AMPLITUDE MODULATION DISCRIMINATION IN INDIVIDUALS WITH NORMAL HEARING SENSITIVITY HAVING TINNITUS

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JULY, 2020

CERTIFICATE

This is to certify that this dissertation entitled **'Amplitude Modulation Discrimination in Individuals with Normal Hearing Sensitivity Having Tinnitus'** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: 18AUD025. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that this dissertation entitled **'Amplitude Modulation Discrimination in Individuals with Normal Hearing Sensitivity Having Tinnitus'** is the result of my own study under the guidance a faculty at 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.

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Abstract

The aim of the study was to evaluating the amplitude modulation discrimination function (rate and depth) in individuals with normal hearing sensitivity having tinnitus. The study consists of two groups of normal hearing individuals in the age range of 18 to 45 years. Group 1 consists of 20 participants with complaint of tinnitus having normal hearing sensitivity and group 2 consists of 20 participants with no audiological complaints. Group 1 was further divided into intermittent and continuous tinnitus (14 intermittent tinnitus individuals and 6 continuous tinnitus individuals). Temporal perception was assessment using amplitude modulation depth discrimination and rate discrimination under two conditions; in quiet and noise condition. The result revealed that the clinical group had poorer discrimination than control group in quiet condition and the perception ability was worse under noise condition. When intermittent and continuous tinnitus patients were analysed, intermittent tinnitus group had slightly poor scores. However, it can be concluded that there is damage at auditory nerve fibers, specifically at low spontaneous rate fibers, which cannot be assessed using routine audiological evaluation. Also, it is insisted to measure at supra-threshold level when individual come with a complaint of tinnitus having normal hearing, which will further help in management.

Chapter 1

Introduction

Tinnitus refers to ringing of sound in the ear without any external stimulus. It has become a very common hearing problem among people across all the age range. Prevalence of tinnitus is about 30% of which, 8% of the population have annoying tinnitus (Shargorodsky, Curhan, & Farwell, 2010) that affect day to day life. Individual with tinnitus have many psychological disturbance such as depression, anxiety, isolation, sleep difficulty (Scott & Lindberg, 2000) that affect day to day life. There are different theories explaining the generation of tinnitus, commonly accepted pathophysiological causes of tinnitus include an increase in neuronal firing, abnormal neuronal synchrony and change in tonotopicity of cortex because of reduction of input signal that reaches the auditory system (Lanting, Kleine, Dijk, 2009). Most of the patient with a complaint of tinnitus will be having associated hearing loss, which is due to compensatory mechanism at the auditory system.

The perception of tinnitus is different from one individual to another individual in terms of pitch and loudness, intermittent or continuous, and ringing or pulsatile features etc. It may be loud and intense which can lead to psychosocial problems and affect their daily activity. Chronic tinnitus can lead to depression (Holgers, Erlandsson, & Barrenas, 2003; Folmer, Griest, & Martin, 2001) anxiety (Folmer, Griest, & Martin, 2001), insomnia (Folmer, Griest, & Martin, 2001), problem with auditory perception (Tyler & Baker, 1983; Wilson, Henry, Andersson, Hallam, & Lindberg 1998) and general and mental health reduced. In extreme cases, suicide may result from intractable tinnitus (Johnston & Walker, 1996).

To focus on subject having tinnitus with normal hearing sensitivity is more challenging, as in to identify their generation site. Schaette and McAlphine (2011) have stated that chronic tinnitus population may have hidden hearing loss due to low spontaneous nerve damage which is not identified in audiogram. Major cause of tinnitus is because of change in neuroplasticity at the level of central auditory system occurred due to age related changes or over noise exposure (Shore, Roberts, & Langguth, 2016). Bharadwaj, Verhulst, Shaheen, Liberman, and Shinn-Cunningham (2014) hypothesized that temporal processing ability is coded by low spontaneous fibers (SR); and any damage to low SR fibers does not affect audiogram threshold. When majority of high SR fibers are normal and only low SR fibers are affected, patient will not have difficulty in quite listening environment (Lobarinas, Salvi, & Ding, 2013), and have difficulty in discriminating or identifying natural speech with noise (Ryu, Ahn, Lim, Joo, & Chung, 2012). When high spontaneous rate fibers are normal and only low spontaneous fibers are damaged hearing thresholds might be normal and will have difficulty in temporal processing abilities. Low SR fibers have good phase locking abilities than high SR fibers at higher levels, especially in noisy environment (Joris &Yin, 1992). In patients with tinnitus, they might have damage in low spontaneous rate fibers which are not evident in audiogram.

Neuroimaging studies have also seen changes in neuronal activity that leaded to change in tonotopic organization in the auditory system (Talavage, Sereno, Melcher, Ledden, Rosen, & Dale, 2004). Change in the neuronal firing activity as such is not seen in fMRI and PET but magnitude of firing change is seen. Tonotopic organization of auditory cortex is changed because of functional loss in auditory nerve fibers (Eggermont, 2007).

The effect of tinnitus in auditory system has been studied subjectively and the effect has been studied using Gap Detection Test (GDT), Masking curve, Duration Pattern Test (DPT), Gap in Noise test (GIN), Modulation detection test (MDT). The results of GDT study revealed that there is minimum or no effect of tinnitus on GDT (Boyen, Başkent, & Dijk, 2003). Study with masking curve suggests that there is no correlation between the audiograms and masking curves (Mitchell, Vernon, & Johnson, 1981). Study using DPT does not reveal any significant differences in tinnitus population (Gilani et al, 2013). Gap in Noise test results identified patients with tinnitus have difficulty in temporal resolution coding (Turner & Parrish, 2008; Gilani, et al, 2013; Fournier & Hebert, 2013). In the present study Amplitude Modulation Depth Discrimination (AMDD), Amplitude Modulation Rate Discrimination (AMRD) is used to code the response of low spontaneous rate fibers with and without the presence of background noise to mask high spontaneous rate fibers.

1.1. Need of the study

Paul, Bruce, and Roberts (2016) have measured the amplitude modulation detection threshold in tinnitus (intermittent and continuous) population with normal hearing to find if there is a damage to auditory nerve fibers that codes for temporal sensitivity which is hidden on the regular hearing evaluation. Perception of temporal abilities involves resolving the fine details in spectrum and temporal envelope of speech signal (Moore, 2003; Summerfield, 1987). Perception of temporal abilities requires solving the fine details in the spectrum and temporal envelope of the speech signal (Moore, 2003; Summerfield, 1987). The temporal resolution, which is a temporal processing feature, refers to the capacity over a period of time to distinguish changes in auditory stimuli. It plays a significant role in the comprehension of speech

in noisy situations (Dubno, Horwitz, & Ahlstrom, 2003; Peters, Moore, & Baer, 1998).

They reported that in individuals with continuous tinnitus, the temporal threshold was significantly lower compared to those without tinnitus suggesting an evidence of hidden hearing loss. However, they have not measured AMRD which is also coded at neural level, which is also an important ability to help code the speech under difficult condition. AMDD and AMRD, which is used to assess the temporal resolution that is coded at the auditory nerve fibers, which is damaged in individual with tinnitus. So there is a need to assess temporal resolution ability under noise condition to assess the true problem faced by patients with tinnitus. The present study measured the temporal resolution in individuals with normal hearing having tinnitus (continuous and intermittent) using AMDR and AMDD in quiet and noise condition to check the coding ability of the auditory nerve fibers with reference to low spontaneous ANFs. There was also a need to compare and measure the amount of damage of auditory nerve fibers in individuals with continuous and intermittent tinnitus.

1.2. Aim

This study aimed at evaluating the amplitude modulation discrimination function (rate and depth) in individuals with normal hearing sensitivity having tinnitus.

1.3. Objectives

- To measure the threshold of amplitude modulation depth discrimination in individuals with and without tinnitus having normal hearing sensitivity.

- To measure the threshold of amplitude modulation rate discrimination in individuals with and without tinnitus having normal hearing sensitivity.
- To compare the amplitude modulation depth and rate discrimination threshold in individuals with continuous tinnitus and intermittent tinnitus.

1.4. Null Hypotheses

- There is no significant difference between the threshold of amplitude modulation depth discrimination in individuals with and without tinnitus having normal hearing.
- There is no significant difference between the threshold of amplitude modulation rate discrimination in individuals with and without tinnitus having normal hearing.
- There is no significant difference between amplitude modulation depth and rate discrimination threshold in individuals with continuous tinnitus and intermittent tinnitus.

