EFFECT OF CLICK RATE AND INTENSITY LEVEL ON ACOUSTIC REFLEX THRESHOLDS AND GROWTH FUNCTIONS IN NORMALS AND SUBJECTS WITH SENSORINEURAL HEARING LOSS

Reg. No. M2K12

An Independent project submitted in part fulfillment for the first year M.Sc (Speech & Hearing) to University of Mysore

ALL INDIA INSTITUTE OF SPEECH & HEARING

MYSORE - 570 006.

MAY - 2001.

... My Parents,

Brother

&

Nishi ...

CERTIFICATE

This is to certify that this independent project entitled **"EFFECT OF CLICK RATE AND INTENSITY LEVEL ON ACOUSTIC REFLEX THRESHOLDS AND GROWTH FUNCTIONS IN NORMALS AND SUBJECTS WITH SENSORINEURAL HEARING LOSS"** is a bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student (Register No. M2K12).

DIRECTOR
All India Institute of
Speech and Hearing.
Mysore - 570 006.

Mysore,
May, 2001

CERTIFICATE

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Guide

Animesh Barman
Lecturer in Audiology,
Department of Audiology,
All India Institute of Speech & Hearing.
Mysore - 570 006.

Mysore,
May, 2001

DECLARATION

This Independent project entitled **"EFFECT OF CLICK RATE AND INTENSITY LEVEL ON ACOUSTIC REFLEX THRESHOLDS AND GROWTH FUNCTIONS IN NORMALS AND SUBJECTS WITH SENSORINEURAL HEARING LOSS"** is the result of my own study under the guidance of **Mr. Animesh Barman,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and not been submitted earlier in any other University for the award of any diploma or degree.

Mysore,
May, 2001 Reg. No. M2K12

Acknowledgements

I extend my deepest gratitude, reverence and heartfelt thanks to ***Animesh*** sir for the excellent guidance and constant help throughout the project.

I am grateful to ***Dr.*** *M.* ***Jayaram,*** Director, All India Institute of Speech and Hearing, Mysore for permitting me to carry out this study.

To ***Rajalakshmi*** ma'am - thank you ma'am, firstly for the enlightening and interesting discussions in class, and for helping me over some speedbreakers in my independent project.

Mummy and ***Papa,*** to you I humbly owe what is today. No amount of eloquence would suffice to express say of my pride and joy in being of you. To the very and of my life and my existences I love you.... Thanks for you confidence in me. I hope I can live upto your expectations.

Dadaji, Chachaji and ***Mamaji,*** your blessings are always a source of strength and inspiration to me.

Sonu, its great to have naughty brother like you; my life is always Sunny when I am with you.

Monu and ***Kuldeep,*** here's to all the wonderful times we have had together.

Dear ***Chandan*** and ***Krithika,*** thanks for making AIISH a home away from home for me, for patiently listening to all my troubles, complaints and for sharing my happiness.

Sharad, we've shared some very special moments of hope, achievements and sentiments. Thanks for a Marathon friendship.

Vathsan and ***Siva:*** Across all these miles, you guys are always thought of with foundness; this is in memory of our good times together......

Aditi, Mukunthan, Siddhartha* and *Kavita - We've had very pleasant times together. So for all the J's, PJ's, and the treasure of memories, thank you all.

Chaya, thanks for being such a wonderful daughter and making me feel little more responsible.

To ***all*** *my classmates,* we are a lethal combination of people - the exact mixture of sugar and spice in life.

I would like to thank ***Dr. Venkatesan* and *Dr. Lancy D'Souza*** for helping me out with my statistical analysis.

Thanks to ***all seniors*** and ***juniors*** for all the fun and experiences we've shared in AIISH.

I thank all my subjects for all their cooperation and patience during the testing.

Graphics, thanks for your neat computer processing of this work.

Lastly, I thank ***God*** for all his blessings.

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INTRODUCTION

Human Ears are exposed to a wide range of environmental sounds of different levels. Few of such intense sounds can cause damage to the ear. In such a case, Middle ear performs a protective function by changing the acoustic impedance at the tympanic membrane. This measurable change, in response to loud sounds, in the acoustic impedance at the tympanic membrane result from a contraction of the stapedius muscles. This is known as Acoustic Reflex (AR). It is a bilateral reflex that is mediated in the brainstem (Borg, 1973, cited in Rawool, 1995). The change in the admittance or impedance in the quiescent versus reflexive states is a magnitude measurement of the acoustic reflex. Reflexive activity is seen in normals at about 80-100 dBSPL for pure tones (Jerger, 1970; Silman, Popelka and Gelfand., 1978).

Acoustic Reflex Threshold (ART) refers to intensity of the eliciting stimulus at which a pre-specified change occurs in the baseline admittance. The magnitude of AR depends upon the frequency as well as the intensity of the stimulus.

The increase in the intensity of the stimulus level causes an increase in reflex magnitude. This relationship between stimulus level and the resulting reflex magnitude is called the Acoustic Reflex Growth Function (ARGF). The ARGF has been studied in response to pure tones and wide-band and narrow-band noise and click activating signals (Silman et al., 1978; Wilson and McBride, 1978; Rawool, 1997).

The duration of acoustic stimulus also plays an important role in the ARGF. As the duration of an activating acoustic stimulus is increased up to a critical duration (e.g. 20 msec to 200 msec), intensity level required to perceive the stimulus decreases. This phenomenon refers to as Temporal Integration or Summation. This phenomenon indicates that the power of the auditory stimulus and the resulting neural activity is added overtime in the auditory system. Thus, less power is required for detection of the stimulus when the duration of the stimulus is increased.

