

An overall significant difference in the ART was seen when repetition rate increased from 50clicks/sec to 300clicks/sec ($p<0.05$). Figure 4.1 shows Mean ART for different click rates in control and experimental group.

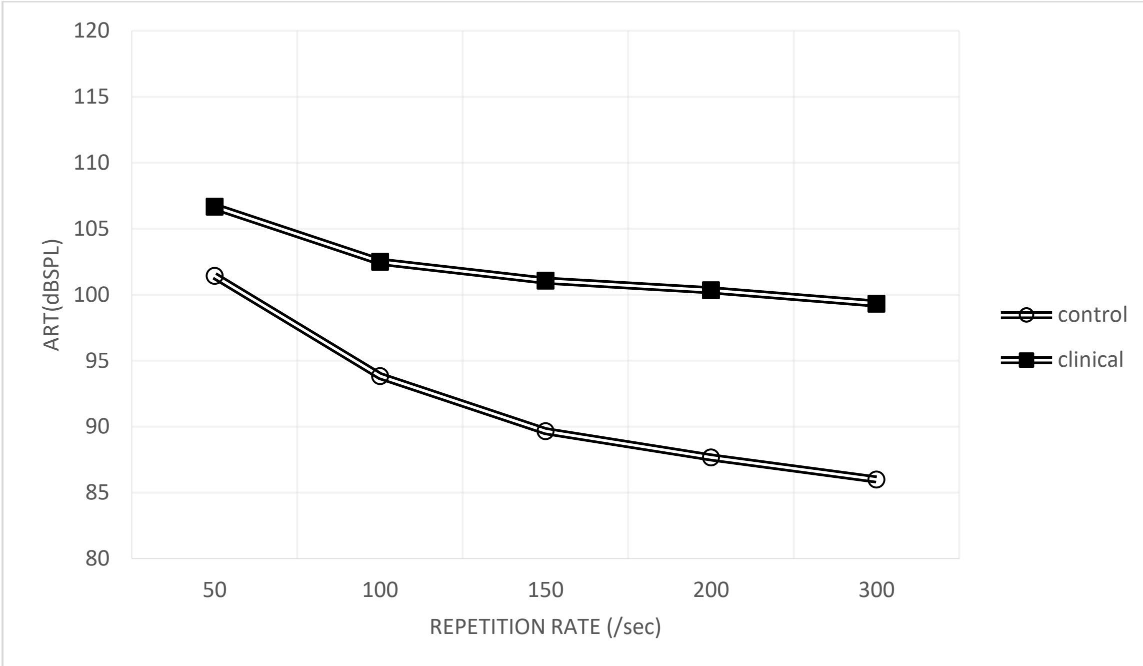

Figure 4.1. *Mean ART for different click rates in control and experimental group.*

The ART improved with increase in the Repetition rate in both control and experimental group. Also ART obtained at each repetition rate seems to be lower in control group than the experimental group attributing to better hearing sensitivity in control group.

4.2 Comparison of improvement in ART for different pairs of click rate

A total of 30 normal ears and 30 ears with sensorineural hearing loss were compared across click rates. Mean, Standard deviation and Median ART for different click rates are given in Table 4.

Table 4. 5; *Mean, Standard deviation and Median of ART across repetition rate.*

Repetition rate (/sec)	N	Mean	SD	Median
50	46	103.48	5.761	105.00
100	56	97.86	7.969	100.00
150	58	95.17	9.223	95.00
200	60	94.00	9.424	95.00
300	60	92.67	9.543	95.00

Acoustic reflex threshold were absent in 14 ears at 50/sec, 4 ears at 100/sec and 2 ears for 150/sec click rates at 110dBpeSPL.

A mean improvement in ART was 5.62 dB between click rates of 50/sec and 100/sec. When the rate was increased from 100/sec to 150/sec, improvement in ART was 2.69dB. Further increase in click rate from 150/sec to 200/sec results in improvement of ART by 1.17dB. Between 200 and 300 clicks/sec, the mean improvement of ART was 1.33dB.

Data obtained at each repetition rate were subjected Friedman's test to examine the effect of click rates on ART. Analysis showed repetition rate had significant effect on ART. Wilcoxon signed rank test was used to see pair wise significant difference among different click rates.

