FREQUENCY DISCRIMINATION TREATMENT AND RELAPSE ON TINNITUS: A SINGLE SUBJECT DESIGN

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CERTIFICATE

This is to certify that the dissertation entitled "**Frequency Discrimination Treatment and Relapse on Tinnitus: A Single Subject Design"** is a bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration Number: 16AUD030). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "**Frequency Discrimination Treatment and Relapse on Tinnitus: A Single Subject Design"** is the result of my own study under the guidance of Dr. Hemanth. N, Reader in Audiology, All India Institute of Speech and Hearing, Mysuru, and has not submitted earlier in any other University for the award of any Diploma or Degree.

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Abstract

Introduction: Tinnitus is the perception of sound without external sound source. There are different methods of treating a tinnitus which includes sound based therapy, habituation therapy and counselling but these techniques are passive sound therapies. Frequency discrimination task is an active sound therapy for treating tinnitus. It holds the intrinsic motivation of client because of its interactive module.

Aim: To investigate FDT treatment and its relapse on tinnitus symptoms

Objectives

1. To compare the tinnitus characteristics in each phase (baseline, treatment and relapse)

2. To comparing pre- and post-treatment effect on tinnitus percept (pitch, loudness, THI and TFI),

3. To compare between post treatment and after withdrawal of treatment on tinnitus percept.

Method: A single subject ABA design was utilized to document treatment of FDT and its relapse on tinnitus percept. Five subjects who had subjective tinnitus with minimal to mild hearing loss were participated in the study. A baseline tinnitus pitch, loudness, THI and TFI were documented. FDT treatment was administered for ten consecutive sessions, where tinnitus pitch and loudness were assessed. In addition, THI and TFI were document at the end of each week. Further, tinnitus characteristics were documented after the cessation of treatment to estimate relapse.

Results: A stable baseline was observed in each of the tinnitus characteristics. During treatment effect, a change in pitch and reduction of loudness was observed. In addition, functional index and handicap severity were reduced. A potential of contrast was seen between baseline and treatment sessions on tinnitus characteristics in each client. It infers a clinically significant habituation to tinnitus was achieved during the FDT treatment sessions. It was observed that each of the tinnitus characteristics overlap between treatment and relapse sessions indicating, breaking of conditioned reflex arc and established cortical reorganization.

Conclusion: FDT treatment showed positive outcome in a reduction of tinnitus percept. In addition, its effect was maintained even after cessation of treatment.

Chapter 1

INTRODUCTION

Tinnitus is the conscious perception of a sound that originates in an involuntary manner in the head (McFadden, 1982). A tinnitus is a frequent phenomenon occurring in an estimated 10 to 15% of the population (Coles, 1984). The maladaptive plasticity in the central auditory pathway resulted from following changes in input from the periphery is considered to be a cause of tinnitus (Roberts, Eggermont, Caspary, Shore, Melcher & Kaltenbach, 2010). There are different methods of treating the tinnitus which includes sound based therapy, habituation therapy and counselling but these techniques take longer duration for treating tinnitus. An alternative use of sound requires active listening in the form of various perceptual training paradigms (Hoare, Stacey, & Hall, 2010). Perceptual training has a base of evidence that auditory cortex is plastic and can be modified by the targeted auditory stimulation (Hoare et al., 2010; Wise, Kobayashi, & Searchfield, 2015). One of the widely published perceptual training method for tinnitus is Frequency discrimination training (FDT) (Hoare et al., 2010).

FDT assumes that the tinnitus is caused by the maladaptive over-representation of tinnitus pitch frequencies in the cortical tonotopic map (Hoare, Kowalkowski, & Hall, 2012; Eggermont & Roberts, 2004). The barrier for the implementation of FDT was the repetitive nature of the task which caused the patients to lose interest on the therapy. Hoare et al., (2014) came up with a solution by building the FDT in to game. It was found that tinnitus reduced by 7 %. In addition, this gaming technique reported to have greater intrinsic motivation to train on the interactive game play technique for patients with tinnitus. Although, this gaming incorporates the FDT that found to be