Chapter 2

Review of literature

Tinnitus is a debilitating condition that affects individual daily life. If the origin of tinnitus is established, then advancing treatment programs can be developed to completely eliminate the tinnitus rather than to alleviate the problems affecting it. In patient with hearing loss, tinnitus is a compensation of cochlear damage. If a person has cochlear damage, it is usually indicated with elevation in hearing threshold. But in few cases cochlear damage are not spotted through elevation in hearing threshold, rather they are notice with complaint of tinnitus without peripheral hearing damage. This condition is commonly seen because of change in neuroplasticity at the level of central auditory system occurred due to age related changes or over noise exposure (Shore, Roberts, & Langguth, 2016).

2.1. Incidence and Prevalence of tinnitus

There are only a few studies available on the incidence of tinnitus. Axelsson and Ringdahl (1989) reported that 14.2% people among randomly selected population complained of tinnitus often or always while 2% of them had severe tinnitus. Tinnitus is common in all age groups, however, studies have shown that either as age increases prevalence of tinnitus increases or tolerance of perception of tinnitus decreases with increase in age. Tinnitus is not a rare condition during childhood; up to age 16 years, about from 13 to 29% in children with normal hearing sensitivity and 59% in children with hearing loss. The presence of tinnitus progressively increases with increase in age (Meric, Gartner, & Chery-Croze, 1998). Hoffman and Reed in 2004 reviewed six studies and found a trend, where higher aged people showed a greater prevalence and a plateau was reached in either 60-69 years or 70-79 years age range. Tinnitus is also more frequently seen in males than females (Axelsson & Rigdahl, 1989) and is more

common in people with hearing loss than in normal people (Axelsson & Ringdahl, 1989; Davis, 1995).

2.2. Types of tinnitus

Instead of conventional classification of tinnitus into subjective and objective tinnitus, Zenner (1998) proposed a tinnitus classification system with the middle ear, inner ear and brain representing the individual functional and anatomical steps involved in the processing of sound. He classified subjective tinnitus into conductive tinnitus, sensorineural tinnitus and central tinnitus. Conductive tinnitus originated due to dysfunction in outer and middle ear, sensorineural tinnitus originates due to the dysfunctions in Outer Hair Cells, Inner Hair Cells, auditory nerve and the extrasensory elements like striavascularis and central tinnitus arises in the brain.

2.3. Characteristics of tinnitus

Meikle et al. (2004) reported that the onset of tinnitus is more often gradual than sudden. In majority of subject, tinnitus is heard like a tone or a ringing sound, while only 3% describes their perception of tinnitus as a clicking, humming, pulsatile or roaring sound (Meikle et al., 2004; Lockwood, Salvi & Burkard, 2003). Majority of tinnitus patients encounter the problem with sleep (Axelsson & Ringdahl, 1989; Jakes et al., 1985; Tyler & Baker, 1983).

2.4. Causes of tinnitus

Tinnitus is a symptom, not a disease, with many cases. The etiology of tinnitus is not well known. Tinnitus can be caused by number of different disorder in the ear or in the auditory nervous system, (Nelson, 2007). Many a times, tinnitus is assumed to be the consequence of any dysfunction or a lesion in the peripheral auditory system. As tinnitus is mostly accompanied with hearing loss, it might be taken as a

support that the origin is cochlea. But sometimes Tinnitus can also be present with normal hearing threshold, where Hair Cells functioning were not affected but neuronal fibers are affected, which can be due to aging or mild acoustic trauma.

2.5. Pathological causes of tinnitus

Tinnitus is an associated symptom of different pathology such as meningitis, stroke and encephalitis, tumour related problems, cardiovascular disorders, ear related infections, carcinoma, ear and head related injury. One of the major symptoms of Vestibular Schwannoma is tinnitus, and tinnitus is also present in acoustic neuroma. In Meniere's disease, tinnitus is always a major symptom that is present with vestibular abnormalities. Other causes for tinnitus can be vascular tumour or arteriovenous abnormalities (Nelson, 2007).

Gaze-induced tinnitus is caused by injury to auditory nerve due to surgery, in which the loudness of perception of tinnitus changes when the angle of gaze changes (Nelson, 2007). Another possible cause for tinnitus is Hyperthyroidism, where Hyperthyroidism can also lead to hearing loss along with tinnitus (Nelson, 2007). Paget's disease of bone, caused by increased bone replacement with new tissues and enlarged arrears at disconnected areas of the skeleton can also lead to hearing loss ad tinnitus (Young, 2006).

2.6. Non pathological causes

Tinnitus can also be a symptom for various Non-Pathological disorders. Although the causative strand is different, it might mostly destroy the auditory structures peripherally or centrally, which may develop tinnitus. Perception of tinnitus and its sensation is emanating from the ear; many researchers believe that it is generated from nervous system. Nelson (2007) states that in the brainstem, the

acoustic signal is coded in the dorsal cochlear nucleus (DCN). Some Non-Pathological causes of tinnitus are:

Noise induced trauma. Noise induced hearing loss is one of the common issue that affect our health majorly (DHHS, 2009) especially damages the cochlear functioning which is noticed least by people because it is affected gradually without any pain. After noise exposure, the elevated threshold may recover within 2-3 weeks (Fowler et al., 1995) (called as temporary threshold shift) or something sustain in elevated hearing threshold (permanent hearing loss) depending on the severity and time of exposure. Permanent noise induced hearing loss is due to damage of outer hair cell in cochlear and also dysfunction in mechano-sensory hair bundles (Liberman and Dodds, 1984). Cochlear hair cell damage can be seen within few minutes of noise exposure, but hair cell death occurs only after long term continuous exposure to noise. In case of temporary threshold shift, hair cell death is not seen much but dysfunction in nerve fibers at the hair cell terminals. Within 24 hours of noise exposure, glutamate excitotoxicity (Goulios & Robertson, 1983) is seen which may lead to swelling of neural synapses. So normal hearing thresholds need not always indicate normal cochlear functioning, mice exposed to mild acoustic trauma, which resulted in temporary threshold shift, but 50-60% permanent deafferentation of nerve fibers (Kujawa and Liberman, 2009). This deafferentation caused by acoustic trauma will majorly affect low spontaneous rate fibers faster compared to high spontaneous rate fibers, which will not elevate hearing threshold and affect at suprathreshold level. Normal hearing threshold with associated dys-functioning of efferent fibers that will affect speech perception in cochlea extended from brainstem (Zhu et al., 2007, Zettel et al., 2007). So, within 24 hours of noise exposure there is a permanent loss of neural synapses, slow and gradual loss of neurons over a month which will not be noticed in

hearing threshold sensitivity that is assessed using pure-tone audiometry, which thereby is affecting at suprathreshold level, that leads to difficulty in understand speech in adverse listening situations.

Ageing. Tinnitus is often reported as a major ear problem by elderly people (Jacobson, 1996). A decline is seen in the perception of speech in noisy condition in older population due to deterioration of peripheral auditory system, which leads to difficulty in processing sounds at central auditory system. Age related deterioration is due to functional damage to the inhibitory neurotransmitter GABA receptor. Inferior colliculus is the important part of auditory system the code complex signals, which uses the excitatory and inhibitory neurotransmitter GABA for processing the complex signal. Functional loss to neurotransmitter GABA due to aging leads to damage in the peripheral auditory system (Caspary et al., 1999) and the decrease in inhibitory function leads to tonotopic reorganization at the cortical level which leads to compensation and causes tinnitus (Eggermon & Roberts, 2004).

Toxic substances. Tinnitus is caused mostly by the use of drugs and medications. Salicylate, aspirin, antibiotics, cisplatin, quinine, furosemide, hydroxychloroquine, ethacrynic acid, bumetanide, amphotericin B, heavy metals such as mercury, antidepressants such as Wellbutrin (Zyban), and possible caffeine can cause tinnitus (Nelson, 2007).

Temporo-Mandibular joint (TMJ) syndrome. In certain cases tinnitus is a symptom of TMJ syndrome, caused by Temporo-Mandibular joint dysfunction in the jaw. The muscles and nerves within the jaw are very close to the nerves that control hearing, so TMJ can cause tinnitus. Although TMJ syndrome is typically associated

with clicking and popping noises, the tinnitus ringing type is often common (Boniver, 2002).