Table 4. 6; *Significance in difference between different pair of click rates*

Repetition rate (/sec)	/Z/	P
50-100	3.416	.000*
100-150	3.317	.001*
150-200	2.646	.008*
200-300	2.249	.014*

(Note: *= p<0.05)

Analysis shows a significant difference across all the click rate combinations (p<0.05) indicating better improvement in ART seen when rate was increased from 50/sec to 100/sec compared to other combination.

4.3 Comparison of Rate induced ART between Normal and hearing impaired subjects.

In order to compare Rate induced ART between normal and hearing impaired group, a mean difference of ART between 50/sec and 300/sec clicks rate were calculated for each group as shown in Table 4.7.

Table 4.7; *Mean, Standard Deviation and Median for difference in ART between 50/sec and 300/sec click rates.*

Group	N	Mean	SD	Median
Normal	28	16.60	4.314	15.00
HI	18	10.27	3.626	10.00

A mean improvement in ART was 16.60 dB in normal hearing subjects compared to 10.27dB improvement in hearing impaired subjects when rate was increased from 50 clicks/sec to 300 clicks/sec.

The data obtained were subjected to Mann-Whitney U test to check for significant difference between the two groups.

Table 4.8; *Significance in difference for improvement in ART between 50/sec and 300/sec in normal and hearing impaired groups.*

Repetition Rate (/sec)	**/Z/**	**P**
Diff 50-300	4.394	0.000*

Note: *= p < 0.05

Analysis shows a significant difference in the improvement of ART when click rate was increased from 50/sec to 300/sec between normal and hearing impaired subjects (p =0 .000) indicating amount of improvement was lesser in dB for hearing impaired ears compared to ears with normal hearing.

The result of this study shows an improvement in the ART when repetition rate was increased from 50 to 300clicks per second in both normal hearing children and children with sensorineural hearing loss. The improvement seen was maximum between rates of 50/sec and 100/sec.

According to Rawool (1995), the average improvement in ART was 21.6dB when click rates were increased from 50/sec to 300/sec in adults. Fielding and Rawool (2002) noted an average rate induced facilitation of 10.5dB when rate increased from 50 to 100/sec in normal hearing children. In the current study, Improvement in the ART was 7.6dB between 50/sec and 100/sec with an overall improvement of 15.43dB when click rate increased from 50 to 300/sec in normal hearing children. In children with mild to moderate sensorineural hearing loss, an overall improvement in the threshold was 7.34dB when the click rate was increased from 50 to 300/sec.

Reasons for improvement in the ART are as follows:

Johnsen and Terkildsen (1980) noted an improvement in acoustic reflex threshold at higher repetition rates indicating higher number of click rates responsible for temporal summation. Garner (1948) reported that shorter duration tone with higher repetition rate perceived louder than the longer steady tone suggesting repetition rate itself causes an improvement in the threshold. This phenomenon involves coding of each click as a separate auditory event and summation of the energy across the different clicks. Davis and McCroskey (1980) delivered pairs of pulses differing in inter pulse interval diotically over headphones and measured the ability to detect successively shorter inter pulse intervals in children between the ages of 3 and 12 years. The inter pulse intervals were varied from 0 through 40ms. There was improvement in the performance between 3 and 8 years of age and the performance was stable between 9 and 11 years of age. At high presentation levels (60dB SL), 6 year olds reported a transition between perception of simultaneous and successive events on the average at inter pulse intervals of 10ms and 10 year olds reported a transition at inter pulse intervals of 4ms similar to that seen in adults.

Temporal summation causes increase in the total acoustic energy. Increase in the repetition rate also causes increase in the acoustic energy. Energy can be kept constant by presenting constant number of clicks across repetition rates. According to Rawool (1996), there was improvement in acoustic reflex threshold with increasing repetition rate even though constant number of clicks were presented across the rates. From this it was concluded that the cause of improvement in acoustic reflex threshold was not only because of temporal summation, but some improvement was attributed to rate integration itself and was termed as Rate induced neural facilitation of acoustic reflex.