The effect of intensity-duration reciprocity phenomenon can be determined in several ways. Most investigators have examined the influence of time by changing the duration of a single stimulus. An alternative of controlling the time factor and studying this time-intensity trade off is presentation of trains of auditory stimuli at varying repetition rates. The phenomenon of temporal integration occurs for trains of repetitive auditory stimuli at threshold as well as suprathreshold stimulation levels. The process of temporal integration for repetitive stimuli has less been extensively studied at higher levels of stimulation than at threshold levels (Garner, 1948 and Pollock, 1958, cited in Rawool, 1995). Temporal integration at higher stimulus levels can also be studied using AR measures. Most of the studies incorporating AR measures have used frequency specific stimuli or broadband noises of varying duration to study this phenomenon.

The selection of click stimuli is favoured in many ways. The clicks have been used extensively in investigations related to electrophysiological studies of auditory system. In addition, Auditory

Brainstem Response (ABR) done at various click repetition rates is being used for the detection of neural pathologies. However, the effect of clicks at various repetition rates on the ART has received limited attention. Johnson and Terkildsen (1980) proposed that click generated contralateral reflexes elicit better-defined thresholds than white noise stimuli. Darling and Price (1989) established that clicks at faster repetition rate require lower intensities for judgements of equal loudness sensation. Similarly, Rawool (1995) reported that thresholds improved significantly with increase in the repetition rate. Rawool (1997) studied the ARGF for clicks (wide-band) stimuli as a function of click repetition rate in normals. Silman et al., (1978) studied the ARGF in individuals with sensorineural hearing loss using tonal signal and broadband noise. To our knowledge no study has been done on individuals with sensorineural pathology using clicks stimuli.

Hence this study was designed to investigate:

i. Effect of click repetition rates on ART in normal hearing subjects and individuals with sensorineural hearing loss,
ii. ARGF for different click rates and intensity levels for normal hearing subjects and individuals with sensorineural hearing loss,
iii. To find significant differences among the two groups, if any.

REVIEW OF LITERATURE

The use of acoustic reflex measures to understand the auditory behavior in humans has been realized years ago. Various activating stimuli have been used to investigate the response of auditory system. Studies have shown that auditory system behaves in a very complex fashion to the different auditory stimuli. In such a context, transient stimuli like clicks provide valuable information about the different aspects of audition like temporal summation, gap detection etc.

Several psychophysical studies have demonstrated a reciprocal relationship between stimulus intensity and the duration required for auditory perception (Zwislocki, 1969). This duration-intensity relation is generally attributed to the phenomenon of temporal Integration or summation. Theoretically, the extent of this time dependant phenomenon in the ear is such that a tenfold change in pure tone duration causes a threshold- intensity change of approx.. 10 dB. However, this perfect integration is rare, especially for broadband stimuli, when stimuli is of brief (i.e. less than 20 ms) and long (i.e. greater than 100 ms) durations, and for stimuli presented at suprathreshold levels (Darling and Price, 1989). Normal hearing listeners typically show a 10-15 dB improvement in threshold as stimulus duration increases from 10 to 500 ms, however this improvement in threshold with increasing stimulus duration is greatly reduced in listener with cochlear hearing loss (Wright, 1968; Solecki and Gerken, 1990). Wright (1968) suggested that cochlear hearing loss cause an abnormal rapid decay in neural output of the cochlea. According to this model, the centrally located neural integrator will have fewer spike discharges to summate overtime. Thus, there will be less improvement in threshold with increasing stimulus duration. An alternative explanation for the reduction in temporal integration with cochlear hearing loss involves a change in the "central integrator" (Zwislocki, 1960) and is also supported by psychophysical studies involving electrical stimulation of the Cochlear Nucleus (CN) and Inferior Colliculus (IC) (Gerken, Solecki and Boettcher, 1991).

In normal hearing animals, the behavioral thresholds for detecting electrical stimuli delivered to the CN or IC show a temporal Integration-like effect in which threshold improve with increasing stimulus duration (Henderson, Richard, Flint and Clock, 1994).

Researches, have shown that temporal integration in apparent in behavioral response to repetitive trains of interrupted tones, interrupted noise, transients and filtered transient stimuli (Garner, 1947, cited in Rawool, 1995; Plomp, 1961; Zwislocki, Hellman and Verrillo, 1962).

Temporal integration also occurs for the acoustic reflex (Woodford, Henderson, Hameraick and Feldman, 1975; Gelfand, Silman and Silverman, 1981). However, it appears that the amount of intensity change needed to counteract a given decrease in stimulus duration is greater for the AR than for pschoacoustic phenomenon (Gelfand, 1998).

1. **Effect of rate on temporal integration:**

An increase in the rate of stimulus presentation also causes an improvement in the auditory thresholds (Garner, 1947, cited in Rawool, 1995). This is associated with increased temporal integration at more rapid rate. Berliner, Durlach and Braida (1997) showed that an increase in the repetition rate of the stimulus is associated with improved intensity discrimination in behavioral measures. The AR amplitude grows more rapidly for stimuli with longer durations, demonstrating improved intensity coding. Thus, the slopes of the acoustic reflex amplitude-intensity functions become steeper with an increase in the duration of the reflex eliciting stimulus (Jerger, Mauldin and Lewis, 1977). Darling and Price (1989) used click trains presented at relatively high intensity levels and at the repetition rates of 11, 31, 51, and 91 clicks/sec. They established that clicks at faster repetition rates require lower intensity for judgements of equal loudness sensation. The ability to perceive small changes in intensity is known to improve with an increase in the stimulus duration (Berliner et al., 1977; Viemeister, 1988, cited in Rawool, 1997). Gorga, Beauchaine, Reiland, Worthington and Javel (1984) studied the effect of stimulus rate on ABR and behavioral thresholds. They noted that behavioral thresholds was more in normal hearing subjects than hearing impaired subjects when the duration of stimulus was increased. But the effect of stimulus rate is different on ABR and behavioral threshold. Behavioral threshold decreases as stimulus rate increases (Gamer, 1947; Zerlin and Naunton, 1975) whereas ABR tends to be less well defined as stimulus rate increases.

