CORRELATION OF THRESHOLD DIFFERENCE BETWEEN PURE TONES, CLICKS AND WIDEBAND EVOKED ACOUSTIC REFLEX

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CERTIFICATE

This is to certify that this dissertation entitled **"Correlation of threshold difference between pure tones, clicks and wideband evoked acoustic reflex"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number: **18AUD002**. 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,

July, 2020

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CERTIFICATE

This is to certify that this dissertation entitled **"Correlation of threshold difference between pure tones, clicks and wideband evoked acoustic reflex"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 18AUD002. This has been carried out 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.

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DECLARATION

This is to certify that this Master's dissertation entitled **"Correlation of threshold difference between pure tones, clicks and wideband evoked acoustic reflex"** is the result of my own study under the guidance of Dr. Devi. N., Reader in Audiology, Department of 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 No: 18AUD002**

July, 2020

DEDICATION

TO PARENTS, FRIEND(S),

FAMILY

AND

TO MY DEAR GUIDE

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"எல்லா புகழும் இறைவனுக்கே"

*First of all, a big thanks to the '**ALMIGHTY'**, for helping me to keep competing in this competitive world by giving me more and more problems and at the same time helping me to learn from that.*

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தந்தை சொல் மிக்க மந்திரம் இல்லை

ஆயிரம் உறவில் பெருமைகள் இல்லை

அன்னை தந்தையே அன்பின் எல்லை"

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அகநக நட்பது நட்பு"

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ABSTRACT

Acoustic reflex is the contraction in the middle ear muscles in response to severe acoustic stimulation. Thresholds of acoustic reflex can be obtained using different stimuli and different stimulus parameters. Comparisons of acoustic reflex thresholds (ART's) across different stimuli, like pure tone and broad band noise, and clicks at different rates are yet to be ascertained for the optimal use. Thus, this study aimed to estimate and correlate the ART's elicited by pure-tones, wide band noise and different rates of click stimuli. ART's were measured in 50 normal hearing individuals including 25 males and 25 females using all the three stimuli. A significant difference was observed between all the three stimuli. ART's elicited by clicks were better than wide band noise and pure-tone. The ART's obtained for wideband noise are better when compared with pure-tone stimuli. ART's were found be better in ipsilateral stimulation than contralateral stimulation. Gender was not found to have effect on ART's. Concluding the ideal rate for click stimulus to elicit better ART as 300/s as it elicited the lowest threshold in normal hearing individuals. Hence, click stimuli at higher rate can be used effectively in measurement of ART's in clinical population especially in individuals with hyperacusis, recruitment, reduced loudness discomfort level and in individuals with moderate hearing loss which cannot be done using pure tone or noise stimuli as their thresholds are comparatively higher.

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Chapter 1

Introduction

The acoustic reflex is ‘the amount of contraction of the middle ear muscle in reaction to intense acoustic stimulation’. Contraction of the stapedius muscle was directly viewed through the perforated ear drum as an outcome of intense sound (Lindsay et al., 1936). It is also defined as ’a bilateral reflex (the reflex occurs in both ears with single ear stimulation) and be measured by recording the change in acoustic impedance and admittance in response to stimuli (tones or noise) to the same ear or opposite ear called the uncrossed and crossed reflex respectively’ (International encyclopedia of public health, 2008). Middle ear comprises muscles that are known as stapedius muscle and tensor tympani muscle. Activity of these muscles can be examined indirectly by tracking air pressure changes in the ear canal reaction to intense noise, i.e. Stapedius muscle contraction causes the ear drum to move outward while contraction of tensor tympani muscle results in pulling the drum inward, this leads to changes in ear canal air pressure during intense sound stimulation (Terkildsen, 1957, 1960; Mendelson, 1957). Several studies have shown that when pathologies like otosclerosis, sectioned stapedius tendon, paralysis of stapedius muscle (Bell’s palsy), affects the stapedius muscle, the stapedius reflex are found to be absent (Jepsen, 1955; Klockhoff, 1961; Feldman, 1967).

The minimum intensity at which the stapedius reflex occurs 50% of the time is called acoustic reflex threshold (ART). The acoustic reflex can be measured in terms of ipsilateral and contralateral acoustic reflex. Ipsilateral acoustic reflex is the contraction of the muscles of the same stimulation ear while the contraction of the muscles of the opposite stimulation ear is the contralateral acoustic reflex (Gelfand, 2001). According to

Green and Margolis, (1984) comparatively less intensive sound are required for eliciting ipsilateral reflex than for contralateral reflex.

The ARTs can be elicited by various acoustic stimuli such as pure tone, broad band noise, and click sounds. The acoustic reflex thresholds were found to vary from 85 to 100 dB SPL while using pure-tone stimuli from 250 to 4000 Hz. (Metz, 1952; Møller, 1962; Jepsen, 1963; Margolis & Popelka, 1975; Wilson & McBride, 1978; Silman, Popelka, & Gelfand, 1978; Gelfand, 1984). The reflex threshold improved by 20 dB when elicited by broadband noise stimulus (Peterson & Liden, 1972; Margolis & Popelka, 1975; Silman et al., 1978; Gelfand, 1984). Flottorp et.al. (1971) reported the relation of acoustic reflex to critical bandwidth induced by complex tones and broadband noise. The contralateral ear was stimulated. The study found that the reflex threshold, expressed in decibels *re* 2.10^{-6} N/m^2, was almost constant for bandwidths less than critical bandwidth. ART decreased by 3-6 dB /oct with increase in bandwidth confirming the involvement of critical bandwidth in loudness summation.

Rawool (1995) explored the impact on the ipsilateral acoustic reflex threshold of click repetition rate. The threshold of 17 female normal hearing ears, i.e. 34 ears between 20 and 26 years of age, was estimated at a repetition rate of 50, 100, 150, 200, 300/sec with a probe tone of 226 Hz with 85 dB SPL. The threshold benefit was 11.2 dB with a rate rise from 50 to 100/sec, 7.8 dB with a rate rise from 100 to 200/sec and further decreased by 200 to 300/s to 2.6 dB. It was found that with the rise in repetition rate, the threshold significantly improved. Rawool (1996) studied the click-rate induced acoustic reflex threshold facilitation and its effect of aging on 26 participants. The study involved two groups in the age range of 18 to 28 years and 50- 65 years. ART was administered to both the groups for clicks with 226Hz probe tone at 85 dB SPL ipsilateraly with varying rates (50/sec, 100/sec, 150/sec, 200/sec, and 300/sec). Results of the study revealed that older adults reports to have decreased rate integration which indicates that older adults demonstrated poorer processing for faster rate of stimuli in the acoustic reflex pathway. Rawool (1996) has also reported on click-rate induced facilitation of the acoustic reflex with constant number of pulses. With constant number of pulse as 300 clicks ART was measured in 19 left ears at repetition rate of 50, 100, 150, 200, 300/s. The results disclosed that the when repetition rate increases, ART improves, even if the acoustic energy is kept constant attributing to the temporal summation.

Rawool (1998) also studied the impact on click evoked ipsilateral acoustic reflex thresholds of gender and probe frequency. Ipsilateral ARTs were evaluated in 12 male and 12 female normal hearing adults with 180/sec clicks using 3 distinct 226, 678 and 1000 Hz probe tone frequencies. Results disclosed no obvious differences in gender. Only the female participants for the 678 Hz probe were considerably correlated with the acoustic reflex thresholds. The elicitation of the reflex at the 226 Hz probe led to the reduction in static admittance in all population. The admittance rose by 42 percent for the 678 Hz probe and reduced by 58 percent of the population. There was an increase in the admittance of all the candidates for the 1,000 Hz probe. It was found that for the estimation of click-evoked acoustic reflex thresholds in adults, either 226 Hz or 1,000 Hz probes can be used.