useful to the beneficiaries, it is not available in stores or not freely downloadable. Thus, indigenous software was developed by Hemanth et al., (2017 ongoing) by utilizing the similar idea of incorporating the FDT in gamification. The FDT game developed by Hoare et al., (2014) presented target and distracters sounds at different azimuth around the head. The patient was instructed to lateralize the target sound in the presence of distracters. However, in the game developed by Hemanth et al., (2017 ongoing) where target sound ($1/3^{rd}$ octave below tinnitus pitch) is delivered alternatively between the ears in the presence of distracter sounds (D2 to D5). The piloting study was carried out to evaluate the treatment effect on tinnitus perception and it was seen that there was a reduction in tinnitus. It is well established fact that once the treatment is withdrawn the relapse of treatment effect on symptoms is seen. However, the relapse of tinnitus treatment by FDT on perception of it is still unrevealed.

1.1 Need for the study

Frequency discrimination task is one of the treatment strategy used to lessen perception of tinnitus. Discrimination of target pitch ($1/3^{rd}$ octave below tinnitus pitch) from a pitch of tinnitus is utmost important to remap the tonotopicity at the auditory cortex. Cortical remap in patients with tinnitus had shown reduction in tinnitus. The setback of this approach is merely discriminating the tones over period results boredom and eventually loses their attention. This may leads to a significant drop out of patients in using FDT treatment task. Thus, involving an intrinsic motivation of patients through gamification encourages them to use the task consistently and effectively for prolonged period (Hemanth et al., 2017 ongoing). A project on gamification of FDT in treating tinnitus is under progress. The results of pilot study had shown tinnitus reduction over a period of time. However, relapse of treatment effect on tinnitus is not considered in their study. A well-established fact is that once the treatment is stopped, they may

gradually revert to have tinnitus. Thus, the present study is taken up to document persistence and or relapse of treatment effect on tinnitus perception after withdrawal of treatment.

1.2 Aim of the study

The aim of the study is to investigate FDT treatment and its relapse on tinnitus symptoms.

1.3 Objectives of the study

1. To compare the tinnitus characteristic in each phase (baseline, treatment and relapse)

2. To comparing pre- and post-treatment effect on tinnitus percept (pitch, loudness, THI and TFI),

3. To compare between post treatment and after withdrawal of treatment on tinnitus percept.

Chapter 2

REVIEW OF LITERATURE

Tinnitus is defined as the perception of sound resulting from the activity within the nerve system and not due to the acoustic and mechanical correlates in the cochlea (Jastreboff, 1990). The tinnitus can be classified as subjective or objective, peripheral or central (McFadden, 1982). From recent past sound therapy has been used to treat tinnitus from audiological perspective. Frequency discrimination task (FDT) is one such sound therapy found to have shown significant reduction in tinnitus percept (Herraiz, Diges, Cobo, Plaza, & Aparicio, 2006) . However, participants have reported boredom due to monotonous in the task (Wise et al., 2015). In addition, none of studies on relapse of FDT treatment on tinnitus has reported. Thus, in the present study FDT treatment was administered in game format to eliminate the monotonous factor and retain the treatment effectiveness. Further, the relapse of FDT treatment on tinnitus percept was documented. The research article on FDT and its possible physiological changes are reviewed.

2.1 Prevalence and audiological characteristics of tinnitus.

Tinnitus is a common symptoms experienced by the most of the people and it is associated with variable symptoms and its severity. The epidemiology studies have shown that the prevalence of tinnitus ranges from 3% to 30% (Sanchez, 2004). The tinnitus is most common in older adults in compared to younger adults (Thirunavukkarasu & Geetha, 2013). A study conducted by Shargorodsky, Curhan, & Farwell (2010) reported that the prevalence of the tinnitus increased with the age and peaking at 60-69 years with 31.4%. Axelsson and Ringdahl (1989) and Sanchez (2004) also found similar results with occurrence of tinnitus in the age range of 60-69 years.

The annoyance caused by tinnitus vary from individual to individual (Coles, 1984). Though the tinnitus is more common in older adults, the annoyence caused by the tinnitus is experienced more in younger adults. A study reported by Axelsson and Ringdahl (1989) wherein 3600 (1800 male and 1800 female) population was randomly selected from 425,000 residents in the age range of 20 to 80 years. The results showed 14.2% had tinnitus and among them 8.3% experience tinnitus often and 5.8% suffer from tinnitus always. The annoyance caused by the tinnitus across age gropus was also recorded in the study, wherein the age group of 20-29 (8.3%) experienced more annoyance and the age group of 70-79 (3.6%) experienced least annoyance.