Ear-related causes. Although wax (cerumen) obstruction of the ear canal is an obvious potential cause of tinnitus, some researchers suggest that even small amounts of ear wax may contribute to tinnitus. Another obvious factor is conductive deafness caused by perforation of the eardrum (Nelson, 2007).

Dental problems. Dental problems are another frequent cause of tinnitus. Tooth abscesses or impacted wisdom teeth can cause tinnitus. Injury of the nerves during extraction of a wisdom tooth has also been known to cause tinnitus (Nelson, 2007).

Middle ear infection. The middle ear can have several problems associated with it. One of the most common causes is the calcification due to high acid levels. The calcification of the three tiny bones in the middle ear is what causes the tinnitus (Nelson, 2007). A recent study by Raj, Bartnik, Pilka, Fabijanska, and Borawska (2008) found that over two third of the cases of tinnitus in patients below the age of 35 are caused by infection. Eustachian tube inflammation can also produce tinnitus, which would usually be accompanied by an earache (otitis) and a sensation of fullness in the ears.

2.7. Tinnitus with Normal Hearing

Tinnitus is presumed to be the result of altered neural activity and may result from a lesion or dysfunction at any auditory system level. Thus, the source of tinnitus perception may be anywhere in the auditory system, although it is believed to be most commonly located in the auditory periphery. Some forms of tinnitus are generated

mostly by abnormal hair cell activity or abnormal functioning of most peripheral part of the auditory nerve in the ear (Cazals, Negrevergne, & Aran, 1978).

Hearing sensitivity as a whole is reduced by 25 or 30 dB HL (Bonfils et al, 1988; Glattke & Robinette, 2002; Lopes & Carlos, 2005), the existence of OAE that confirm the integrity of the cochlear system. A number of studies (Ceranic et al., 1995; 1998) have shown evidence that in tinnitus patients; OAEs are not normal or easily detectable at the tinnitus frequency region, even in subjects with normal hearing thresholds.

Almieda et al. (2006) reported that TEOAEs were abnormal in 70.2% of subject with normal hearing (with tinnitus) than subjects without tinnitus. DPOAEs were abnormal in 68.4% of subjects who had normal hearing with tinnitus. DPOAE levels in tinnitus patients with normal hearing were reported to be lower or higher than those in individuals with normal hearing without tinnitus (Norton et al., 1990 & Mitchell et al., 1993). In tinnitus group there is a decrease in DPOAE amplitude for some frequencies and steeper slope of input-output curve (Bartnik, Rogowski, & Borawska, 2004). Kaul et al. (2008), suggested that tinnitus is frequently associated with varying degrees of cochlear dysfunction in normal hearing patients. He observed that patients with bilateral tinnitus displayed higher percentage of irregular SNRs at most frequencies as opposed to unilateral cases.

2.8. Assessment of tinnitus

Medical Evaluation. For patients with pulsatile tinnitus, who often have a certain physical pathology, medical examination is particularly important (Sismanis, 1998; Wackym & Friedland, 2004). A radiological or laboratory test in patients with tinnitus may be recommended to determine whether there is a reasonable possibility

that the tinnitus might be a correctable cause (Perry & Gantz, 2000; Wackym & Friedland, 2004).

Audiological Evaluation. Audiological evaluation should incorporate pure-tone audiometry, speech-recognition thresholds, speech identification scores, immittance evaluation & tinnitus psychoacoustic measures. Loudness discomfort levels (LDLs) should also be determined at audiometry frequencies to make sure that patients are not exposed to any sound during testing that can exceeds their LDLs.

Tinnitus Psychoacoustic Assessment. Tinnitus psychoacoustic evaluation often involves finding the best matched frequency and intensity of the tinnitus perceived and whether residual inhibition (temporary suppression or elimination of tinnitus following auditory stimulation) exists. After obtaining the pure-tone audiogram, examiner focuses on finding a pitch match and a loudness match of the tinnitus perceived. Tinnitus psychoacoustic evaluation is necessary to assess or document the effect of masking stimuli on the tinnitus perception (Henry & Meikle, 2000; Schechter & Henry, 2002). These measures are also important for individualized counselling purposes, particularly in treatment like Tinnitus Retraining Therapy (TRT) (Jastreboff, 1995). In addition, psychoacoustic tests are useful in evaluating and verifying the subjective indications of the patient's tinnitus condition when the patent is involved in the tinnitus-related legal action (Henry, 2004).

Vernon and Meikle (1981) described in detail a protocol for the loudness and pitch matching. Their approach included three different methods, which regularly vary between threshold checking, matching, and pitch matching.

Questionnaires to assess severity of tinnitus. Questionnaires can be used to measure tinnitus and tinnitus questionnaires have an index score to assess the impact

of tinnitus on the day-to-day life of the patient (Meikle, Griest, Stewart, & Press, 1995). To be able to categorize tinnitus frequency, certain tinnitus instruments suggest specific ranges of their index scores (Newman, Sandrige, & Jacobson 1998). Although an index score is usually helpful in establishing the need for management, it can over-estimate or under-estimate tinnitus severity. Some of the questionnaires which are used for tinnitus evaluation includes; Tinnitus Severity Index (TSI), Tinnitus Handicap Inventory (THI).

The TSI is a questionnaire of twelve items that measures the effect of tinnitus on work and social activity and the overall quality of life with a rating scale of 3 to 5. The THI is a questionnaire of twenty-item self-assessment in which patients must answer either "yes," "often," or "no" to show the impact of tinnitus on emotions and everyday activities. The answers are graded on a scale of 4-2-0, respectively; thus THI scores will range between 0 and 100. Higher THI scores indicate greater perceived disability from tinnitus.

Tinnitus and Temporal Processing. Temporary processing is an important auditing skill required for the complex auditory task required for higher level audit processing. Temporal processing in the auditory domain refers to the processing of timing aspects. This ability is one of the very important basic behaviours of auditory system, which helps in higher level processing, like perception of speech in quiet and in noisy background conditions, localization, binaural integration and separation and also pattern processing ability (Musiek et al, 2005; Musiek, Chermak, & Weihing, 2007). Tinnitus is a problem with is always accompanied with other disorders, whether it is generated peripherally or centrally, it is spontaneous too. Tinnitus patients who have more difficulty in understanding speech that is degraded, also have

poor temporal processing ability (Gilani et al., 2013), which will also provide information, whether the generation of tinnitus is peripheral or central mechanism.

The study conducted on rats using acoustic startle reflex to measure gap detection in order to find the ability to process temporally in animals. The result revealed that in experimental group noise induced tinnitus rats had higher threshold compared to controls group and they conclude saying that higher threshold are due to poor temporal processing ability (Turner et al., 2006; Fournier & Hebert, 2012).

Sanches, Sanchez, and Carvallo (2010) investigated the effect of cochlear damage that influences the temporal resolution ability in tinnitus population with normal hearing. Total of 48 subjects participated in the study having normal hearing sensitivity, grouped into two groups, control group with no auditory complaints and research group with complaint of tinnitus. They measured distortion production otoacoustic emission test, Gap in noise test and high frequency pure tone thresholds. Their results revealed significant difference between the two groups and more prominent in Gap in Noise test and high frequency thresholds. They conclude by saying temporal resolution is affected by partial damage or dysfunction in the peripheral auditory system in patients with tinnitus.

Sanches, Sanchez, and Carvallo (2010) compared the correlation between gap in noise test with hearing threshold and age in 44 subjects having normal hearing sensitivity, which was further grouped into two groups; control group without tinnitus and experimental group with tinnitus. All subjects underwent routine audiological evaluation along with Gap in Noise test. When compared Gap In Noise test with both the groups subjects without tinnitus detected gap having shorter time than compared to experimental group. Age did not correlate with Gap in Noise test. So, they

concluded that Gap in Noise test can be used to identify temporal resolution deficit in patient with tinnitus.

Similar pattern of results was acquired by Gilani et al. (2013) in which 20 individuals participated in the study with auditory complaint of tinnitus and having normal hearing sensitivity. Results reported that their temporal resolution ability was poor when Gap in Noise test was assessed. In the next study by Haas et al. (2012), in which thresholds for gap identification were measured and contrasted with patients with tinnitus and without tinnitus having normal ability to hear. However, Acrani, and Pereira (2010) in their study investigated temporal resolution among 15 individual having chronic tinnitus in both the ear with normal hearing and control group with no auditory complaints. Results revealed no significant difference between both the groups.