Johnsen and Terkildsen (1980) investigated the middle ear reflex threshold with white noise and 46 normal hearing young adults with clicks. The findings showed that the threshold was spread around 72.7 dB SPL for white noise and the threshold was around

73.9 dB SPL for click stimulus at a repetition rate of 128/sec. It was found that the threshold produced by click reflexes was well defined than those produced by white noise. However, there are very few research studies in the literature that has made an effort in comparing the threshold difference between pure-tone evoked and click evoked acoustic reflex thresholds.

1.1 Need for the study

Deutsch (1972) studied the stapedial reflex thresholds for pure tone and noise stimuli in 30 young normal hearing adults and results showed that thresholds for noise stimuli were comparably better and stable than pure tones. Bennett and Weatherby (1982) studied acoustic reflexes to noise (broad band noise & filtered noise) and pure tone signals in newborn babies aged 4-8 days. The results revealed that the mean reflex threshold for broad band noise was better or lower than filtered noise or pure tones. Studies have been reported in finding of ART using different stimuli such as pure tone, and noise at different frequencies. ARTs stimulated by different stimuli is being compared in studies to find the better stimuli for each population like young and older adults, so that it can be implicated appropriately in clinics.

Tyagi (2001) studied growth of acoustic reflex amplitude at varying click rates as a result of varying intensity levels. In individuals with normal hearing there was a significant increase in amplitude at the rates from 0 dB SL to 12 dB SL and it was significant only from100/s to 200/s. In individuals with sensorineural hearing loss the amplitude growth was significant from 0 dB SL to 8 dB SL and it was significant at the rates from 50/s to 100/s, concluding that Acoustic Reflex Growth Function was better in individuals with normal hearing than individuals with sensorineural hearing loss, which was attributed to reduced temporal integration in individuals with sensori-neural hearing loss.

Rajith (2017) studied the click rate induced facilitation of acoustic reflex in children with sensori-neural hearing loss. ART had a mean improvement of 15.43 dB while increasing the rate from 50 to 300/s in children with normal hearing and 7.34 dB in children with sensorineural hearing loss. This result is attributed to the fact that temporal integration is better in children with normal hearing than children with sensorineural hearing loss. Deutsch (1972) compared the ART using noise and pure tones in 30 normal hearing individuals. The stimuli utilized for the study were 500 ms bursts of white noise, narrow bands of noise centered at 2000 and 4000 Hz, and pure tones of 250, 2000 and 4000 Hz. The results showed that threshold values utilized about 20 dB of additional stimulation energy to obtain a response in pure tones rather than noise. Similar studies were ART stimulated by noise and pure tone was compared and a difference of 20dB was found (Peterson & Liden, 1972; Margolis & Popelka, 1975; Silman et al., 1978; Gelfand, 1984). In individuals with hyperacusis increased acoustic startle response amplitude was found that is, these individuals had reduced tolerance for moderate to high level sounds (Salloum et al., 2014). There is dearth in literature on comparison and correlation of the click evoked acoustic reflex with pure tones across the rates which will be of great clinical utility in difficult to test population like hyperacusis, reduced UCL, recruitment and children.

1.2 Aim of the study

To estimate and correlate the threshold for clicks, wide band noise and pure tone induced acoustic reflexes in individuals with normal hearing.

1.3 Objectives of the study

1. To estimate acoustic reflex thresholds using clicks at different click rates.
2. To estimate acoustic reflex thresholds using pure-tones at different frequencies as 500, 1000, 2000 and 4000 Hz and wide band noise.
3. To compare and correlate the difference in acoustic reflex thresholds using pure tones, clicks and wide band noise.

Chapter 2

Review of literature

Acoustic reflex also called middle ear reflex, stapedius reflex is an involuntary contraction of the stapedius muscle in response to intense sounds preventing the damage of inner ear and thus conserving hearing sensitivity. Acoustic reflex threshold measurement being a physiological test, acts as an important measurement in diagnosing hearing disorders. It helps in differentiating middle ear disorders, cochlear pathology and retro-cochlear pathology (Stach, 1987).

2.1 Acoustic reflexes in various disorders

2.1.1 ART in sensory neural hearing loss

Sensori-neural hearing loss is caused due to any damage in the inner ear i.e. the cochlea, its associated structures or vestibulo-cochlear nerve. Acoustic reflexes are found in individuals with SNHL to a degree of mild to moderate. Rajith (2017) studied the acoustic reflex induced by click rates in 30 children with sensori-neural hearing loss (26 to 55 dB HL) and was compared with 30 typically developing children. The experimental group had ART or elevated ART at 500, 1000, 2000 Hz and normal tympanometric findings. A 226 Hz probe tone with 85 dB SPL stimuli was used to record the ART. Clicks were presented to each ear at different rates such as 50, 100, 150, 200, 250 and 300/s. Click duration was 6s for 50/s, 2s for 150/s and 1s for 300/s. Initially stimuli was presented at 70 dB peSPL which was increased or decreased by 5dB depending upon the presence or absence of ART. The results revealed that ART had a mean improvement was 7.6 dB, 4.16 dB, 2 dB and 1.6 dB when the rates increased from 50 to 100/s, 100 to

150/s, 150 to 200/s and 200 to 300/s respectively in normal hearing children. Whereas, mean improvement of 4.17 dB, 1.43 dB, 0.74 dB and 1 dB were found in children with sensori neural hearing loss when the rates increased from 50 to 100/s, 100 to 150/s, 150 to 200/s and 200 to 300/s respectively. The mean ART improvement was 16.06 dB in normal hearing children and 10.27 dB in children with hearing impairment.

Olsen et al., (1975) studied the occurrence of acoustic reflex in individuals with cochlear and eight nerve lesion. Testing was carried out in 50 normal hearing ears, 128 ears with sensori-neural hearing loss including 50 high frequency loss due to noise trauma, 50 Meniere, and 28 retrocochlear pathology of 16 to 60 years. Reflexes were absent in 1 normal ear, 10 high frequency loss ears, 11 ears of Meniere disease and 24 ears with eighth nerve lesion indicating retrocochlear lesion in them.

2.1.2 ART in individuals with otitis media

Otitis media is the inflammation of the middle ear often accompanied by fluid effusion. Commonly found in children. This results in conductive hearing loss that may fluctuate. It is recurrent in most cases. Schwartz and Schwartz (1980) evaluated the sensitivity of acoustic reflex and tympanometry in identifying acute otitis media. The participants included 103 children (161 ears) diagnosed with acute otitis media between the age ranges of 4 months to 17 years. Tympanogram was identified as flat in 102 ears (63%), negative in 17 ears (11%) and shallow/rounded in 18 ears (11%). 15 ears were found to have normal tympanometry findings and 19 ears were found to have high positive pressure peak. Study concluded that the sensitivity of tympanometry for establishing acute otitis media was about 74.5% and acoustic reflex was about 71%

suggesting that the acoustic immitance measures are unsatisfying to identify acute otitis media.