There are two types of facilitation, temporal facilitation and spatial facilitation. Temporal facilitation occurs when two stimuli are presented in close enough succession, the second stimulus begins before the refractory period of the neuron has ended following the first stimulus. The neuron is still in a state of excitation and the response to the second stimulus begins not from the baseline, but from this level of excitation. This causes the neuron to reach threshold at lower intensity levels than if it had started from baseline. As the stimuli are presented in rapid succession, the excitation from one click builds up the excitation from the previous click (Schmidt, Dudel and Zimmerman, 1975).

Spatial facilitation occurs when one neuron becomes depolarized due to stimulation from more than one neuron. Two neurons, which synapse with the single neuron, simultaneously depolarize and their additive excitation causes the neuron to reach threshold. If only one neuron had depolarized, this single neuron would not have reached threshold. In the acoustic reflex arc, spatial facilitation occurs because many superior olivary neurons synapse with each stapedial motor neuron involved in the acoustic reflex and the neurons can depolarize simultaneously (Moller, 1984). According to Rawool (1995) Depolarisation of multiple neurons is more likely to occur at higher repetition rate and also suggested that temporal and/or spatial facilitation may be responsible for improvement in the acoustic reflex threshold. At higher presentation rates, children may not be performing similar to that of adults i.e., at higher click rates, improvement in the acoustic reflex threshold may not be same in children compared to young adults. Rawool (1996) compared the reflex induced facilitation in older and younger adults by increasing click rates from 50/sec to 300/sec. The results revealed significant improvement in the ART when rate increased from 50/sec to 150/sec in both the groups. When repetition rate was increased from 100 to 300/sec, threshold improved significantly in younger group, but there was no significant difference noted in older group.

According to ‘multiple look’ model by Viemeister and Wakefield (1991), the Envelop or output of the auditory filters are sampled likely at higher rate, and these samples or looks are assessed and processed selectively for integration. Rawool (1996) suggested that aging system might not be able to sample the output at higher rates, Thus when stimuli are presented at very high rates the slower speed of sampling will allow only limited number of stimuli or ‘looks’ to be processed, so improvement in thresholds at higher rate may not be possible in older individuals. A similar phenomenon may be apparent in younger children since temporal processing in them might not be matured.

Improvement in the threshold with increase in the stimulus duration is greatly reduced in listeners with cochlear hearing loss due to rapid decay in the neural output (Wright, 1968). In an unpublished independent project, Tyagi (2008) reported lesser amount of threshold improvement in adults with sensorineural hearing loss. Improvement in ART was 8.3 dB in individuals with Sensorineural hearing loss compared to 14.2 dB in Normal hearing adults when rate was increased from 50/sec to 300/sec.

Present study shows an improvement in the ART of 7.34 dB in children with sensorineural hearing loss compared to 15.43 dB improvement in children with hearing sensitivity within normal limits. Lesser improvement in the threshold for children with sensorineural hearing impairment may be attributed to reduced temporal integration due to cochlear hearing loss along with lack of maturation of auditory system. Results also shows that improvement in the acoustic reflex threshold was maximum or greater for click rates between 50/sec to 100/sec and it decreases with increasing further from 100 to 300/sec. The major factor in the improvement of ART when rate was increased from 50/sec to 300/sec is likely to be summation at the muscular level. Since acoustic reflex relaxation time to 50% of maximum amplitude of response is between 100 to 500ms (Borg and Nilsson, 1984). The stapedius muscle is likely to be stimulated before it is fully relaxed for all the repetition rates in the study. Therefore, following the initial contraction, the next contraction is expected to start from a higher initial tension in the muscle attaining a higher maximal force than the first contraction. Thus a series of contraction leading to uniform force or ‘fused tetanus’ expected in the study even at lower rate of stimulation (50clicks/sec). With increase in the repetition rate, the summation of contractile force can also increase up to 100/sec or 125/sec where it reaches a plateau and above which there is only slight fluctuation in the contractile force with increasing the rate (Dudel, 1975, cited in Rawool, 1995). Another reason for decrease in the threshold advantage with increase in the repetition rate may be due to contractions elicited by initial clicks attenuate the succeeding stimulus levels, especially the lower frequency component in the stimuli reaching the cochlea (Borg, 1968) and this attenuation may be larger at higher repetition rate.