Auditory temporal processing ability is required to code the fine temporal structures of speech sounds and which is processed at the integral auditory system for transmitting acoustical information through the auditory pathway. Majority of the studies have assessed a gap detection task and found a poor performance, which can be attributed to lesions in the external or internal cilia or the auditory tract, altered spontaneous activities of the auditory system in tinnitus subjects.

Ability of understanding Speech perception in quiet and noisy environment was measured in all the subjects having tinnitus, which was split into two classes, with and without hearing loss, to determine whether tinnitus leads to speech comprehension difficulties. Testing the speech recognition ability in quiet condition will not predict the ability of recognition in noisy environment (Killion, 2002). Individuals having severe degree of cochlear or neural damage perform poorer in

speech test under quiet condition itself, but individual with subtle cochlear damage may not indicate hearing deficit when tested in quiet condition. Therefore, clinicians should directly measure the speech recognition in noisy conditions (Killion, 2002).

Newman, Wharton, Shivapuja, and Jacobson (1994) investigated the comparison among tinnitus evaluation of pitch matching and loudness matching, speech understanding test and self-perceived handicap in individual with complaint reduced hearing sensitivity and tinnitus. Subjects showed difficulty in identify speech in noisy condition, which had low redundancy. They concluded that patients with complaint of tinnitus have difficulty in perceiving speech in noisy condition when linguistic redundancy is reduced.

Huang et al. (2007) used Mandarin Speech Perception in Noise Test (MSPIN) to evaluate 20 participants having tinnitus and normal hearing ability. The result showed that control group had significantly better scores in Mandarin Speech Perception in Noise Test (MSPIN) compared to research group. Similar study done by Ryu et al., (2012), they conclude that tinnitus by itself is the major cause that reduced the perception of speech ability under noisy condition.

Hennig, costa, Urnau, Becker, and Schuster (2011) measured and compared speech recognition ability in quiet and noise condition in patients with Tinnitus and Hyperacusis, having normal hearing thresholds. The result of the study showed no significant difference between both the clinical and control groups in quiet condition but significantly lower performance in noise condition in tinnitus and hyperacusis group compared to control group with no complaint of tinnitus and hyperacusis.

In factory workers with tinnitus those were exposed to environmental or occupational noise without the presence of competing noise, Soalheiro et al. (2012)

studied speech recognition indices. Among all the subjects with tinnitus, 50.4% classified their tinnitus as mild, 23% as moderate, 22.4% as intense, 2.0% said it was heard in the presence of silence, for 0.4%, tinnitus was heard after the workday, and 1.8% of people said it was unspecified. Of the 359 workers with tinnitus hearing loss and symptoms of occupational noise exposure, 51.55% found speech perception difficulties. Among workers with normal hearing sensitivity who reported exposure to occupational noise and tinnitus, 83.1% reported problems with sound localisation, speech perception and one or more non-auditory symptoms such as tachycardia, insomnia, anxiety, irritation and difficulties in concentration and attention.

Thus, in the literature majority of the studies reported that subjects with tinnitus as a sole condition have difficulty in speech perception under noisy condition. Therefore when patients come with complaint of tinnitus should be measured under noise condition to understand the true deficit.

Chapter 3

Method

The present study was conceived to investigate the effect of tinnitus on the auditory system's temporal characteristics. Speech perception abilities were measured indirectly using psychophysical testing with and without noise in individual with normal hearing sensitivity having tinnitus. The comparisons were done with psychophysical test under two conditions, with noise and without noise conditions.

3.1. Selection of participants

The study involved two groups of individuals in the age range of 18 to 45 years. Group 1 consists of 20 individuals with no auditory complaint having normal hearing sensitivity and Group 2 consists of 20 individuals with normal hearing sensitivity having tinnitus. All participants gave signed consent form before testing, which specifies their willingness to take part in the study. The following inclusion and exclusion criteria were used for participant selection in the study.

3.1.1. Clinical group (Group 1)

- All subject had continuous tinnitus in one or both the ear for at least three months
- All participants had 25 dB HL pure tone thresholds in octave frequencies ranging from 250-8000 Hz for air conduction and 250-4000 Hz for bone conduction;
- Participants had an SIS score more than 80% in quiet.
- All the subjects had “A” type tympanogram.
- None of them had a history of ototoxicity and exposure to noise which might cause a hearing loss.

- None of them had an observable neurological symptom or any other general body weakness noticed or reported.
- None of them had an auditory processing deficit.
- None of them had any history of ear pain, ear discharge, and giddiness.
- None of them had any recent history of cold.

3.1.2. Control group (Group 2)

- All subjects had pure tone thresholds within 25 dB HL in octave frequencies from 250 - 8000 Hz for air conduction and 250 - 4000 Hz for bone conduction.
- Participants had an SIS score more than 80%.
- All the participants had "A" type tympanogram.
- None of them had a history of ototoxicity and exposure to noise which might cause a hearing loss.
- None of them had an observable neurological symptom or any other general body weakness noticed or reported.
- None of them had an auditory processing deficit.
- None of them had any history of ear pain, ear discharge, and giddiness.

3.2. Population Size

Two group of participants were included within 18-45 years of age (mean age: 28.1 years) to fulfil the study's objective. The clinical group comprised 20 participants with a tinnitus issue with normal sensitivity to hearing. The participants of the study include 20 individuals with no history of tinnitus (control group) and 20 individuals with tinnitus unilateral or bilateral; intermittent or continuous tinnitus (study group). Age range of 18 - 45 years was considered for the study for both the groups. All the

participants having tinnitus was administered with Tinnitus Handicap Inventory (THI) to assess the severity of tinnitus and participants with mild and above degree were included in the study. The control group involved participants aged 20 matched with average hearing sensitivity and without tinnitus. Table 3.1 gives the mean age and age range of subjects that participated in the study.

Table 3.1

Mean age and age range of the participants

		No. of subjects	Age (years)	
			Mean	**Range**
Clinical group	Male	11	31.63	21-42
	Female	9	33.22	22-45
	Total	20	32.35	21-44
Control group	Male	8	27.12	21-43
	Female	12	26.25	21-45
	Total	20	26.60	21-45

3.3. Instrumentation

- A calibrated 'high frequency audiometry' (Piano Inventis) with TDH 39 headphones enclosed in MX-41/AR supra-aural ear cushions to estimate the air-conduction thresholds, SRT and SIS; and Radio Ear B-71 bone vibrator to estimate the bone conduction thresholds.
- A calibrated 'Grason-Stadler Tympstar (version 2)' middle ear analyzer to evaluate the status of the middle ear.
- HP laptop, core i3processor loaded with the Psycon 2.18 software.
- The laptop's audio output will be routed through a THD-39 headphone housed in supra-aural MX-41AR cushions.

3.4. Test Environment

All the evaluations were carried in a sound treated double room where the noise levels are with the permissible limits specifies by ANSI S3. 1999 (R2008).

3.5. Procedure

Written consent for willing involvement in the study was obtained from all the subjects. For the presence of hearing loss and middle ear pathology, all subjects from both clinical and control groups were assessed.

3.5.1. Case history. A detailed case history was obtained to find out whether the subject had any recent history of hearing loss or any middle ear pathology which may or may not cause a hearing loss. Case history also included the information about the tinnitus such as type of sound, duration of tinnitus, how frequent it occurs and how it affects the daily living to the clinical group.

3.5.2. Otoscopy. Otoscopic examination was done to check that external ear and tympanic membrane status to make sure that the sound conduction is not affected due to external ear pathology.

3.5.3. Pure-tone audiometry. All the participants were subjected to pure-tone audiometry with octave frequencies of 250-8000 Hz for air conduction testing and 250-4000 Hz for bone conduction testing to ensure that the subject had normal hearing. To achieve pure-tone thresholds a modified version of the Hughson and Westlake technique (Carhart & Jerger, 1959) was used. Those subjects with behavioural thresholds below 25 dB were considered for further research in all octave frequencies.