Ryding et al., (2002) studied the auditory sequel of recurrent acute purulent otitis media. Two groups of children followed from birth to 3 years incorporated in the study. One group included 12 children who had recurrent acute otitis media and other group included 21 children with no acute otitis media. At age 10 these groups were followed and identified with no acute or secretory otitis media. The hearing thresholds between the groups were indifferent. ARTs were elicited by pure-tone stimulus at 500, 1000 and 2000 Hz using Grason Stadler GSI 1723 middle ear analyzer. ARTs could not be elicited in 3 children at any of the frequencies. Acoustic middle ear reflex thresholds were found to be raised, middle ear compliance was comparatively greater and middle ear pressures were lower in children who had recurrent acute otitis media suggesting impaired middle ear mechanics in children who had recurrent acute otitis media.

2.1.3 ART in individuals with Auditory Neuropathy Spectrum disorder (ANSD)

Auditory neuropathy is a disorder wherein the outer hair cells remain unharmed while the inner hair cells and eighth cranial nerve or the lower brainstem is affected. Pure tone thresholds remain within normal limits with speech perception being severely disturbed. It occurs around all age groups. Berlin et al., (2005) studied the middle ear reflexes in participants with auditory neuropathy or dys-synchrony for 136 with the age range of 2 months to 74 years. Normal reflexes were not found in any of the patient at any frequency. 133 patients were observed to have reflexes above 100 dB or absent. Three patients elicited reflexes at 95 dB HL or below but not at 1 kHz or 2 kHz. Though OAE’s were present reflexes were found to be absent in 1 kHz and 2 kHz for ANSD individuals. Shallop (2002) studied the auditory characteristics of 10 children with ANSD who were cochlear implant users implanted at around 15 to 76 months. Electrical ART was measured and it is was found to be present in 9 children.1 child showed absent reflexes and the author has suggested that it might be either due to middle ear anomaly or technical issue. Till dated ART using clicks stimulus is not measured for individuals with ANSD. Hypothesizing better ART using clicks stimuli the study is carried out. If proved, clicks can be used to elicit ART in individuals with ANSD as better thresholds can be obtained.

2.1.4 ART in individuals with Otosclerosis

Otosclerosis is a condition in which the temporal bone is progressively resorbed and replaced by spongy bone which hardens to become sclerotic. It is also called otospongiosis. Commonly it is bilaterally present and result in progressive hearing loss. It hinders the normal movement of stapedial footplate may also lead to ankylosis. Keefe et al, (2017) studied the identification of otosclerosis using aural acoustic test of absorbance, group delay, oto-acoustic emission and acoustic reflex threshold. Three groups were included in the study - a group with otosclerosis, a group which received surgery for otosclerosis and a control group. ART was measured both ipsilaterally and contralaterally using tonal and broad band noise. ART's were found to be absent in individuals diagnosed with otosclerosis and in individuals who has undergone surgery.

Terkildsen et al., (1973) studied the middle ear reflexes in 34 ears in 32 patients with otosclerosis which consisted of 22 patients who had undergone unilateral stapedectomy, 2 patients with bilateral early otosclerosis and 8 with unilateral otosclerosis. Middle ear reflexes were elicited using pure tone of 1000Hz and observed in

18 ears. Patients with otosclerosis less than 5 years (n=17) of duration had reflexes and absent for patients with duration of more than 10 years (n=13). Between 5 to 10 years of duration of disease reflexes were observed for 2 out of 4 patients. Reflexes were observed in early otosclerosis condition in negative-going on-off type not as the once observed in individuals with no pathology. Similarly ARTs can be measured using clicks stimulus for otosclerosis to check whether this similar pattern of ART was observed.

2.1.5 ART in individuals with high frequency hearing loss

High frequency hearing loss is denoted by loss of hearing at about 2 kHz and its higher frequencies. It is sensori-neural loss caused due to damage in the hair cells of inner ear. Noise trauma also leads to high frequency hearing loss. Silman and Gelfand (1979) studied the prediction of hearing loss using ART. The study included 3 groups. Group 1 consisted normal hearing individuals. Group 2 included 17 subjects with a loss of $\geq$ 40 dB HL at 2000 Hz or above i.e. high frequency loss. Group 3 included 15 subjects with pure tone averages of $\geq$ 32 dB HL. ART was measured pure-tone signal and noise. Using pure tones mean reflex thresholds were elevated at frequencies with hearing loss in hearing impaired individuals. Using noise the reflex thresholds were found to be higher than normal group.

Silman and Gelfand (1981) studied the association linking ART and magnitude of hearing loss. 280 subjects were included in the study with their hearing levels varying from 0 to 110 dB. ART was measured and it was found that the ART was kept constant for hearing loss up to 60-65 dB HL for 500 and 1000 Hz, and 50-55 dB HL for 2000 Hz. With increase in the hearing loss the elevation of ART was observed. Reflexes were absent rarely for hearing loss less than 80 dB HL when it is corresponded to cochlear involvement.

2.1.6 ART in individuals with third window disorders

Third window disorders are caused due to damage in the integrity of bony structure of inner ear. It includes semicircular canal dehiscence, enlarged vestibular aqueduct, peri-labyrinthine fistula, X-linked stapes gusher, dehiscence of the scala vestibuli side of the cochlea and bone dyscrasias. Hong et al., (2015) examined the effectualness of acoustic reflex screening in identification of third window disorders. 212 ears of 192 patients with conductive hearing loss who had absent reflexes in the previous testing were incorporated in the study. They were classified to 5 sub group based on etiology of hearing loss as (1) ossicular abnormalities, (2) third window disorders, (3) both ossicular and third window etiologies, (4) other etiology, and (5) unknown etiology. Acoustic reflex screening was carried out and it was found that for ossicular etiology, the positive and negative predictive values were 89% and 57% when acoustic reflex was solely used for screening, 89% and 39% when third window symptoms were alone, and 94% and 71% when reflexes and symptoms were combined, respectively.They concluded that acoustic reflex as an effectual means to identify third window disorders.

2.1.7 ART in individuals with CAPD

CAPD is defined as “having difficulty in retrieving, transforming, analyzing, organizing, and storing information from audible acoustic signals” (ASHA, 1992). CAPD is defined as ‘involving deficits in localization, lateralization, auditory discrimination, pattern recognition skills, temporal processing, and performance decrements with competing or degraded auditory signals' (ASHA, 1996). Kunze et al, (2017) studied the stapedial reflex in children with and without CAPD. The study included 2 groups, a control group with 50 healthy children and a group with 57 children diagnosed with CAPD. ART was done in noise and sinus tones. Significant difference was not found between ART of both the groups. Hence the study concluded that ART measurement cannot be used for identification or discrimination of individuals with CAPD.

Meneguello et al., (2001) studied the abnormalities in acoustic reflex using pure tones of 500, 1000 and 2000 Hz in 100 individuals with auditory processing disorder within the age ranging from 7 to 18 years having normal hearing thresholds and normal tympanograms. 62 % of the individuals showed acoustic reflex level abnormalities. It concluded that auditory processing test should be administered in participants with normal hearing and abnormal reflex to rule out the condition. ARTs can be measured using click stimulus to check whether this similar pattern is observed or not.