Rawool (1995) used the clicks at the repetition rates of 50, 100, 150, 200, 250 and 300/sec and found out the ipsilateral ART at these rates. Results indicated that ipsilateral click-evoked ART improve with an increase in the click repetition rate.

2. Effect of level on amount of temporal integration:

The amount of temporal integration clearly varies with stimulus level and is largest at moderate SL in all normals and in most of the impaired listeners (Buus, Florentine and Poulsen, 1999). The effect of level on the amount of temporal integration varies considerably among normal listeners and varies even more among impaired listeners. They also found that the amount of temporal integration for loudness near threshold generally approach that for detection and tends to be smaller in impaired listeners than in normal listener. The amount of temporal integration for loudness at high SPLs is usually the same or even slightly lower in impaired listeners than in normal listeners tested at the same SPLs. When evaluated at equal SLs, the impaired listeners tend to show normal or less than normal amounts of temporal integration. Silman et al. (1978) studied the ARGF in normal and sensorineural hearing loss individuals using 500Hz, 1000Hz and 2000Hz tones and broadband noise. Results showed that ARGF for broadband noise was curvilinear at high stimulus levels in normals and was flat for sensorineural hearing loss subjects, approximating the normal amplitude at high stimulus levels. Wilson and McBride (1978) studied the threshold and growth of acoustic reflex using pure tones and broadband noise. Their results suggested that thresholds for broadband noise are >20 dB better than those for pure tones. They also reported that broadband noise and

100 Hz stimuli produce the largest reflex magnitudes. The magnitude of AR increases with stimulus intensity to the levels of 116 dBSPL. The slope characteristics of pure tones are steeper than those for Broadband noise and it also showed that the higher the stimulus frequency, the lower the sound pressure level (SPL) at which saturation of growth function occurs. Rawool (1997) studied the ARGF using clicks. She reported that amplitude of reflex grows with increasing repetition rate from 50/sec to 300/sec. The slopes of the ARGF between 0 dBSL and 10 dBSL increased significantly with increase in the repetition rate from 50 to 100 clicks / sec and 100 to 150 clicks/sec.

3. Gap detection and temporal integration:

Gap detection provides lucid appreciation of temporal resolution. Temporal resolution refers to the shortest period of time over which the ear can discriminate two signals. In order to find out the shortest detectable gap between signals, a short gap is introduced in the center of the continuos signal and subject is asked whether he hears the gap. Hence the shortest detectable duration of the gap is called the Gap Detection Threshold (GDT). In normals GDT has been found to vary from 2-5 ms (e.g. Fitzgibbons, 1983; Forest and Green, 1987). Listeners with sensorineural hearing loss have been found to have difficulty detecting a gap in a continuos noise (Boothroyd, 1973, cited in Gelfand, 1998). Fitzgibbons and Wightman (1982) found minimum detectable gap values of 8.0 and 5.1 ms for impaired listeners and normal listeners respectively. Florentine and Buus (1984) found minimum detectable gap for levels between 80 and 90 dBSPL to be 6.3 ms for impaired listeners and about 3.3 ms for normal listeners. Hence, it can be said that enlarged GDT of impaired listeners can be a result of reduced temporal resolution.

After a glance into the review, it can be concluded that there is a difference in the way that the auditory system behaves for the normal and sensorineural hearing loss population with regard to click rate and gap between the clicks and the duration of the stimulus. Hence this study has been taken up in an attempt to observe effect of these parameters on the AR in normal hearing individuals and individuals with sensorineural hearing loss (essentially cochlear pathology).

METHODOLOGY

The aim of the present study was to compare the effect of click repetition rates on Acoustic Reflex Threshold (ART) and also the Acoustic Reflex Growth Function (ARGF) in subjects with normal hearing and individuals with sensorineural hearing loss.

Subjects: The subjects were divided into two groups:

1. Control group:

This consisted of 30 ears of both males and females age ranged from 17-40 years.

Subjects were selected based on the following criteria:

a. Pure tone thresholds less than or equal to 15 dBHL (Clark, 1981,cited in Yantis, 1994) at the octave-interval test frequencies between .25 to 8 kHz.
b. Normal tympanogram and static admittance (Jerger, 1970) in the test ear.
c. Stapedial Reflexes at 500, 1000 and 2000 Hz present in the test ear at Sensation Levels (SLs) classified as normal by Jerger (1970).
d. Negative Reflex Decay (Anderson, Barr and Wedenberg, 1969, cited in Wiley and Fowler, 1997) at 500 and 1000 Hz.
e. Negative otological and neurological history.

2. Experimental group:

This consisted of 21 ears of both males and females age ranged from 17-40 years.

Selection Criteria:

a. Mild to moderate sensorineural hearing loss at the octave - interval frequencies between .25 to 8 kHz.
b. Stapedial reflexes at 500, 1000 and 2000 Hz present or elevated in test ear.
c. Normal tympanogram and static admittance (Jerger, 1970) in the test ear.
d. Subjects with negative Reflex Decay (Anderson et al., 1969, cited in Wiley and Fowler, 1997) at 500 and 1000 Hz in test ear.