3.5.4. Immittance Audiometry. Immittance audiometry was conducted to rule out any pathology on the middle ear. Tympanogram was obtained for a 226 Hz probe tone by sweeping the presence in the ear canal from +200 to -400 dapa, and for 500, 1000, 2000 and 4000 Hz pure-tone at peak pressure, ipsilateral and contralateral reflexometry. During this test subjects were made to sit comfortably and were asked not to cough. The existence of acoustic reflex was considered to be a minimum admittance shift of 0.03 ml after the onset of the reflex eliciting signal.

3.5.5. Tinnitus pitch and loudness matching. All the subject of the clinical group underwent tinnitus pitch and loudness matching.

Pitch matching. The pitch matching of tinnitus is assessed using 2 alternate force choice method until an approximate pitch was obtained, two tones, in alternating manner (Tyler and Conrad-Armes, 1983), were presented and the client was asked to choose one of the two which closely matched the pitch of his/her tinnitus. This continued till the pitch match is made. For testing, pure tones or narrow band noises were used. The presentation level was 20 dB above the subject's pure tone threshold to the contralateral side to the ear in which the tinnitus was perceived in case of unilateral tinnitus. For those with bilateral tinnitus, if tinnitus was heard equally loud in both ears, the signal was given to the side contralateral to the ear with predominant tinnitus, or to the right ear. The subject was advised to determine which of these types of signals most closely resembled the pitch of the perceived sound in their ear, which was again continuously varied around the audiometric frequencies until the subject found that the pitch of the signal and the pitch of their tinnitus are best matched. The signal frequency which best matched the tinnitus pitch was considered the tinnitus pitch and served as a reference signal for tinnitus loudness matching.

Loudness matching. Using method of limit, loudness was measured. The reference signal was presented to the contralateral side of the ear (Tyler and Conrad-Armes, 1983), in which the tinnitus was perceived in cases of unilateral tinnitus. In cases of bilateral tinnitus, if tinnitus was perceived equally loud in both ears, the reference signal was presented to the side contralateral to the ear with predominant tinnitus, or to the right ear. The intensity of the signal was varied at a 5 dB step till the subject heard the sound which was the threshold for a particular signal. Then the intensity was further increased in 5 dB step till the subject indicates that the signal is equally loud as tinnitus. The difference between the threshold and level of the signal at which the loudness match was obtained is the loudness of the tinnitus.

3.5.6. Experiment 1

Amplitude modulation depth discrimination. Psychoacoustic test for AM depth discrimination was done using PYSCON 2.18 software with adaptive procedure of three alternative forced choice method. After each test, it estimated the likelihood of obtaining the listener response to all the stimuli presented by that test and determined the subsequent stimulus taking into account the psychometric function which gives the highest probability. Out of three stimuli, 2 stimuli were unmodulated sound and one stimulus with different modulation depth. Patient task was to identify the deviant rate stimulus. Least modulation depth of the individual was considered as threshold. Last 4 reversals were considered to average the threshold. Level of presentation was 75 dB SPL. AM depth discrimination test was done at 5 kHz with and without masking noise (masking noise is presented at 50 dB SPL) in control and tinnitus population.

3.5.7. Experiment 2

Amplitude modulation rate discrimination. AMRD was measured using PYSCON 2.18 software with adaptive procedure of three alternative forced choice method. Amplitude modulation rate discrimination was measured at different rates (10 Hz, 40 Hz, & 100 Hz) with 100% depth in both the condition (with and without noise). The invariant stimulus was of higher rates with respect to reference rate. The participants were asked to discriminate the stimulus with different rate and the least discrimination rate was the threshold that is averaged based on last 4 reversals. Level of presentation was 75 dB SPL, AM depth discrimination test was done at 5 kHz with and without masking noise (masking noise is presented at 50 dB SPL) in control and tinnitus population.

3.6. Statistical analysis

The data obtained was tabulated using statistical package for social sciences (SPSS, Version 21.0). Appropriate statistical analysis was carried out in SPSS software.

Chapter 4

Result

The objective of this study was to define the impact of amplitude modulation discrimination (rate and depth) in people with normal hearing sensitivity having tinnitus in quiet and noisy environments. The data obtained underwent statistical analysis using version 20 of the SPSS software. Descriptive statistics was done to estimate the Median for all the tests. The following statistical analysis was performed through the entire community.

- Mann-Whitney U Test was done to see the significant difference in Amplitude Modulation Depth Discrimination between control and clinical groups.
- Mann-Whitney U Test was done between control and clinical group to compare the scores of AMRD.
- Mann-Whitney U Test was done to see the significant difference in AMDD between control and clinical groups.
- Mann-Whitney Test was done between control and clinical group to compare the scores of AMRD.
- Wilcoxon Signed Ranks Test was done on continuous and intermittent tinnitus group to compare the scores of AMDD and AMRD in without noise and noise condition

In the study, Temporal resolution was assessed using amplitude modulation depth discrimination and amplitude modulation rate discrimination in control group with no audiological complaints and clinical group with complaint of tinnitus having normal hearing sensitivity.

Shapiro Wilk's test of normality was administered to check whether the scores of both the working memory tests employed for the test follows the normality curve. The test revealed that the data followed the non-normal distribution ($p<0.05$) curve, hence non-parametric tests were chosen for analysis.

4.1. Amplitude Modulation Depth Discrimination (AMDD)

Figure 1 shows the Median value of AMDD score for both the clinical and control group. In the figure, x-axis represents the clinical and control groups and y-axis represents the scores of AMDD (dB). It can be noted that AMDD scores are almost similar in both the clinical and control groups.

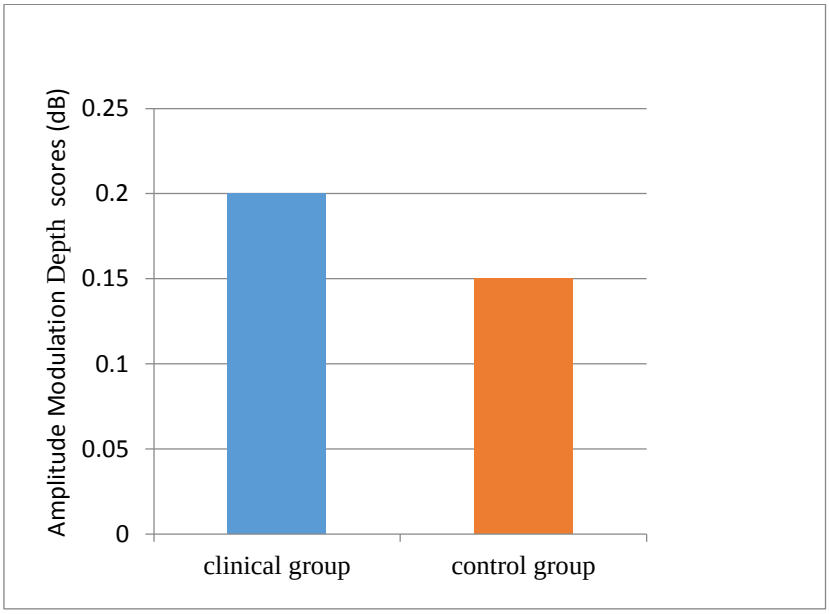

Figure 4.1: Median value of Amplitude Modulation Depth Discrimination for control and clinical groups.

Mann-Whitney Test was done to see the significant difference in Amplitude Modulation Depth Discrimination between control and clinical groups. The result showed that there was no significant difference in Amplitude Modulation Depth Discrimination between both the groups ($Z= -.146$; $p>0.05$).

4.2. Amplitude modulation rate discrimination (AMRD)

The Amplitude modulation rate discrimination test was carried out at three different rates (10 Hz, 40 Hz, & 100 Hz). Figure- 2 shows the Median of AMRD score for both the clinical and control group. In the figure, x-axis represents AMRD at 10 Hz, 40 Hz, and 100 Hz modulation rate and y-axis represents the scores of AMRD (Hz) test. It can be noted that AMRD scores are higher in clinical group than control group. Here higher the scores, poor the discrimination.