2.2 Acoustic reflex threshold using Clicks

Rawool (1996) studied the on click-rate induced acoustic reflex threshold facilitation and its effect of aging on 26 participants. The study involved two groups of participants in the age range of 18 to 28 years and 50 to 65 years. The subjects had normal hearing sensitivity and normal tympanometric findings. ART was administered to both the groups using clicks with 226 Hz probe tone at 85 dB SPL ipsilateraly with varying rate (50/sec, 100/sec, 150/sec, 200/sec, and 300/sec). Each measurement was done for 1.5 seconds. Initial presentation was 70dBSPL reduced or increased depending upon the presence or absence of reflex. Results of the study revealed that older adults reported decreased rate integration which indicates that older adults demonstrate poorer processing for faster stimuli in the acoustic reflex pathway. Static admittance and rate integration had significant negative correlation. Smaller static admittance was found in younger females than older females but males did not differ. ART obtained at 300/sec only had correlation with static admittance. Older and younger group had better ART in the click repetition rate from 50/s to 150/s. From 110/s to 300/s there was a significant improvement in ART for younger group but not in older group. The ART were lower for younger females than younger males in all frequencies expect 4 kHz ad 8 kHz. Older males and females didn't differ expect 0.25 kHz. At 4, 6 & 8 kHz younger male had lower threshold than older male and vice versa at 0.25 kHz. At all frequencies younger female had lower threshold than older female.

Rawool (1996) has also reported on click-rate induced facilitation of the acoustic reflex with constant number of pulses. With constant number of pulse as 300 clicks ART was measured in 19 left ears at repetition rate of 50, 100, 150, 200, 300/s. The probe frequency was 226 Hz and intensity was 85 dB SPL. The duration of the click train was varied with the number of clicks being held constant. The duration was 6s, 3s, 2s, 1.5s, 1s for 50, 100, 150, 200, 300 rate/s respectively. The initial presentation was 70dBSPL increased or decreased by 5 dB depending on presence or absence of ART. ART obtained at the rate of 50/s was significantly different from all other ARTs obtained at other rates. With higher number of pulses better threshold were obtained at 50 clicks/s and 300 clicks/s. Variation of saturation rate was observed from 150 clicks/s to 300 click/s. The results disclosed that the when repetition rate increases, ART improves, even if the acoustic energy is kept constant.

Rawool (1998) also studied the impact on click evoked ipsilateral acoustic reflex thresholds of gender and probe frequency. Ipsilateral ARTs were evaluated in 12 males and 12 females with normal auditory sensitivity, normal tympanometric findings with presence of ART at 226, 678 and 1000 Hz probe frequencies. Grason–Stadler GSI 33, Version 2 was used. Ipsilateral acoustic reflex is obtained in left ear at the rate of 180/sec clicks using 3 distinct 226, 678 and 1000 Hz probe tone frequencies. Results disclosed no obvious differences in gender. Only the female participants for the 678 Hz probe were considerably correlated with the acoustic reflex thresholds. The elicitation of the reflex at the 226 Hz probe led to a reduction in static admittance in all population. The admittance rose by 42 percent for the 678 Hz probe and reduced by 58 percent of the population. There was an increase in the admittance of all the candidates for the 1,000 Hz probe tone. It was found that for the estimation of click-evoked acoustic reflex thresholds in adults, either 226 Hz or 1,000 Hz probe tones can be used.

Rawool (1995) explored the impact on the ipsilateral ART of varying click repetition rate. The threshold of 17 female normal hearing ears, i.e. 34 ears between 20 and 26 years of age, was estimated at a repetition rate of 50, 100, 150, 200, 300/sec with a probe tone of 226 Hz with 85 dB SPL. The initial presentation level was 70 dB SPL, the intensity was reduced by 5 dB if reflex was present. The threshold benefit was 11.2 dB with a rate rise from 50 to 100/sec, 7.8 dB with a rate rise from 100 to 200/sec and further decreased by 2.6 dB for 200 to 300/s. It was found that with the rise in repetition rate, the threshold significantly improved. The tones that have short duration and high repetition rate will be perceived louder.

Johnsen and Terkildsen (1980) investigated the middle ear reflex threshold with white noise and clicks in 46 individuals (25 females and 21 males) with audiometric findings within normal limits, ear drum compliance between 0.4 to 1.3 ml, with mean age of 25 years. Stimuli were presented contra-laterally with duration of 2 seconds. ART was measured using ascending descending method of 5 dB. The repetition rates were 8, 16, 32, 64, and 128/sec. Pure tones of 500, 1000, 2000 Hz were used and the middle ear reflex threshold of pure tones 0.5, 1.2 kHz are 97.2 dB, 92dB, and 91.3 dB respectively. And white noise was 72.7 dB and for clicks at a repetition rate of 8, 16, 32, 64, and 128 clicks/sec were 120 dB, 101.8 dB, 86.8 dB, 76 dB, and 73.9 dB respectively. The threshold was spread around 72.7 dB SPL for white noise and the threshold was around 73.9 dB SPL for click stimulus at a repetition rate of 128/sec. It was found that the reflex threshold obtained from white noise and click at a repetition rate of 128 clicks/sec were almost identical. Reflexes was absent at repetition rate of 8/s for 3 individuals even at maximum intensity level. The threshold produced by click reflexes was well defined than those produced by white noise. In sensori-neural hearing impaired individuals the click evoked muscle response depend on degree of impairment same as white noise. However, there are very few research studies in the literature that has made an effort in comparing the threshold difference between pure-tone evoked and click evoked acoustic reflex threshold.

Tyagi (2001) studied growth of acoustic reflex amplitude at varying click rates as a function of varying intensity levels. Thirty participants with normal hearing of who were between 17 – 40 years of age were chosen. There was a significant increase in amplitude at the rates from 0 dB SL to 12 dB SL and it was significant only from100/s to

200/s. In 21 ears of 17 to 40 years with mild to moderate sensori-neural hearing loss the amplitude growth was significant from 0 dB SL to 8 dB SL and it was significant at the rates from 50/s to 100/s, concluding that Acoustic Reflex Growth Function was better in subjects with normal hearing than participants with sensori-neural hearing loss, which was attributed to reduced temporal integration in subjects with sensori-neural hearing loss. Till dated studies there are numerous studies on ART elicited using pure tones and clicks. But, comparison between the two stimuli has not reported. This study aimed in comparing the ART elicited by pure tones, wide band noise and clicks stimuli at different rates.

Chapter 3

Methods

3.1 Participants

A total of 50 particpants (25 males and 25 females) within the age range of 18 – 40 years with mean of 22.76 ± 3.66 years in males and 23.84 ± 3.82 in females were participated in the study. A written consent was procured from all the participants and they were informed regarding the complete test procedure and approximate time needed for each test before conducting the study which specifies the willingness of subjects to participate in the study.

3.1.1 Inclusive criteria of the participants

Participants are selected for the study based on following conditions:

- No history of external and middle ear infections such as ear pain, ear discharge.
- No record or existence of any structural or neurological abnormalities of ear.
- Bilateral air conduction pure tone hearing thresholds at octave frequencies 250 Hz to 8000 Hz less than or equal to 15 dB HL as measured by pure tone audiometry using modified Hughson-Westlake method (Carhart & Jerger, 1959)as considered.
- Normal middle ear functioning as stated by type ' A ' tympanogram (Margolis & Heller, 1987) with acoustic reflexes at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz in immittance audiometry.
- Transient Evoked Oto-acoustic Emissions (TEOAE) presence in both ears.

3.2 Instrumentation

- A calibrated ' clinical audiometer ' (GSI 61) with TDH 39 earphones included in MX-41/AR supra-aural ear cushions to estimate air-conduction thresholds, SRT and SIS ; and Bone vibrator Radio Ear B-71 for evaluating bone conduction thresholds, and calibrated ILO v6 to evaluate oto-acoustic emissions.
- A calibrated middle ear analyzer ' Grason-Stadler TympStar (version 2) ' to evaluate the middle ear status and to determine the auditory reflex threshold.