Equipment used:

The following instruments were used:

1. GSI-61 clinical audiometer (calibrated as per ANSI S3.6-1969) with standard accessories as specified by manufacturer was used to establish pure tone thresholds.
2. GSI-33 Version 2 Middle Ear Analyzer (calibrated as per ANSI S3.39 - 1987) was used for generating and control of acoustic stimuli and for recording reflexes. This system uses a multiplexed stimulus approach in the ipsilateral mode to minimize stimulus artifacts. Such stimulus artifacts may result from inadequate frequency separation of the reflex eliciting stimulus and probe tone, or from inter-modulation distortion (Green and Margolis, 1984, cited in Rawool, 1995). The polarity of the clicks is condensation and the duration is 100 ms. The frequency range of the ipsilaterally delivered clicks as described in the GSI 33 manual is 50 to 4000 Hz. The uniformity across the frequency spectrum is better than 10 dB.

Test Environment:

All the testing were conducted in an audiometric room with the noise level within the permissible limits as specified by ANSI S3.1-1977.

Procedure:

All the subjects were given standard instructions for the pure tone audiometry and were also instructed not to move their head, jaw, swallow or to talk during immittance measurements as it may alter the results. Reflex Decay Test (RDT) was carried out for all the subjects at the frequencies specified earlier, to rule out any retrocochlear pathology. Subjects who met the above mentioned criteria were selected for the study.

Measurements of ART and amplitude growth were carried out in 2 different steps for both the groups. Each measurement of AR was made over a period of 1.5 sec, baseline data were obtained 1.5 sec before the initiation of measurement and 1.5 sec following the end of the measurement.

1. The test was initiated with the establishment of ART ipsilaterally at different click rates of 50, 100, 150, 200, 250 and 300/sec in step - size of 2 dB. For the different subjects measurements of ART was initiated at different rates and levels to avoid the 'order effect', if any. Criteria for acoustic reflex threshold were a minimum of 0.03 ml change in admittance on at least two of three trials. If amplitude of acoustic reflex was greater than 0.03 ml, stimulus was lowered by 2 dB and presented to ensure absence of the reflex. Probe frequency of 226 Hz was kept constant throughout the test procedure.

2. Acoustic reflex amplitude was measured, for a particular click rate, at ART and also at various SLs in steps of 4 dB upto 110 dB peSPL, which is the upper intensity limit of the instrument. Likewise measurements were carried out at different click rates of 50, 100, 150, 200, 250 and 300/sec in normal cases and individuals with essentially cochlear hearing loss.

Analysis:

The 3-way ANOVA was planned to examine:

1. The effect of click repetition rate on ART.
2. Effect of click repetition rate and stimulus level on growth of acoustic reflex.
3. To find out significant difference among the two groups, if any.

RESULTS

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

a. Effect of click rate on ART in normals and individuals with sensorineural hearing loss.
b. Growth of Acoustic Reflex Amplitude as a function of different SLs in normals and individuals with sensorineural hearing loss.

a. Effect of click rate on ART

l.In normals subjects:

ART at click rates of 50, 100, 150, 200, 250 and 300/sec were obtained. Mean, Standard Deviation (SD) and Range are shown in Table. I.

Table. I. Means of acoustic reflex thresholds (dBpeSPL), standard deviation & range at different click rates for control group.

	Repetition Rate (Clicks /sec)					
	50	100	150	200	250	300
Mean	100.5 (16)*	99.4 (28)	94.6 (31)	92.8 (31)	91.4 (31)	90.9 (31)
SD	7.92	7.76	7.37	8.0	7.89	8.77
Range	>110-82	>110-86	74-104	72-104	70-102	70-100

* Number of subjects for whom ART was obtained

At the rate of 50 clicks/sec, out of 31 ears only 16 ears had measurable ART below 110 dBpeSPL, which is the upper intensity limit of the instrument. The mean improvement in the ART when repetition rate was increased from 50/sec to 100/sec was greater than >1.1 dB (15 ears did not show any measurable ART at maximum intensity limit). However, if 110 dBpeSPL is considered as ART for those subjects who did not show any ART either for 50 clicks/sec or 100 clicks/sec at maximum intensity limit and calculate the mean for 31 ears, the improvement in ART was >4.7 dB when rate was increased from 50/sec to 100/sec (>105.1 dB at 50/sec and >100.4 dB at 100 /sec). When the rate was increased from 100/sec to 150/sec, this improvement was >5.8 dB (>100.4 dB at 100/sec and 94.6 dB at 150/sec). The improvement was 3.2 dB when rate was increased from 150/sec to 250/sec. Further increase of rate from 250/sec to 300/sec resulted in an improvement of only 0.5 dB. The mean ART improvement was >14.2 dB from repetition rate of 50/sec to 300/sec.

It can also be noted that range of ART differ at each click rate. It is largest at 50 clicks/sec and gradually becomes shorter as the click rate increases, being shortest at the repetition rate of 300/sec. ARTs obtained from the subjects were subjected to one-way ANOVA to examine the effect of rate on ART. Analysis showed that the rate had significant effect on ART even at 0.000 level. Duncan's Post-hoc test was used to see the significant difference among the different click rates. Test results showed a significant difference ($p = 0.000$) between 100 clicks/sec and 150 clicks/sec.

2. In individuals with sensorineural hearing loss (essentially cochlear pathology).

ART were obtained at click rates of 50, 100, 150, 200, 250 and 300/sec from individuals with sensorineural hearing loss. Mean, Standard Deviation (SD) and Range are shown in Table. II.

Table. II. Means of acoustic reflex thresholds (dBpeSPL), standard deviation & range at different click rates for experimental group.