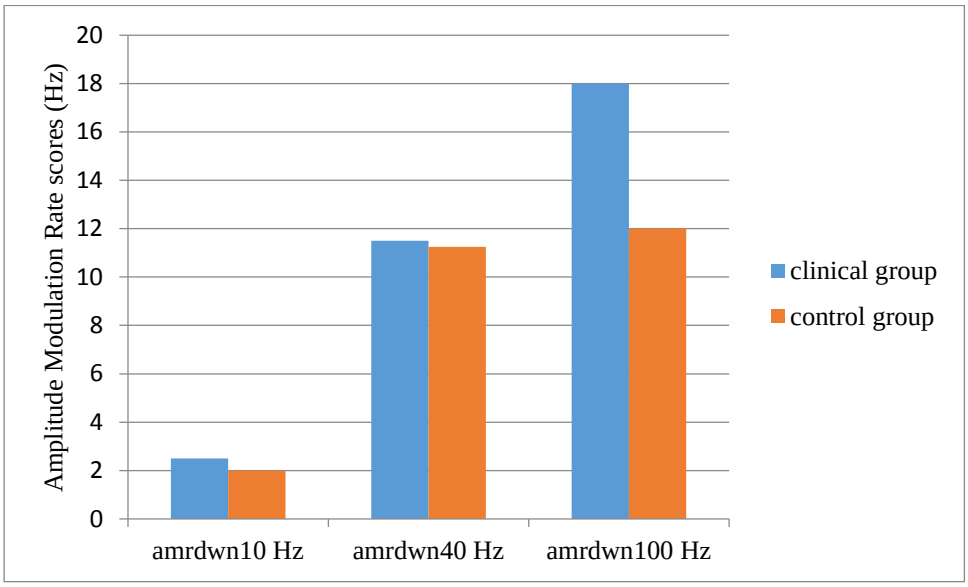

Figure 4.2. Median value of Amplitude Modulation Rate Discrimination OF 10 Hz, 40 Hz, & 100 Hz for control and clinical groups.
Note. amrdwn: Amplitude Modulation Rate Discrimination without noise

Mann-Whitney U Test was done between control and clinical group to compare the scores of AMRD and result showed that AMRD obtained from both the groups were statistically significant for 10 Hz and 100 Hz modulation rate in without noise conditions and no significant difference at 40 Hz modulation rate in without noise condition. The result of the analysis shows that both the groups were statistically significant for 10 Hz and 100 Hz modulation rate in without noise conditions and no significant difference at 40 Hz modulation rate in without noise condition which is given in Table 4. 2.

Table 4.1.

Z value and significance level of AMRD at 10 Hz, 40 Hz and 100 Hz modulation rate between clinical and control group.

	AMRD 10 Hz	AMRD 40 Hz	AMRD 100 Hz
Z Value	**-2.670**	**-2.670**	**-2.670**
Significance level	**P< 0.05**	**P> 0.05**	**P< 0.05**

The result of the current study revealed that individual with tinnitus even though having normal hearing required larger modulation depth and larger rate to discriminate than individual without any complaint of tinnitus. These findings indirectly indicate that individual with tinnitus has problem with temporal resolution even with normal hearing. The scores of the present study are consistent with the previous studies done by Sanches et al. (2010), Gilani et al. (2013) and Haas et al. (2012).

4.3. Effect of noise on AMDD and AMRD

In the present study all the test were measured in two conditions, in quiet and in noise. A noise of 50 dB SPL as given to mask the response of high spontaneous rate fibers and only the response of low spontaneous rate fibers was taken. This is because response of high spontaneous rate fibers can be measured with routine audiological evaluation, but low spontaneous rate fibers can only be assessed at supra-threshold level.

4.3.1. Amplitude modulation depth discrimination

Figure 4.3 shows comparison between the median value of Amplitude Modulation Depth Discrimination score in noise and without noise condition for both the clinical and control group. In the figure, x-axis represents the clinical and control groups and y-axis represents the scores of Amplitude Modulation Depth Discrimination (dB).

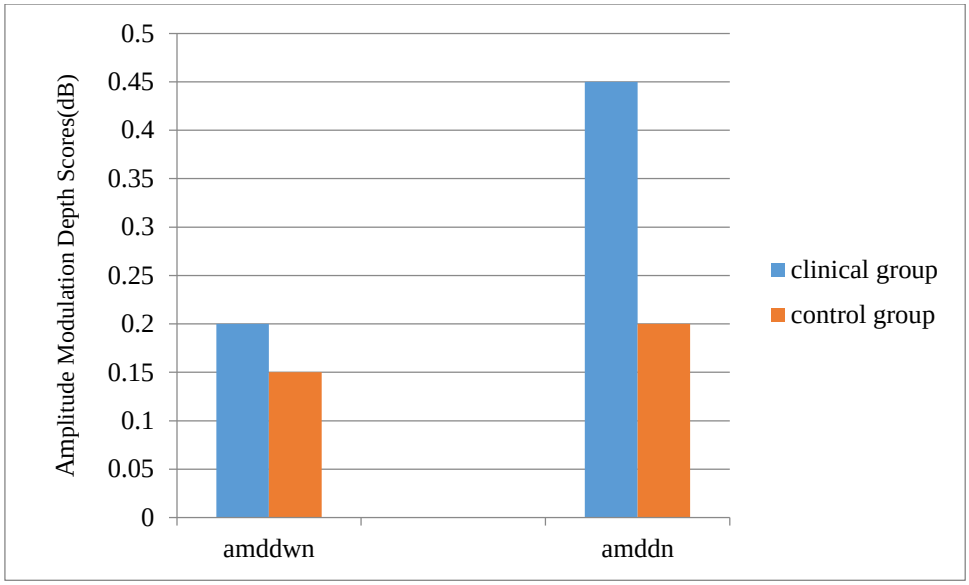

Figure 4.3: Comparison between Median value of Amplitude Modulation depth Discrimination in noise and without noise condition for control and clinical groups.
Note. amrdwn: Amplitude Modulation Rate Discrimination without noise; *amrdn:* Amplitude Modulation Rate Discrimination with noise

It can be noted that AMDD scores are almost similar in both the clinical and control groups in without noise condition but the scores have larger variation in noise condition, where the clinical group have higher scores compared to control group. Further, Mann-Whitney U Test was done to see the significant difference in AMDD between control and clinical groups. The result showed that AMDD is statistically significant in noise ($Z= -4.834$; $p<0.05$).

4.3.2 Amplitude Modulation Rate Discrimination

Figure 4.4 depicts the comparison of Median value of Amplitude Modulation Rate Discrimination score in noise and without noise condition for both the clinical and control group. In the Figure, x-axis represents Amplitude Modulation Rate Discrimination at different rates in noise and without noise condition for both clinical and control groups and y-axis represents the scores of the test, higher the scores poorer the discrimination ability. It can be noted that Amplitude Modulation Rate Discrimination scores are higher in clinical group than control group in both the

condition and the scores are even higher in noise condition for clinical group and almost same in control group.

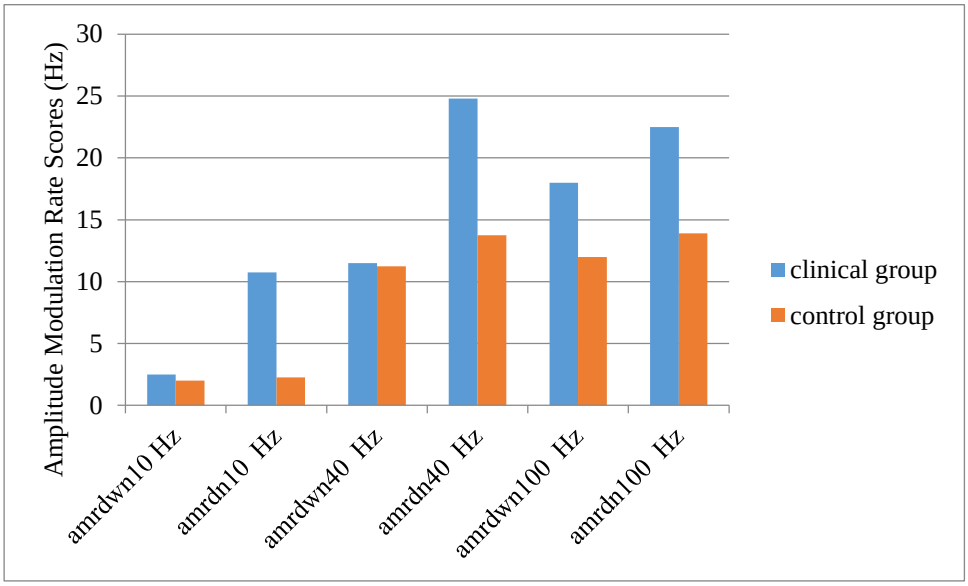

Figure 4.4: Comparison between Median value of Amplitude Modulation Rate Discrimination in noise and without noise condition for control and clinical groups.
Note. amrdwn: Amplitude Modulation Rate Discrimination without noise; *amrdn:* Amplitude Modulation Rate Discrimination with noise

Mann-Whitney Test was done between control and clinical group to compare the scores of AMRD and result showed that AMRD obtained from both the groups were statistically significant across all the three modulation rates in both without noise and noise condition except at 40 Hz modulation rate in without noise condition. The result of the analysis shows that there was a significant difference between both the groups across all the three modulation rates in both without noise and noise condition except at 40 Hz modulation rate in without noise condition which is given in Table 4.2.