3.3 Test environment

All the participants were subjected to tests in an acoustically treated room which meets the ambient noise level criteria specified by ANSI S3.1-1999(R2008)

3.4 Procedure

3.4.1 Otoscopic examination

Otoscopic examination was done on both right ears and left ears of every participant to ensure intact tympanic membrane to proceed with reflex audiometry.

3.4.2 Pure tone Audiometry

Pure tone audiometry testing was carried which comprised of both the air conduction (250 Hz to 8000 Hz) and bone conduction audiometry (250 Hz to 4000 Hz) tests administered using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959). Average of hearing thresholds obtained at octave frequencies 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for air conduction audiometry was taken as the pure tone average in order to estimate the degree of hearing.

3.4.3 Tympanometry

Immittance Evaluation included tympanometry and acoustic reflex threshold estimation using a 226 Hz probe tone at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz was done using GSI Tympstar middle ear analyzer (Grason-Stadler Inc, USA) to rule out any middle ear pathology.

3.4.4 Acoustic Reflex Audiometry

Initially acoustic reflex threshold was estimated for both ipsilateral and contralateral recording using 500, 1000, 2000 and 4000 Hz tonal stimulus. Similarly ART thresholds using wide band noise is estimated both ipsilateral and contralateral using regular acoustic paradigm. Then for click induced ART measurement, the GSI tympstar version 2 was used, where the total envelope for the Multiplexed approach is 115ms; clicks will be off for 53 ms and on for 44 ms with 18 ms as total rise time and fall time. The click duration is 100 µs with condensation polarity. Thresholds was obtained for click stimuli at different rates such as 50/second, 100/second, 150/second, 200/second, 250/second, and 300 clicks/second. The initial presentation was 50 dB peSPL. Until the reflex threshold is obtained the intensity level was increased by 2 dB. To ensure the absence of reflex the stimulus presentation was repeated at 2 dB lower level whenever the change in the amplitude of acoustic reflex will be $\geq$ 0.03 ml.

Out of these, the rate at which the maximum number of participants elicits the minimum acoustic reflex threshold were noted for further analysis of the data.

3.5 Data analysis

The data obtained was tabulated and analyzed with appropriate statistical analysis using SPSS (version 20) software

1. Normality of the data collected in the present study was found using Shapiro- Wilk test and Kolmogorov-Smirnov.
2. Descriptive statistics were done to estimate the mean threshold of acoustic reflex for pure-tones, wide band noise and clicks stimuli at different rates.
3. Wilcoxon Signed Rank test and Friedman test were used to compare the acoustic reflex threshold elicited using pure tones, wide band noise and clicks stimuli
4. Acoustic reflex threshold of right and left ear elicited by pure tones, wide band noise and click stimuli were compared using Wilcoxon Signed Rank test.
5. Acoustic reflex threshold of males and females elicited by pure tones, wide band noise and click stimuli were compared using Mann-Whitney test.
6. Acoustic reflex threshold induced by pure tones, wide band noise and clicks stimuli were correlated using Spearman's rho test.

Chapter 4

Results

The present study was carried out to estimate and correlate the acoustic reflex threshold for clicks, wide band noise and pure tones in individuals with normal hearing. The participants were 50 normal hearing individuals including 25 males and 25 females for whom acoustic reflex threshold (ART) estimation was done. Descriptive and inferential statistics were carried out using SPSS (version 20) software. Shapiro Wilk's test of normality was done to analysis the normality of the data and this study's data were found to be non-normally distributed ($p < 0.05$). Hence, non-parametric inferential statistics was carried out for further analysis. The results of the study are explained in the following headings:

4.1. Estimation of acoustic reflex thresholds using clicks at different click rates, pure tones at different frequencies 500, 1000, 2000 and 4000 Hz and wide band noise.

4.2. Comparison of the difference in thresholds between pure tones at 500, 1000, 2000 and 4000 Hz (ipsilateral and contralateral) and acoustic reflex using clicks, and wide band noise.

4.3. Correlation of the difference in thresholds for pure tones at different 500, 1000, 2000 and 4000 Hz (ipsilateral and contralateral) and acoustic reflex using clicks, and wide band noise.

4.1. Estimation of acoustic reflex thresholds using clicks at different click rates, pure tones at different frequencies 500, 1000, 2000 and 4000 Hz and wide band noise.

The data was collected separately for males and females. Before further statistical comparison of the difference in thresholds between different stimuli, the obtained data was subjected for its statistical analysis between gender and ears.

4.1.1. Effect of gender on ART

Mann-Whitney test was used to identity the consequence of gender on ART. Table 4.1.1.1 depicts the results of Mann-Whitney test for ART between genders on each test stimuli.

Table 4.1.1.1

Results of Mann-Whitney test comparing the ART between genders for all the test stimuli

Stimuli	**Z-value**	***p*-value**	**Stimuli**	**Z-value**	***p*-value**
RPTi500	-0.64	0.52	RCLi150/s	-0.70	0.48
RPTi1K	-0.12	0.89	RCLi200/s	-0.84	0.39
RPTi2K	-0.70	0.48	RCLi250/s	-0.68	0.49
RPTi4K	-0.74	0.45	RCLi300/s	-0.52	0.59
RPTc500	-0.51	0.60	RCLc50/s	-0.94	0.34
RPTc1K	0.000	1.0	RCLc100/s	-0.88	0.37
RPTc2K	-0.38	0.70	RCLc150/s	-0.86	0.38
RPTc4K	-0.68	0.49	RCLc200/s	-0.82	0.40
LPTi500	-0.20	0.84	RCLc250/s	-0.83	0.40
LPTi1K	-0.19	0.84	RCLc300/s	-0.80	0.41
LPTi2K	-0.34	0.72	LCLi50/s	-1.88	0.06
LPTi4K	-1.06	0.28	LCLi100/s	-1.69	0.09
LPTc500	-0.30	0.75	LCLi150/s	-1.58	0.11
LPTc1K	-0.59	0.55	LCLi200/s	-1.60	0.10
LPTc2K	-0.91	0.36	LCLi250/s	-1.33	0.18
LPTc4K	-0.66	0.50	LCLi300/s	-0.41	0.68
RiWBN	-0.87	0.38	LCLc50/s	-0.88	0.37
RcWBN	-0.91	0.36	LCLc100/s	-0.45	0.64
LiWBN	-0.68	0.49	LCLc150/s	-0.87	0.38
LcWBN	-1.51	0.13	LCLc200/s	-0.53	0.59
RCLi50/s	-1.34	0.17	LCLc250/s	-0.25	0.80
RCLi100/s	-0.89	0.36	LCLc300/s	-0.36	0.71

Note: R= right ear, L= left ear, i= ipsilateral, c= contralateral, PT= Pure tone (in Hz), WBN= Wide band noise, CL= Clicks.

Results of Table 4.1.1.1 revealed that no significant difference ($p > 0.05$) was found between ART values of males and females for most of the stimulus parameter of pure tones, clicks, and wideband noise. Hence, for further analysis the data of male and females were combined.

4.1.2 Comparison of ART between right and left ear for the entire test stimulus:

The ART elicited by pure tones, clicks, wideband noise at different frequencies were compared between right and left ear using Wilcoxon Signed Rank test. Table 4.1.2.1 depicts the results of Wilcoxon signed Rank test for comparison of ART values between ears.