	Repetition Rate (Clicks /sec)					
	50	100	150	200	250	300
Mean	98.8 (13)*	102.1 (20)	99.8 (22)	97.2 (22)	96.1 (22)	95 (22)
SD	26.71	6.76	7.11	7.45	8.18	7.8
Range	>110-96	>110-86	110-84	108-82	106-78	104-76

* Number of subjects for whom ART was obtained.

In 9 ears, no thresholds were apparent for 50/sec rate at 110 dBpeSPL. Above Table shows an increase in ARTs by <3.3 dB when rate was increased from 50/sec to 100/sec. This deterioration in thresholds from 50/sec to 100/sec can be attributed to less number of ears showing ART at 50 clicks/sec. However, if 110 dBpeSPL is considered as ART for the subjects who did not show any ART at maximum intensity limit for click rates of either 50/sec or 100/sec and calculate mean ART for 22 ears, then the improvement in ART was >0.5 dB on increasing the click rate from 50/sec to 100/sec (>102.8 dB at 50/sec and >103.3 dB at 100/sec). The mean improvement in ART when the repetition rate was increased from 100 to 150/sec was >3 dB

(>103.3 dB at 100/sec and 99.8 dB at 150/sec). When the rate was increased form 150/sec to 250/sec, this improvement seen in ART was about 3.7 dB. An overall >8.3 dB improvement in ART was seen between 50 and 300 clicks/sec.

The upper and lower limits of the ranges are different at various click rates but the range is almost same at all the click rates. ARTs at different click rates were subjected to one-way ANOVA. Analysis showed statistically non-significant rate effect ($p = 0.337$) between various click rates.

The 2-way ANOVA was performed to see any difference between the two groups. Analysis indicated a significant difference ($p = 0.005$) between the groups. Fig.l shows mean ART for the clicks at different rates for both the groups.

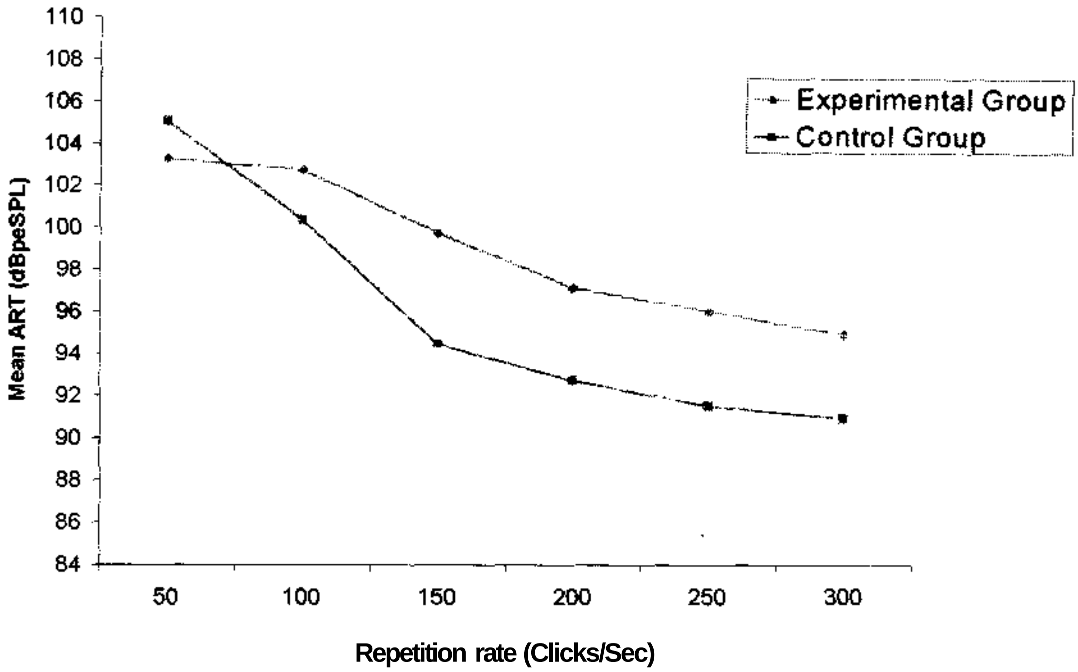

Figure. 1. Mean ART for the clicks for the control and experimental groups

It can be clearly seen from the above Fig. that the ART improved with the increase in click rates in control group and experimental group. Also ART obtained at different rates seems to be lower in control group than the experimental group as the hearing sensitivity is better in control group.

b. Growth of Acoustic reflex amplitude as a function of different intensity levels at varying click rates.

1. In control group:

The means of acoustic reflex amplitude at the various repetition rates and intensity levels are displayed in Fig. 2.