Chapter 6

Summary and Conclusion

Temporal integration refers to summation of the acoustic energy of the stimulus that results in the summation of neural activity over time, requiring less sound pressure to detect the auditory signal. Increasing the stimulus rate results in improvement in hearing threshold for tonal and wide band stimulus. Increasing the rate of brief stimulus involves temporal integration in similar manner to increase in the duration of the continuous stimuli. Rate induced facilitation of acoustic reflex refers to improvement in the Acoustic reflex threshold with increasing repetition of clicks per second. In order to maintain equal acoustic energy across the repetition rate, the total number of clicks presented at each rate were kept constant.

Rawool (1996) reported an improvement in the acoustic reflex threshold by 17.37 dB with increase in the repetition rate between 50 and 300/sec in normal hearing adults while 10.5 dB improvement in children in the age range of 6-10 years (Fielding and Rawool, 2002). The phenomenon of slower speed of sampling by auditory filter that limits processing of stimulus presented at higher rates may be apparent in younger children. Temporal processing in the auditory system is inefficient in infancy and matures till 12 years of age (Irwin et al (1985), Werner et al (1992), Whightman et al (1989)). Wright (1968) reported that, improvement in the threshold with increase in stimulus duration was greatly reduced in listeners with cochlear hearing loss due to rapid decay in the neural output. In an unpublished independent project, Tyagi (2008) reported lesser amount of improvement in the acoustic threshold with increase in the repetition rate of clicks.

The present study was taken with the aim of verifying temporal integration in children with sensorineural hearing loss using click rate induced facilitation of acoustic reflex i.e., checking improvement in acoustic reflex threshold when click rates are varied from 50 clicks/sec to 300 clicks/sec while presenting constant number of clicks across different repetition rates.

30 ears with normal hearing sensitivity and 30 ears with mild to moderate sensorineural hearing loss aged between 5-10 years with the presence of acoustic reflex threshold at 500Hz, 1kHz and 2kHz were included in the study. ART for different click rates (50/s, 100/s, 150/s, 200/s and 300/s) was measured using Grason-Stadler GSI tympstar version 2 middle ear analyser. The lowest intensity value at which minimum change of 0.03-ml in admittance for at least two trials was considered as acoustic reflex threshold.

Results from the present study revealed that improvement in the ART by 7.34dB in children with mild to moderate sensorineural hearing loss compared to 15.43dB in normal hearing children. Lesser improvement in hearing impaired children may be attributed to immature temporal processing as well as rapid decay in the neural output due to cochlear hearing loss.

5.1 Clinical implication

It can be used as an objective test in measuring rate integration in children with sensorineural hearing loss. RIF can overcome limitations of behavioural procedures used for studying temporal integration.

5.2 Limitations

Presence of acoustic reflex is a criteria in order to check for reflex induced facilitation**.** Children with sensorineural hearing loss can have absence of stapedial reflex irrespective of degree of hearing loss. In those children checking RIF is not possible**.**

References

Abdala, C., & Keefe, D. H. (2012). Morphological and functional ear development. In *Human Auditory Development* (pp. 19-59). Springer New York.

Beattie, R. C., & Rochverger, I. (2001). Normative behavioral thresholds for short tone-bursts. *JOURNAL-AMERICAN ACADEMY OF AUDIOLOGY*, *12*(9), 453-461.

Borg, E. (1973). On the neuronal organization of the acoustic middle ear reflex. A physiological and anatomical study. *Brain research*, *49*(1), 101-123.

Cacace, A. T., Margolis, R. H., & Relkin, E. M. (1991). Threshold and suprathreshold temporal integration effects in the crossed and uncrossed human acoustic stapedius reflex. *The Journal of the Acoustical Society of America*, *89*(3), 1255-1261.

Carlyon, R. P., Buus, S. R., & Florentine, M. (1990). Temporal integration of trains of tone pulses by normal and by cochlearly impaired listeners. *The Journal of the Acoustical Society of America*, *87*(1), 260-268.

Darling, R. M., & Price, L. L. (1989). Temporal summation of repetitive click stimuli. *Ear and hearing*, *10*(3), 173-177.

Davis, S. M., & McCroskey, R. L. (1980). Auditory fusion in children. *Child Development*, 75-80.