Table 4.1.2.1

Results of Wilcoxon signed Rank test for comparison of ART between ears for all the test stimuli

Stimuli	Z-value	*p*-value	Stimuli	Z-value	*p*-value
LPTi500 - RPTi500	-1.34	0.18	LCLi100 - RCLi100/s	-2.69	0.00**
LPTi1K - RPTi1K	-0.68	0.49	LCLi150 - RCLi150/s	-3.34	0.00**
LPTi2K - RPTi2K	-0.53	0.59	LCLi200 - RCLi200/s	-3.30	0.00**
LPTi4K - RPTi4K	-1.13	0.25	LCLi250 - RCLi250/s	-3.06	0.00**
LPTc500 - RPTc500	-2.62	0.00**	LCLi300 - RCLi300/s	-3.34	0.00**
LPTc1K - RPTc1K	-1.67	0.09	LCLc50 - RCLc50/s	-0.44	0.65
LPTc2K - RPTc2K	-0.03	0.97	LCLc100 - RCLc100/s	-0.17	0.86
LPTc4K - RPTc4K	-0.71	0.47	LCLc150 - RCLc150/s	-0.07	0.94
LiWBN – RiWBN	-2.36	0.01*	LCLc200 - RCLc200/s	-1.14	0.25
LcWBN – RcWBN	-0.98	0.32	LCLc250 - RCLc250/s	-0.24	0.80
LCLi50 - RCLi50/s	-2.57	0.01*	LCLc300 - RCLc300/s	-0.07	0.93

Note: R= right ear, L= left ear, i= ipsilateral, c= contralateral, PT= Pure tone (in Hz), WBN=Wide band noise, CL= Clicks

** indicates significant difference $p < 0.001$, * indicates significant difference $p < 0.05$

From the above Table 4.1.2.1 it is evident that the analysis revealed the presence of significant difference ($p < 0.05$) between right and left in the test stimuli of contralateral 500 Hz pure tone, ipsilateral wide band noise, all ipsilateral stimulation of clicks at 50/s, 100/s, 150/s, 200/s, 250/s and 300/s and contralateral stimulation of clicks at 200/s. Hence, the further analysis of the data was done separately for the ears since some of the stimuli have ear differences. The mean and standard deviation (SD) values for the entire test stimulus are depicted in Table 4.1.2.2.

Table 4.1.2.2

Mean and SD of ART for different test stimuli at different frequencies

Stimuli	Mean (dB HL)	SD	Stimuli	Mean (dB HL)	SD
RPTi500	86.20	6.74	RCLi150/s	72.86	8.09
RPTi1K	88.90	7.23	RCLi200/s	70.30	7.62
RPTi2K	92.70	6.48	RCLi250/s	69.74	7.53
RPTi4K	94.40	5.11	RCLi300/s	68.74	7.57
RPTc500	94.60	8.68	RCLc50/s	89.6	10.44
RPTc1K	97.80	8.69	RCLc100/s	83.4	9.44
RPTc2K	99.90	8.04	RCLc150/s	79.3	8.63
RPTc4K	105.70	7.69	RCLc200/s	77.3	7.91
LPTi500	85.40	6.29	RCLc250/s	76.6	8.31
LPTi1K	88.5	6.56	RCLc300/s	75.6	8.34
LPTi2K	92.40	7.70	LCLi50/s	83.2	9.28
LPTi4K	92.00	13.66	LCLi100/s	76.4	8.45
LPTc500	92.70	7.77	LCLi150/s	70.26	7.65
LPTc1K	115.40	135.14	LCLi200/s	67.62	7.25
LPTc2K	100.00	8.32	LCLi250/s	67.22	7.03
LPTc4K	104.70	7.24	LCLi300/s	66.02	8.33
RiWBN	80.80	6.41	LCLc50/s	89.94	10.05
RcWBN	82.90	17.46	LCLc100/s	83.38	9.19
LiWBN	79.20	7.02	LCLc150/s	79.46	7.79
LcWBN	99.28	90.61	LCLc200/s	76.74	7.76
RCLi50/s	84.50	9.62	LCLc250/s	76.42	7.56
RCLi100/s	78.42	9.01	LCLc300/s	75.58	8.11

Note: SD = Standard Deviation, R= right ear, L= left ear, i= ipsilateral, c= contralateral, PT= Pure tone (in Hz), WBN= Wide band noise, CL= Clicks.

From Table 4.1.2.2. It is evident that the ART's elicited by pure-tone stimulus was better at 500 Hz i.e., 86.2 dB HL, 85.4 dB HL for right and left ipsilateral stimulation and 94.6 dB HL, 92.7 dB HL for right and left contralateral stimulation respectively. In ART elicited by click stimulus, better threshold was obtained at 300/s rate i.e., 68.7 dB HL, 66.0 dB HL for right and left ipsilateral and 75.6 dB HL, 75.5 dB HL for right and left contralateral stimulation respectively. For the ART elicited by wide band noise stimuli the thresholds obtained are 80.8 dB HL and 79.2 dB HL for ipsilateral stimulation at right and left ear respectively, and 82.9 dB HL and 99.2 dB HL for contralateral stimulation at right and left ear respectively. From Table 4.1.2.2, it was observed that pure tones of 500 Hz and 1000 Hz had better thresholds hence it was taken for further analysis to find a difference in thresholds with respect to other two stimuli.

Mean value reveals that ART elicited by pure-tones and wide band noise are poorer in thresholds than for click stimuli. Comparing pure-tone and wide band noise better ART was observed for wide band noise stimuli. Comparing wide band noise and clicks better ART was observed for click stimuli. Comparing the ART between ipsilateral and contralateral stimulation, better ART was observed in ipsilateral stimulation than contralateral stimulation for all stimuli. Equating the ART elicited by click stimulus at different rates, better ART was observed as rate of clicks increased in both ipsilateral and contralateral stimulation i.e., 84.5 dB HL to 68.74 dB HL at right ipsilateral 50/s to 300/s stimulation respectively, 89.6 dB HL to 75.6 dB HL at right contralateral 50/s to 300/s stimulation respectively, 83 dB HL to 66 dB HL at left ipsilateral 50/s to 300/s stimulation respectively, and 89.9 dB HL to 75.7 dB HL at left contralateral 50/s to 300/s stimulation respectively. Figure 4.1.2.1 depicts the ART across different rates of click stimuli obtained on both ears for ipsilateral and contralateral stimulation.