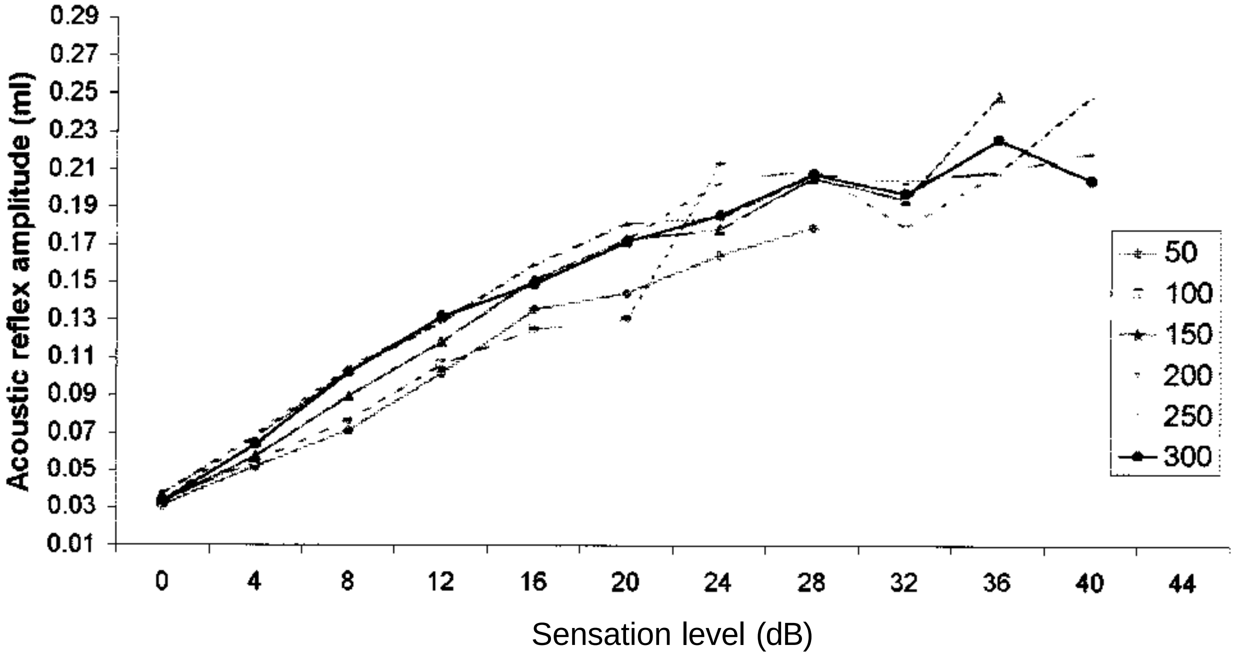

Figure. 2. Mean acoustic reflex amplitudes (ml) in the control group

The ANOVA revealed a significant rate effect (P = 0.030), a significant level effect (P = 0.000) but rate* level interaction was not significant (P = 0.999). Comparisons between various click rates and between various intensity levels were planned with Duncan's post-hoc test. The test showed a significant increase in amplitude from 0 dBSL to 12 dBSL and beyond which amplitude growth was not statistically significant.indicating proximity towards saturation. Test also showed that amplitude growth was significant only from 100/sec to 200/sec which can be seen in the Fig. 2.

2. In individuals with sensorineural hearing loss

Means of AR amplitude at various intensity level and click rates are displayed in Fig. 3.

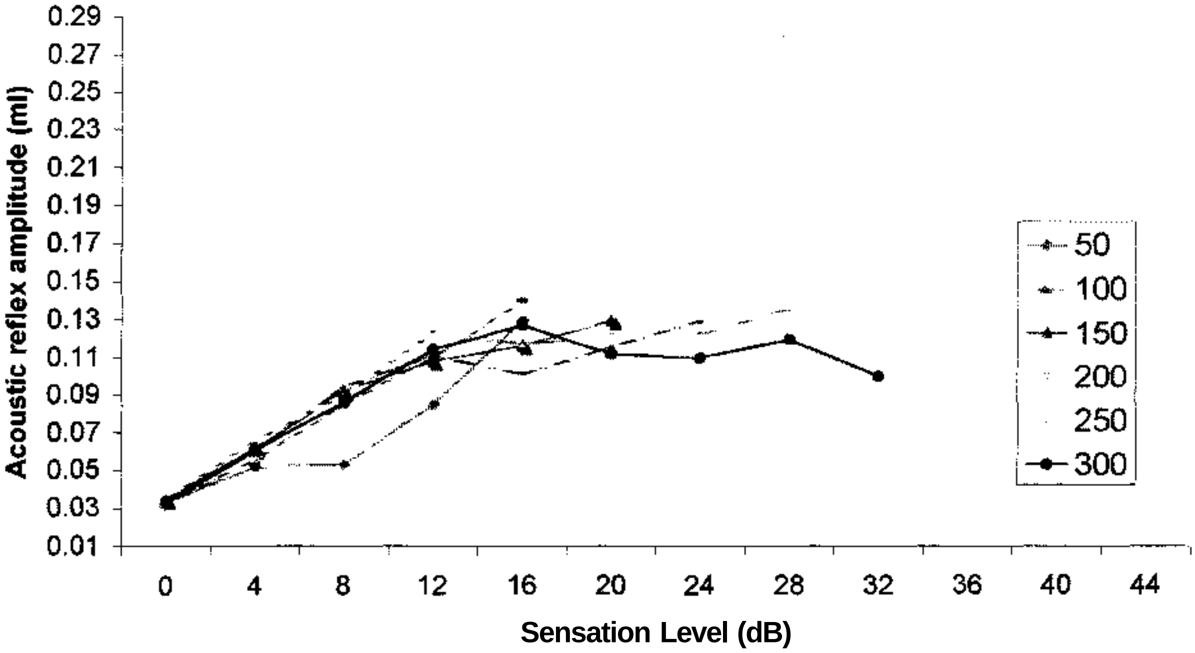

Figure. 3. Mean acoustic reflex amplitude (ml) in the experimental group

The ANOVA showed a significant rate and level effect (p = 0.000) but rate * level interaction (p = 0.103) was not significant. Duncan's post-hoc test was planned to make comparison between various click rates and between various intensity levels. Test results showed that amplitude growth was most significant from 0 dBSL to 8 dBSL, indicating proximity towards saturation. It also showed that amplitude growth was most significant at rates from 50/sec to 100/sec.

The 3-way ANOVA was used to examine the difference between the groups as a function of intensity level and click rate. Results showed a significant rate effect ($P = 0.023$) and a significant intensity effect ($P=0.000$) on the growth of acoustic reflex between the groups.