Table 4.2.

Z value and significance level of AMRD at 10 Hz, 40 Hz and 100 Hz modulation rate between clinical and control group for noise and without noise condition

AMRD	10 HZ	40 Hz	100 Hz
Without noise condition Z value	-2.670	-1.139	-2.347
Significant value	p< 0.05	p> 0.05	p< 0.05
Noise condition Z value	-5.096	-3.790	-3.316
Significant value	p< 0.05	P<0.05	p< 0.05

The findings in the current study reveal that the ability of perception of speech in noisy environment is reduced in individual having tinnitus when compared to those without any complaint of tinnitus. Similar results were found and reported in previous studies (Newman et al., 1994; Huang et al., 2007; Ryu, Ahn, Lim, Joo, & Chung 2012; Hennig, Costa, Urnau, Becker, & Schuster, 2011; Soalheiro et al., 2012).

4.4. Effect of intermittent and continuous tinnitus

In this study, the factors that caused to differentiate and the significant characteristics that affect the continuous tinnitus and intermittent tinnitus was also measured. So, the clinical group was divided into two based on case history into continuous tinnitus group and intermittent tinnitus group.

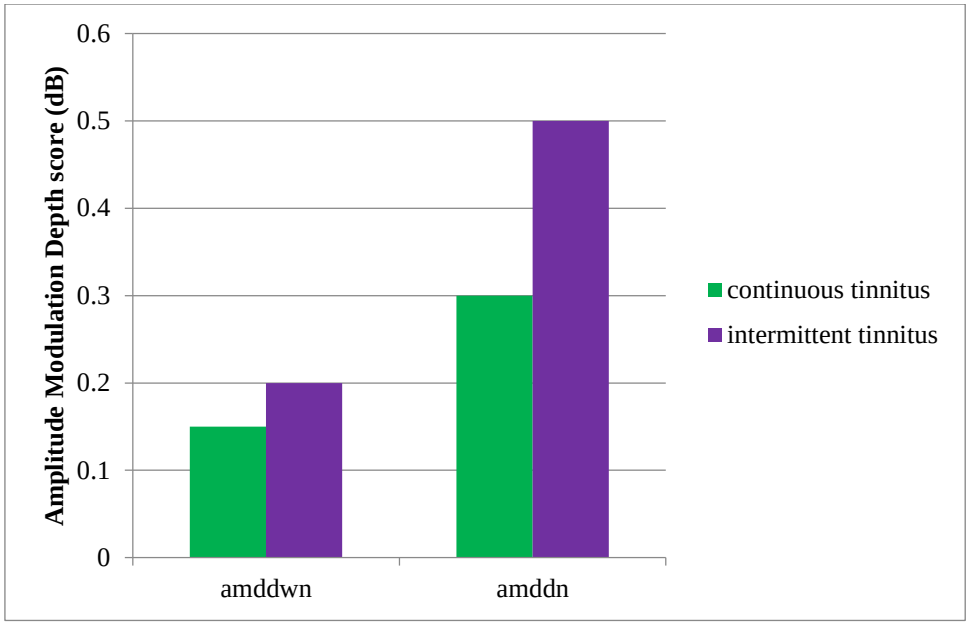

Figure 4.5: Comparison between Median of Amplitude Modulation Depth Discrimination score in noise and without noise condition for continuous and intermittent tinnitus groups.
Note. amrdwn: Amplitude Modulation Rate Discrimination without noise; *amrdn:* Amplitude Modulation Rate Discrimination with noise

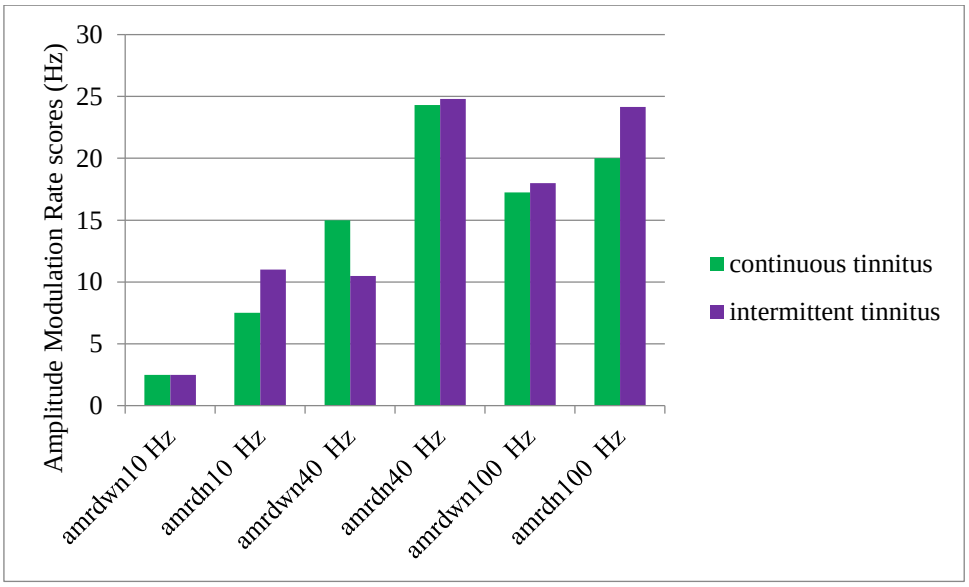

Figure 4.6: Comparison between Median of Amplitude Modulation Rate Discrimination score and Amplitude Modulation Depth Discrimination score in noise and without noise condition for continuous and intermittent tinnitus groups.
Note. amrdwn: Amplitude Modulation Rate Discrimination without noise; *amrdn:* Amplitude Modulation Rate Discrimination with noise

Figure 4.5 depicts the comparison of Median value of AMDD score in noise and without noise condition for continuous and intermittent tinnitus group and Figure 4.6 depicts the comparison of Median value of AMRD score in noise and without noise condition for continuous and intermittent tinnitus group which is sub-grouped with clinical group. In the figure 4.5 and 4.6, x-axis represents Amplitude Modulation Depth Discrimination at different rates and Amplitude Modulation Rate Discrimination test, respectively, in noise and without noise condition for both continuous and intermittent tinnitus group and y-axis represents the scores of the test, higher the scores poorer the discrimination ability. When descriptive statistics was done with both the experiment, Amplitude Modulation Depth Discrimination test scores where similar and same in both the groups for both without noise and noise condition. In second experiment, Amplitude Modulation Rate Discrimination at different rates, there was a very small differences seen in both the groups and did not follow any pattern of scores. At 40 Hz modulation rate, intermittent tinnitus group had little difficulty in both the condition compared to continuous tinnitus group and in 10 Hz and 100 Hz there was no much difference seen.

Wilcoxon Signed Ranks Test was done on continuous and intermittent tinnitus group to compare the scores of AMDD and AMRD in without noise and noise condition and result showed that both AMDD and AMRD test scores obtained statistically significant for both without noise and noise condition except for ARMD 100 Hz modulation rate. The result of the analysis shows that there was a significant difference in both the experiment for both without noise and noise condition except for ARMD 100 Hz modulation rate which is given in Table. 4.3.

Table 4.3.

Z value and significance level of AMDD and AMRD in without noise and noise condition

Groups	AMRD 10 Hz0	AMRD 40 Hz	AMRD 100 Hz	AMDD (dB)
Continuous tinnitus				
Z value	-2.201	-2.201	-1.577	-2.121
Significant value	p< 0.05	p< 0.05	p> 0.05	p< 0.05
Intermittent tinnitus				
Z value	-3.302	-3.297	-2.831	-3.354
Significant value	p< 0.05	p< 0.05	p< 0.05	p< 0.05

The effect of speech perception in intermittent and continuous tinnitus was not studied as far as our knowledge. In this present study an attempt was done to check which group of population (intermittent or continuous tinnitus) had more problem with speech perception. According to the result of the present study, intermittent tinnitus had slightly more problem in speech perception compared to continuous tinnitus.