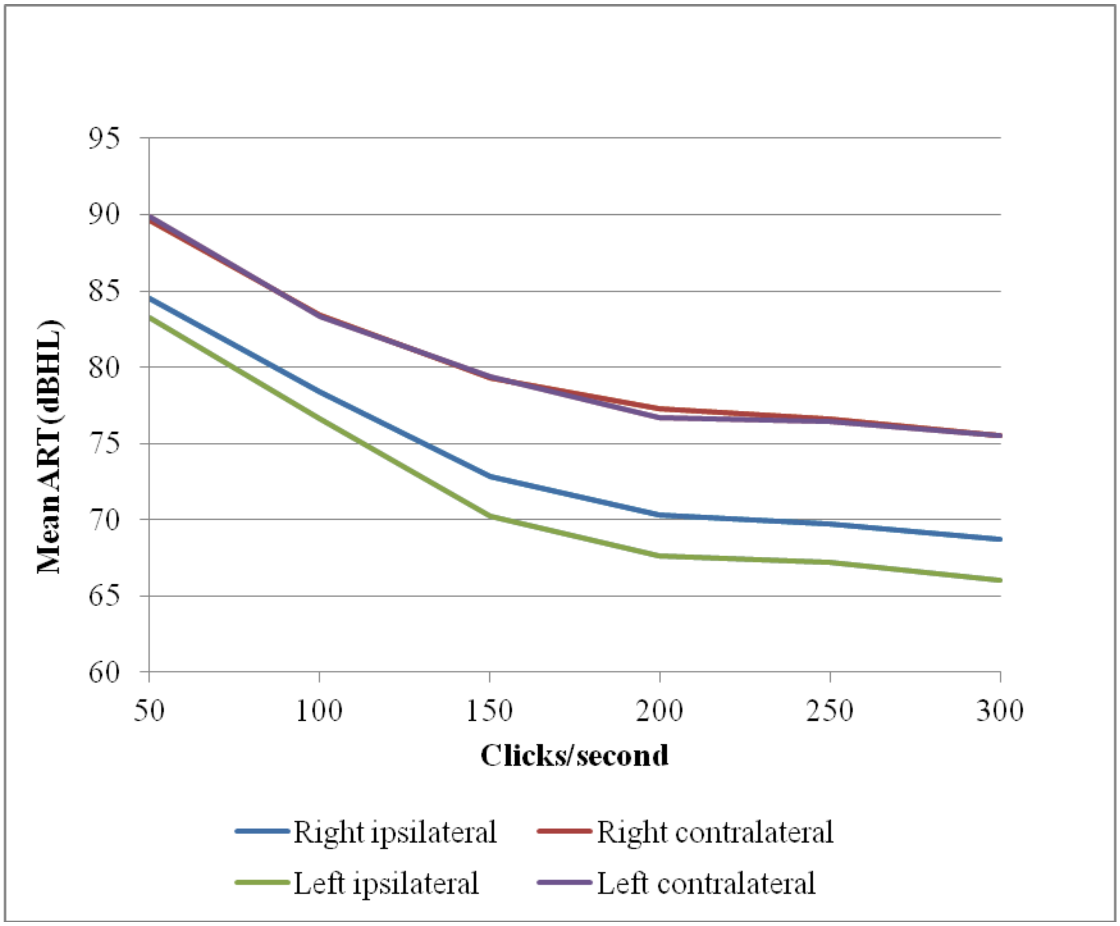

Figure 4.1.2.1: Mean ART across different rates of click stimuli obtained for ipsilateral and contralateral stimulation for both the ears

From Figure 4.1.2.1 it can be observed that for click stimulus, highest threshold was obtained at 50/s and a drastic improvement in threshold was seen when click rate was increased to 150/s due to the factor of temporal integration. For further increase in click rates like 200/s, 250/s and 300/s, there was further improvement in thresholds but it was observed to be minimal improvement. On the whole at 300/s, better threshold was obtained and so it was taken for further comparison with other two stimuli.

Threshold differences of 17.46 dB HL was obtained between right ipsilateral pure tone 500 Hz and clicks at 300/s; 5.4 dB HL between right ipsilateral wide band noise and pure tone 500 Hz; 12.06 dB HL between right ipsilateral clicks at 300/s and wide band noise; 19.38 dB HL between left ipsilateral pure tone 500 Hz and clicks at 300/s; 6.2 dB HL between left ipsilateral wide band noise and pure tone 500 Hz; 13.18 dB HL between left ipsilateral clicks at 300/s and wide band noise; 19 dB HL between right contralateral pure tone 500 Hz and clicks at 300/s; 11.7 dB HL between right contralateral wide band noise and pure tone 500 Hz; 7.3 dB HL between right contralateral clicks at 300/s and wide band noise; 17.12 dB HL between left contralateral pure tone 500 Hz and clicks at 300/s; -6.58 dB HL between left contra lateral wide band noise and pure tone 500 Hz (average of wide band noise is more than pure tone average); 23.7 dB HL between left contralateral clicks at 300/s and wide band noise.

Similarly, threshold differences of 20.16 dB HL was obtained between right ipsilateral pure tone 1KHz and clicks at 300/s; 8.1 dB HL between right ipsilateral wide band noise and pure tone 1KHz; 22.48 dB HL between left ipsilateral pure tone 1 kHz and clicks at 300/s; 9.3 dB HL between left ipsilateral wide band noise and pure tone 1 kHz; 22.2 dB HL between right contralateral pure tone 1 kHz and clicks at 300/s; 14.9 dB HL between right contralateral wide band noise and pure tone 1 kHz; 39.82 dB HL between left contralateral pure tone 1 kHz and clicks at 300/s; 16.12 dB HL between left contralateral wide band noise and pure tone 500 Hz. Thus, by comparing the ART's elicited by different stimuli it is found clicks stimulus elicited better thresholds comparing to pure tones and wide band noise. However, before analyzing if these responses are statistically different, the data was analyzed between right and left ear to check if there are any ear differences.

4.2. Comparison of the difference in thresholds between pure tones at 500, 1000, 2000 and 4000 Hz (ipsilateral and contralateral) and acoustic reflex using clicks at different rates, and wide band noise.

Non-parametric Friedman test of differences among repeated measures was carried out to compare the ART thresholds within the ear for both contralateral and ipsilateral stimulation on both the ears separately. Friedman test was performed. The results of the test for comparison of right ear ipsilateral stimulation reveals [χ^2 (12) = 512.77, $p < 0.001$]. Wilcoxon sign rank test was administered to obtain pairwise comparison. The results revealed a significant difference ($p < 0.05$) among all the pairs of test stimuli compared with results of Right ear ipsilateral stimulation. Similarly the results of the test for comparison of right ear contralateral stimulation reveals [χ^2 (12) = 504.19, $p < 0.001$]. Further, Wilcoxon sign rank test was administered for pair wise comparison. The results revealed a significant difference ($p < 0.05$) among all the pairs of test stimuli compared with results of Right ear contralateral stimulation. The results of the test for comparison of left ear ipsilateral stimulation reveals [χ^2 (12) = 506.98, $p < 0.001$]. Further, to obtain a pair-wise comparison, Results of Wilcoxon sign rank test for pair wise comparison reveals a significant difference ($p < 0.05$) among all the pairs of test stimuli compared with results of left ear ipsilateral stimulation. The results of the test for comparison of left ear contra lateral stimulation reveals [χ^2 (12) = 503.97, $p < 0.001$]. The results of Wilcoxon sign rank test for pair wise comparison revealed a significant difference (p < 0.05) among all the pairs of test stimuli compared with results of left ear contralateral stimulation.

4.3. Correlation of the difference in thresholds for pure-tones at different 500, 1000, 2000 and 4000 Hz (ipsilateral and contralateral) and acoustic reflex using clicks, and wide band noise.

Spearman's rho coefficient correlation (r_s) was carried to find the existence of ART correlation between different stimuli. Results revealed a significant moderate to strong positive correlation between all the stimuli in both right and left ear for ipsilateral and contralateral responses across all test frequencies.

Chapter 5

Discussion

Acoustic reflex threshold being a physiological test, acts as one of the promising measurement in diagnosing hearing disorders in the field of diagnostic audiology. According to literature review, acoustic reflex thresholds (ART's) are measured with different stimuli across different population and comparisons are being reported between them. This particular study aimed at estimating ART using click stimulus at different rates on fifty normal hearing individual and comparing ART's elicited by pure tones, clicks and wide band noise.