Fielding, E. D., & Rawool, V. W. (2002). Acoustic reflex thresholds at varying click rates in children. *International journal of pediatric otorhinolaryngology*, *63*(3), 243-252.

Fielding, E. D., & Rawool, V. W. (2002). Acoustic reflex thresholds at varying click rates in children. *International journal of pediatric otorhinolaryngology*, *63*(3), 243-252.

Garner, W. R. (1948). The loudness of repeated short tones. *The Journal of the Acoustical Society of America*, *20*(4), 513-527.

Gorga, M. P., Beauchaine, K. A., Reiland, J. K., Worthington, D. W., & Javel, E. (1984). The effects of stimulus duration on ABR and behavioral thresholds. *The Journal of the Acoustical Society of America*, *76*(2), 616-619.

Irwin, R. J., Ball, A. K., Kay, N., Stillman, J. A., & Rosser, J. (1985). The development of auditory temporal acuity in children. *Child development*, 614-620.

Jerger, J. (1970). Clinical experience with impedance audiometry. *Archives of otolaryngology*, *92*(4), 311-324.

Jerger, J., Hayes, D., Anthony, L., & Mauldin, L. (1978). Factors influencing prediction of hearing level from the acoustic reflex. *Monogr Contemp Audiol*, *1*(1).

Jerger, J., Jerger, S., & Mauldin, L. (1972). Studies in impedance audiometry: I. Normal and sensorineural ears. *Archives of Otolaryngology*, *96*(6), 513-523.

Jerger, J., Mauldin, L., & Lewis, N. (1977). Temporal summation of the acoustic reflex. *Audiology*, *16*(3), 177-200.

Johnsen, N. J., & Terkildsen, K. (1980). The normal middle ear reflex thresholds towards white noise and acoustic clicks in young adults. *Scandinavian audiology*, *9*(3), 131-135.

Keith, R. W. (1986). *Scan: A Screening Test Auditory Processing Disorders*. Psychological Corporation Harcourt Brace Jovanovich, Incorporated.

Morrongiello, B. A., & Trehub, S. E. (1987). Age-related changes in auditory temporal perception. *Journal of Experimental Child Psychology*, *44*(3), 413-426.

Pedersen, C. B., & Salomon, G. (1977). Temporal integration of acoustic energy. *Acta oto-laryngologica*, *83*(1-6), 417-423.

Pollack, I. (1958). Loudness of periodically interrupted white noise. *The Journal of the Acoustical Society of America*, *30*(3), 181-185.

Rawool, V. W. (1995). Ipsilateral acoustic reflex thresholds at varying click rates in humans. *Scandinavian audiology*, *24*(3), 199-205.

Rawool, V. W. (1996). Effect of aging on the click-rate induced facilitation of acoustic reflex thresholds. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *51*(2), B124-B131.

Schmidt, R.F., Dudel, J., & Zimmerman, S. (Eds.). Fundamentals of Neurophysiology, Springer, New York, 1975.

Silman, S., Popelka, G. R., & Gelfand, S. A. (1978). Effect of sensorineural hearing loss on acoustic stapedius reflex growth functions. *The Journal of the Acoustical Society of America*, *64*(5), 1406-1411.

Viemeister, N. F., & Wakefield, G. H. (1991). Temporal integration and multiple looks. *The Journal of the Acoustical Society of America*, *90*(2), 858-865.

Werner, L. A., Marean, G. C., Halpin, C. F., Spetner, N. B., & Gillenwater, J. M. (1992). Infant auditory temporal acuity: Gap detection. *Child development*, 260-272.

Wightman, F., Allen, P., Dolan, T., Kistler, D., & Jamieson, D. (1989). Temporal resolution in children. *Child Development*, 611-624.

Yost, W. A., & Klein, A. J. (1979). Thresholds of filtered transients. *Audiology*, *18*(1), 17-23.

Zwislocki, J. (1960). Theory of temporal auditory summation. *The Journal of the Acoustical Society of America*, *32*(8), 1046-1060.

Zwislocki, J. J. (1969). Temporal summation of loudness: An analysis. *The Journal of the Acoustical Society of America*, *46*(2B), 431-441.