DISCUSSION

A. Effect of Repetition rate on ART:

The results of this study show that an increase in the click repetition rate upto 300/sec can lead to improvement in the ipsilateral ART. The most prominent improvement in mean threshold was seen between 100/sec and 150/sec for both the groups.

Rawool (1995) noted an average improvement of 21.6 dB when the repetition rate was increased from 50 to 300/sec. In the current study, in case of normal hearing individuals, as improvement of > 14.2 dB was apparent with an increase in the repetition rate from 50 /sec to 300/sec

Whereas in case of individuals with essentially cochlear pathology overall improvement of >8.3 dB was seen when repetition rate was increased form 50 /sec to 300 /sec. This improvement can be due to following reason.

Rawool (1995) used criterion of greater than 0.02 ml change in baseline admittance for the reflex to be present, where as in the present study, reflex was considered to be present when there was a change of greater than 0.03 ml in baseline admittance.

When the stimuli are presented over same duration (e.g. 1.5sec) then at the lower rates the number of clicks presented is less than the number of clicks presented at the higher repetition rate. Thus, there is more total energy for the higher repetition rate. Johnson and

Terkildersen (1980) proposed that the threshold improvement for higher repetition rates could be related to number of clicks rather than the repetition rate. However, Garner (1948), cited in Rawool (1995) reported that if two tones are 'on' the same total fraction of time, with the same intensity, but have different durations and repetition rates, the tones that have the higher repetition rates and shorter durations are perceived to be louder.

i. Gap detection of stimuli with less than 0.5 ms duration can be as low as 0.5 ms (Abel, 1972). The gaps or interstimulies intervals in the present investigation were at least 3 ms for the highest repetition rate (300 /sec). Thus, theoretically, each click presented in the duration of 1.5 sec can be considered discrete acoustic stimulus separated from adjacent clicks by a 'silent' interval with the perception of internal noise. Since the energy in each click is the same, irrespective of the repetition rate, it is likely that ART may be better for clicks presented at higher, repetition rates irrespective of the total effective duration of the stimulus. It is also possible that both numbers of stimuli and repetition rates may have interacted in yielding the threshold advantage apparent in the current study. More number of studies are required to resolve this issue (Rawool, 1995).

Another possibility which arise due to the ability of gap detection is that improved ARTs at higher rates which is seen in case of normal hearing individuals, may not be due to temporal integration because GDT for normal hearing individuals ranges from 2-5 ms (Florentine and Buus, 1984; Fitzgibbons and Wightman, 1982). The interstimulus interval in the present study is about 3ms at highest rate i.e. 300/sec (Rawool, 1995). Therefore the normal hearing individuals can perceive the clicks as discrete even at all the rates (as the rate decreases the interstimulus time increases). On the other hand, GDT for individuals with essentially cochlear hearing loss has been reported to be about 7-8 ms (Florentine and Buus, 1985; Fitzgibbons and Wightman, 1984). Hence, these individuals can perceive the clicks as discrete only upto about 150clicks/sec to 200clicks/sec. Beyond this rate the clicks would be perceived as continuous hence increasing the duration of the stimulus and in such a condition temporal integration may play a role. So it can be suggested that threshold improvement in normal hearing subjects with higher click rate is not a result of temporal integration. Whereas in hearing impaired group temporal integration may be evident at higher click rates as tenfold increase in stimulus duration cause 10 dB improvement in hearing threshold (Darling and Price, 1989). However, this improvement in threshold with increasing stimulus duration is greatly reduced in listeners with cochlear hearing loss due to rapid decay in neural output (Wright, 1968). Hence, a lesser amount of threshold improvement is seen in the experimental group may be a result of this process.

The physiological factors underlying the threshold advantage with stimuli of higher repetition rates are probably facilitation and summation. Various facilitation processes as evidenced by an increase in the synchronous release of ACh quanta have been demonstrated following repetitive stimulation of nerve fibers (Reviewed in Silinsky, 1985, cited in Rawool, 1995). Temporal summation is possible within the acoustic reflex arc due to successive stimulation of the same neurons. Spatial summation of two different presynaptic neurous is possible because many superior olivary neurons may impinge on each facial motorneuron that is involved in the acoustic reflex (Mollar, 1984, cited in Rawool, 1995).

We have also seen that improvement in the acoustic reflex threshold with increase in the repetition rates is maximum between 50/sec and 150/sec but this threshold advantage decreases with further increase in repetition rate. This can be because since the acoustic reflex relax time to 50% of maximum amplitude of response is between 100 and 500 ms (Borg and Nilsson, 1984, cited in Rawool, 1995). For all repetition rates in the study, the stapedius muscle is likely to be stimulated before it is fully relaxed. 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 contractions leading to a uniform force or 'fused tetanus' is expected in the current study even at the lowest rate (50/sec) of stimulation. The summation of contractile forces can increase with an increase in the repetition rate. However, after a certain number of stimuli (100 to 125/sec), the increase in the contractile force with the increase in the stimulus rate is expected to reach a plateau when the contractile force is likely to fluctuate only slightly (Dudel, 1975, cited in Rawool, 1995).

Another reason for the decrease in the threshold advantage with the increase in the repetition rate may be that contractions elicited by the initial clicks attenuate succeeding stimulus levels, especially the lower frequency components in the stimuli reaching the cochlea (Borg, 1968) and this stimulus attenuation may be greater at the higher repetition rates.