5.1 Comparison of ARTs elicited by different stimuli

The results of the current study revealed that ART obtained for wide band noise was better than pure-tone stimuli in accordance with the studies in literature Peterson and Linden (1972) which concluded that ART elicited by pure tones are approximately 15 dB lower than the other stimuli. However, the authors had used narrow band noise and white noise for comparison. Margolis and Popelka (1975) reported a 5 dB better threshold for broad band noise to pure-tone stimuli. Comparing WBN and Click stimuli the present study found comparatively better ART for clicks. Johnsen and Terkildsen (1980) had concluded that ART elicited by click stimuli was well defined than white noise.

5.2 Relationship between different click rates and ARTs

The present study results revealed that the ARTs decreased from 50/s to 300/s i.e., 84.5 to 68.74 dB HL at right ipsilateral 50/s to 300/s stimulation (with mean improvement of 6.08 dB, 5.56 dB, 2.56 dB, and 1.56 dB as rates increased from 50 to

100/s, 100 to 150/s, 150 to 200/s and 200 to 300/s) respectively, 89.6 to 75.6 dB HL at right contralateral 50/s to300/s stimulation (with mean improvement of 6.18 dB, 4.12 dB, 2.0 dB, and 1.68 dB as rates increased from 50 to 100/s, 100 to 150/s, 150 to 200/s and 200 to 300/s) respectively, 83 to 66 dB HL at left ipsilateral 50/s to 300/s stimulation (with mean improvement of 6.84 dB, 6.16 dB, 2.64 dB, and 1.6 dB as rates increased from 50 to 100/s, 100 to 150/s, 150 to 200/s and 200 to 300/s) respectively, and 89.9 to 75.7 dB HL at left contralateral 50/s to 300/s stimulation (with mean improvement of 6.56 dB, 3.92 dB, 2.72 dB, and 1.16 dB as rates increased from 50 to 100/s, 100 to 150/s, 150 to 200/s and 200 to 300/s) respectively which is in accord with the study done by Rawool (1995;1996) which concluded that threshold benefit was 11.2 dB with a rate rise from 50 to 100/sec, 7.8 dB with a rate rise from 100 to 200/sec and further decreased for 200 to 300/s to 2.6 dB which is attributed to temporal integration. Fielding and Rawool (2002) also have reported similar results in children with 10.5 dB improvement from 50/s to 100/s. Rajith (2017) also concluded in accord with this study by reporting a mean improvement of 7.6 dB, 4.16 dB, 2 dB and 1.6 dB as rates increased from 50 to 100/s, 100 to 150/s, 150 to 200/s and 200 to 300/s respectively in normal hearing children.

5.3 Comparison of ARTs elicited by ipsilateral and contralateral stimulation

ART obtained for all the stimuli in the present study was found to be better in ipsilateral stimulation compared to contra-lateral stimulation such as 5-10 dB difference for pure-tone and broad band stimuli and 7 to 12 dB difference in clicks stimuli, which is in accord with Rawool (2011) which had reported measurement of ARTs using click stimulus in 14 normal hearing females whose the age ranging from 19 to 32 years. The results of the study concluded an 11.42 dB betterment in ART by ipsilateral stimulation compared to contralateral stimulation. Cacace et al, (1991) also found ipsilateral thresholds better than contralateral thresholds. However, the present study's results are in disagreement with Laukli and Mair (1980) reported on 20 normal-hearing adults which found no significant difference between ipsilateral and contralateral stimulated ART.

5.4 Effect of gender on ART

The present study's comparison of ARTs between genders revealed no significant difference. This result is in agreement with the study done by Rawool (1998), which studied the impact of gender on ipsilateral ART in 24 normal-hearing adults using click stimulus and found no obvious difference between genders. Osterhammel and Osterhammel (1979) had also reported no significant gender difference when ARTs were measured for 143 females and males within the age group of 10 to 80 years. This was also supported by the study done by Jerger (1972) with 1133 individuals, including normal hearing and sensori-neural hearing loss individuals where no significant gender differences are reported.

Chapter 6

Summary and Conclusions

Acoustic reflex is the contraction in the middle ear muscle in reaction to severe acoustic stimulation. Numerous studies have been reported were acoustic reflex thresholds (ART's) are obtained using different stimuli and different stimulus parameters. And there are studies which compared acoustic reflex thresholds across different stimuli, like pure tone and broad band noise, broad band noise and clicks. Comparison between ART's elicited by click and pure-tone stimuli are not found in literature so it was taken up in this study. Thereby, the present study was designed with the aim to estimate acoustic reflex thresholds using clicks at different click rates, pure-tones of different frequencies such as 500, 1000, 2000 and 4000 Hz and wide band noise. Also to compare and correlate the variations in acoustic reflex thresholds using pure tones, clicks and wide band noise.

The present study included 50 normal hearing individuals in the age varying from 18 to 40 years. All the participants were subjected to pure tone audiometry, otoscopic evaluation and tympanometry and the participants who only had normal findings were preceded for the further evaluation. Initially acoustic reflex thresholds for pure tones of different frequencies such as 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz was recorded for both ipsilateral and contra-lateral responses for both the ears. Then ART for wide band noise for the same were recorded. Then ART for click stimuli (frequency range of 1000 to 4000 Hz) at different click rates such as 50/s, 100/s, 150/s, 200/s, 250/s and 300/s was recorded for the same.

The analysis revealed significant difference in ARTs between all the three stimuli. ART obtained by wide band noise was better than pure tone stimuli by 5-15 dB HL, clicks were better than wide band noise by 7-15 dB HL, clicks were also better than pure tone by 17-25 dB HL. Comparing all the three stimuli clicks were found to yield better threshold, this might be due to the stimulation of wide frequency range and more energy compared to other test stimulus used. The ARTs decreased from 50/s to 300/s i.e., 84.5 to 68.74 dB HL at right ipsilateral 50/s to300/s stimulation respectively, 89.6 to 75.6 dB HL at right contralateral 50/s to300/s stimulation respectively, 83 to 66 dB HL at left ipsilateral 50/s to 300/s stimulation respectively, and 89.9 to 75.7 dB HL at left contralateral 50/s to 300/s stimulation respectively. The ART's obtained for all the stimuli in the present study was found to be better in ipsilateral stimulation compared to contra-lateral stimulation such as 5-10 dB difference for pure tone and wide band stimuli and 7 to 12 dB difference in clicks stimuli was found. On comparing the ART's between gender, significant difference was not found revealing absence of impact of gender on ART's.

Implications of the study

- The ideal rate of clicks such 300/s can be used to evaluate ART effectively in clinical population.
- Click stimuli can be used to measure ART's in difficult to test population like individuals with hyperacusis, reduced loudness discomfort level and recruitment.
- It can also be used as a screening tool for difficult to test population, as it is less time consuming.

- Click induced ART’s can also be used to measure ART’s in individuals having more than mild to moderate hearing loss which cannot be done using pure tones or noise stimuli as their thresholds are comparatively more.

Limitations of the study

ART’s were elicited in 5 dB step pattern for pure tones and wide band noise stimuli while for clicks 2 dB step was used. Better ART’s could have been found if 2 dB pattern was followed for pure tones and wide band noise stimuli also.

Future directions

- Similar study can be done for different age groups from children to older adults to find the ART difference between different stimuli.
- ART’s can be measured for different clinical population using click stimulus as it was found to yield better thresholds and can be compared with the ART’s elicited using pure tones which is present in the literature.
- ART’s using clicks can be measured for individuals with hyperacusis and individuals with higher degree of hearing loss.

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