Chapter 5

Discussion

Tinnitus is a condition where, the symptoms are otologic in nature, several researchers are still unclear about the pathology and origin of tinnitus generation, whether it involves peripheral system or central system, and also some of the studies strongly suggest that the origin of tinnitus involve the neural auditory system. All the cochlear disorders cannot be diagnosed only by routine audiological evaluation such as pure tone audiogram and immittance; further detailed evaluation will be required to find the individual true problem. Some authors such as Ami et al. (2008) and Hesse et al. (2005) used distortion production OAE to check the activity of outer hair cell which will help us to detect even a minor change in the activity prior to shift in the threshold of hearing.

Also, in some published research papers, authors claims that tinnitus is perceived because to dysfunction in neural activity in the auditory system (Ashton et al., 2007; Bartels et al., 2007). Bartels et al., 2007, suggested that the activity of afferent input is altered through the auditory pathway, which may be the cause for tinnitus perception at the nervous structures of auditory system.

Assessing central auditory system was also done by many authors to find the generation of tinnitus. Gap in noise test was done by Musiek et al. (2005), in tinnitus population with confirmed involvement of central auditory nervous system and they reported that the clinical group had larger gap compared to control group, which indicates that GIN is a clinical test in assessment of the ability of temporal resolution, which is also the ability of central auditory system. They tested gap detection in individuals with tinnitus in a study by Fournier and Hebert (2012), and found that the

tinnitus community showed a gap processing deficit for both low and high background noise frequencies. The explanation for poor gap detection may be that chronic tinnitus blocks the gap and leads to impaired gap detection. In normal hearing listeners, Sanches et al. (2010) used the GIN test to assess the capacity of the auditory temporal resolution on 18 people with tinnitus and 23 people without tinnitus. They indicated that there were shorter differences in control group than clinical group. Haas et al. (2012) also noted longer GDT in tinnitus subjects compared to non-tinnitus subjects, and hypothesized that this could be due to some changes in tinnitus patients' neural activity that could prolong.

In the current study, individual with tinnitus needed larger modulation depth and rate for both noise and without noise condition when compared to individuals without tinnitus which suggests poor temporal resolution ability in the clinical population. To the best knowledge, effect of temporal processing on tinnitus using amplitude modulation rate discrimination was not studied earlier.

Consequently, the results of both AMDD and AMRD showed impaired temporal perception in the clinical group compared to control group that is consistent with the literature data. The reason for the same could be due to the deficit at the level of auditory nerve fibers which reduced the ability to temporal resolution and led to tinnitus perception. In the current study, amplitude modulation depth discrimination and amplitude modulation rate discrimination test was used to assess the temporal resolution and also to assess the speech perception in noise ability, the assess the same experiment with noise condition. The results revealed that individual with tinnitus needed larger rate of modulation to discriminate in both without noise and noise condition compared to control group. In amplitude modulation depth discrimination, both the clinical and control group had similar depth discrimination scores but when

noise was given in the background, larger modulation depth was needed for tinnitus population. This suggests that, there is a reduced ability of temporal perception in tinnitus population, especially in noise condition.

Hennig, Costa, Urnau, Becker, and Schuster, (2011) tested speech comprehension in normal hearing individuals with tinnitus and hyperacusis in the presence of competitive noise. They concluded that both groups performed similarly in silence for speech recognition, but a lower level performance on speech perception in noise was seen in tinnitus patients as compared to normal-hearing patients without tinnitus and hyperacusis complaints. Similar findings was reported by Jain and Sahoo in 2014; they used modulation detection test to assess the temporal resolution in tinnitus population with normal hearing and reported that tinnitus population needed greater modulation depth in noise with wide range of modulation frequencies, which was also similar to our study. The result of the present study of both amplitude modulation depth discrimination and amplitude modulation rate discrimination test showed impaired temporal resolution in individual with tinnitus and more impairment was seen under noise condition which is in accordance with the literature. The cause may be due to deficiency in the auditory system's neural systems, which contributes to tinnitus perception, and impairs temporal resolution.

Also, in this study, we evaluated the same test with background noise in both clinical and control group and the result revealed the performance was as reduced in quiet condition and more drastically affected in noise condition for patients with complaint of tinnitus when compared to individual with no complaint of tinnitus. Similar finding were also reported by many authors (Hennig et al., 2011; Ryu et al., 2012; Newman et al., 1994; Huang et al., 2007).

This reduced ability would be the fact because of the many reasons. One is perception of tinnitus solely can affect speech perception and the activity of medial olivary cochlear system could be reduced and that might affect speech perception in noise (Breuel et al., 2001; Grataloup et al., 2008). Also, Hennig et al., 2011, measured speech recognition with competing background noise in tinnitus and control group with normal hearing sensitivity and also patients with hyperacusis. They concluded saying that both the group performed similarly in quiet condition but under competing background noise condition speech perception scores was poorer in tinnitus group when compared to normal group. Therefore we can state that tinnitus patient who have normal hearing sensitivity can have problem with different communication environment, which may be due to deficit in neural activity and also because of dysfunction in medial olivary cochlear system.

Chapter 6

Summary and Conclusion

Tinnitus is perception of sound without any external sound. The pathophysiology for the tinnitus generation is still not clearly understood, as there is no single hypothesis, theory or the model can explain pathophysiology of tinnitus. Some Studies reported that tinnitus is generated majorly because of cortical reorganization in the central auditory nervous system (Eggermont & Komiya 2000; Rajan & Irvine, 1998) or hyperactivity of central auditory pathway (Sasaki et al., 1980; Kaltenbach et al., 2002). Most of the studies say the origin of tinnitus generation is peripheral auditory pathway and these disturbances in peripheral pathway leads to changes in central auditory system (Bauer et al., 2008; Brozoshki et al., 2002; Heffner & Harrington, 2002; Kaltenbach et al., 2004).

This study was conducted to compare the peripheral pathway functioning in individual with tinnitus with normal hearing sensitivity as the clinical group, and no auditory complaint as the control group. The study consists of two groups in the age range of 18 to 45 years. Group 1 consist of 20 participants with tinnitus having normal hearing sensitivity and group 2 consist of 20 participants of with normal hearing and no other auditory complaints. Group 1 was further divided into intermittent and continuous tinnitus, where 14 had intermittent tinnitus and 6 had continuous tinnitus. Two experiments such as AMDD and AMRD at 10 Hz, 40 Hz, and 100 Hz modulation rates were done in quiet and background noise condition to assess the functioning of auditory nerve fibers.

The result of the study showed that the temporal perception is affected in individual with tinnitus even though they have normal hearing. And also when

background noise was given, the scores were even poorer in tinnitus individuals, which suggest that their speech perception is more difficult in noisy situation. Within the tinnitus group, intermittent tinnitus had slightly more difficult in perception compared to continuous tinnitus.

Based on the results of this study, it can be conclude that in patients with tinnitus, temporal perception and speech perception in noise ability is affected even in individual with normal hearing sensitivity. This reduced ability can be called neuropathy which is often seen in aging and noise trauma that is more obvious at suprathreshold level. With routine audiological evaluation, these deficits are not ruled not. This study was done to allow assessment of suprathreshold hearing status to know the true deficit and cause of tinnitus with individual having normal hearing.

Clinical implications

- The present study was a preliminary attempt to investigate amplitude modulation discrimination for rate and depth in individuals with tinnitus, to check the functioning of auditory nerve fibers.
- The presence of masking noise on rate and depth parameters provided us an insight about the functioning of low-spontaneous rate fibers in tinnitus population.
- The result of the study will be useful in understanding whether there is a dysfunction at the level of low spontaneous rate fibers in tinnitus patients which is not evident in regular audiological evaluations.

Future directions

- The number of individuals in sub-clinical groups (intermittent and continuous tinnitus) was less to generalize the results. Hence, the future study can use large sample size to find the true deficit in intermittent and continuous tinnitus patients.

- It was the first attempt to assess the tinnitus population with amplitude modulation rate discrimination. In the future study, the same test can be done with different degrees of tinnitus, to know the degree of deficit in temporal resolution.

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