From the results of this study, it is apparent that the pattern of improvement in ART with increasing click rate in sensorineural hearing loss group is similar to that observed in case of normal hearing individuals but the rate of improvement in ART and overall improvement are less compare to normal hearing group. This can be attributed to the reduced temporal integration in individuals with sensorineural hearing loss (Gengel and Watson, 1971; Hall and Fernandes, 1983; Carlyon, Buus, and Florentine, 1990). There is a trend for higher absolute thresholds to be associated with more reduced temporal integration.

B. Growth of Acoustic reflex amplitude as a function of different intensity levels at varying click rates:

1. *In normal:*

There is significant improvement in acoustic reflex amplitude when click rate was increased from 100/sec to 200/sec which indicate better coding of intensity at higher click rates within the acoustic reflex pathway (Rawool, 1997). Based on a study on the ARGF, Silman et al. (1978) concluded that the rate of response growth for noise stimulus in the normal hearing group increases gradually until 94 dBSPL. Hence the growth curve of reflex amplitude in normal subjects is curvilinear at higher level, which suggest a reduced reflex growth at higher level. Based on this the asymptote seen at about 28 dBSL can be due to saturation of the afferent neurons within the AR pathway (Rawool, 1997) and further growth in reflex amplitude becomes slow.

2. In individuals with essentially cochlear hearing loss:

The results suggest that the growth in reflex amplitude is more significant at repetition rates from 50/sec to 100/sec, which could be due to improved intensity coding in AR pathway as seen in case of normal hearing individuals but a major difference between the two groups is that significant reflex growth is seen only from 0 dBSL to 8 dBSL as compare to normal hearing group in which it is from 0 dBSL to 12 dBSL. This can be due to elevated thresholds seen in hearing impaired individuals. Temporal integration of loudness in listeners with essentially cochlear loss is less when compared to normal hearing individuals at equal SPLs (Buus et al., 1999). Hence amplitude growth reaches saturation at lower SL in hearing impaired group when compared to normal hearing group.

Results of the comparison made between the groups also indicate a significant difference between them as a function of rate and intensity, which could be due to elevated thresholds and the impaired mechanism for efficient temporal integration in hearing, impaired individuals. These findings are in good agreement with the observations of Wright (1968). Solecki and Gerken (1990) who found that improvement in threshold with increasing stimulus duration is greatly reduced in listeners with cochlear hearing loss. Findings of Beedle and Harford (1973) indicated that cochlear pathology reduces the rate of reflex response growth when compared to normal ears.

Clinical implications of the study:

1. The use of higher repetition rate may be helpful in diagnosis of retro cochlear pathology. When frequency specific stimuli are used for detection of retro-cochlear pathology, the use of signal frequency criterion, without consideration of other frequencies, is known to yield a high rate of false negative (Prasher and Cohen, 1993). For this purpose, click stimuli may be more efficient, since clicks have a broader frequency spectrum.
2. The loudness growth function vary among individuals with normal hearing and hearing impairment and therefore the knowledge of the individual's ARGF is valuable in prescription of gains and/or the maximum output setting on a hearing aid especially non-linear hearing aid, for a hearing impaired individual. The non-linear hearing aids often have different compression thresholds for low frequencies then for the high frequencies (Tecca, 1994). Thus, at signal input levels above the compression knee-point, use of pure tones for eliciting ARGFs may cause errors in estimating the loudness at lower frequencies. Clicks provide a broadband stimulus that may be better for evaluation of non- linear hearing aids.
3. Temporal integration is reduced in case of cochlear hearing loss as also been supported by others (Silman et al, 1978; Buus et al., 1999). This can help us to distinguish normals from cochlear hearing loss.

SUMMARY **AND** CONCLUSIONS

Few authors have studied the effect of click and supra-threshold level on the characteristics of the AR but such effects in essentially cochlear pathology has not been well defined. Hence the present study was designed with the aim:

a) To examine the effect of click rates on ipsilateral ART in normal hearing subjects and subjects with individuals with essentially cochlear hearing loss.

b) To examine the ARGF in and individuals with normal hearing and essentially cochlear pathology, as a function of click rates and stimulus intensity levels.

c) To find out a significant difference among the two groups, if any.

Subjects were divided into two groups. Normal hearing individuals served as control group whereas individuals with sensorineural hearing loss and negative results on RDT served as experimental group. ART was measured across different click rates (50, 100, 150, 200, 250, and 300/sec) ipsilaterally. Following this reflex amplitudes were measured at various SLs levels until 110 dBpeSPL, which is the upper intensity limit of the instrument. The analysis showed that the thresholds improved significantly with increase in the repetition rates. The mean threshold advantage for control and experimental groups were >14.2 dB and >8.3 dB respectively when the rate was increased from 50 to 300 clicks /sec. Significant improvement in ART was seen when rate was increased form 100 to 150 clicks /sec. Whereas for experimental group improvement was more significant when rate was increased from 50 to 100 clicks /sec. This suggests better coding of intensity at higher click repetition rates within the ipsilateral acoustic reflex pathway. This is in agreement with the results of the study by Rawool (1995).

For both the groups, the amplitude of AR grew more rapidly at lower SLs. On comparison, the rate of reflex growth seems to be better in control group than in experimental group which may be due to reduced temporal integration in individuals with essentially cochlear pathology.

Hence it can be concluded that both the groups showed different response pattern for the click stimuli. This study also supports the existing belief that individuals with essentially cochlear pathology show reduced temporal integration, which can lead to impaired ability to perceive very short stimuli, which are the characteristics of our speech production.

Suggestions for the further studies:

- Age -related charges in the ART and effects of aging on the ARGF can be studied using clicks.
- Based on click-evoked ARGF and ART, differential diagnosis of cochlear - retro-cochlear pathology needs to be studied.
- Clinical applications of click evolved AGRFs for hearing aid prescriptions may be explored in future studies.

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