Thirunavukkarasu and Geetha (2013) found that the tinnitus was more common in males than in femalesand it was seen that tinnitus was more common in left ear than right ear. There is a contradicting study which reports no age and gender effect (Nondahl, Cruickshanks, Wiley Ronald Klein, Klein, & Tweed, 2002). Most of the studies relate tinnitus with hearing loss. The tinnitus is more common in individuals with hearing loss than with normal hearing (Axelsson & Ringdahl, 1989). A prevalence study done by Thirunavukkarasu and Geetha (2013) reported that, 2.5% of the population experienced tinnitus were noted to have normal hearing and 97.5% had varying degree of hearing loss. They also reported that 64.2% with sensorineural hearing loss had experienced tinnitus, 33.4% with mixed hearing loss and 2.4% with conductive hearing loss. In addition, the configuration of hearing loss has relation with tinnitus. The population with high frequency or sloping configuration experience tinnitus more commonly than the flat or raising pattern (Sanchez, 2004). In a prevalence study by Mazurek, Olze, Haupt, & Szczepek (2010) reported that, out of 531 individuals with experiencing tinnitus 441 had high frequency hearing loss similar to NIHL. Remaining 84 individuals had different configuration of hearing loss and six had

normal hearing sensitivity. In addition they have found positive correlation between degree of hearing loss and severity of tinnitus (Sanchez, 2004).

Hearing loss and age are the major risk factor for tinnitus (Sanchez, 2004; Thirunavukkarasu & Geetha, 2013). Recent studies have shown that there are other risk factors for tinnitus perception. Shargorodsky et al.,(2010) reported the other risk factors for tinnitus perception includes smoking, significant middle ear disease, diabetics, hypertension, head injury and stress. (Melo, Meneses, & Marchiori, 2012; Nondahl et al., 2002; Sanchez, 2004; Thirunavukkarasu & Geetha, 2013).

2.2 Pathophysiology of Tinnitus.

There are number of hypothesis on mechanism for generation of tinnitus. Moller (1997) reported wide spectrum of tinnitus cannot be explained by one hypothesis. Till date there were many theories, models and hypotheses to explain the possible cause of tinnitus (Baguley, 2002). Tinnitus can also occur as a symptom of some pathology like otosclerosis, vestibular schwannoma and Meniere's disease.

2.2.1 Cochlear models.

2.2.1.1 Spontaneous oto-acoustic emissions: There are evidences which show that individuals with normal cochlear functioning may generate low level tonal or narrow band sounds without the external stimulation (Gold, 1948). A study by Kemp (1978) where he recorded a small amount of acoustic signal that generated by the cochlea as a by-product of OHC's electro motile activity which propagate in to external canal which he called as the Spontaneous oto-acoustic emissions (SOAEs). These SOAEs can be perceived as tinnitus.

2.2.1.2 Discordant damage of IHC and OHC: According to this theory it is hypothesized that damage or dysfunction of OHC and IHC at a given portion of basilar

membrane in the cochlea give rise to discordant activation of type I and type II auditory nerve fibers. Damage to the cochlear hair cell and its differentiation at the type I and type II neurons results in disinhibition of neurons at the dorsal cochlear nuclei (DCNs). Abnormal inhibition at DCN results in increased spontaneous activity which received from the excitation input from IHCs and this is perceived as tinnitus (Jastreboff & Hazell, 1993).

2.2.2. Non-cochlear mechanisms of tinnitus generation. Neurophysiological model of tinnitus perception by Jastreboff (1990) explained the concept of 'signal recognition and classification circuits' in central auditory system (CAS) for perception of tinnitus. Every new sound induced patterns in the CAS are compared with the auditory memory and then passed to higher cognitive center and further evaluated. These sounds will be classified into three categories: neutral, pleasant and unpleasant with the help of limbic system and autonomic nervous system to create oriental reactions (startle reflex). The tinnitus generated due to cochlear dysfunction may be in weaker form but tinnitus activity increases and persist due to 'the negative emotional reinforcement' attached to the sound by activation of limbic and autonomic nervous system.

2.2.2.1 Synchronization of spontaneous neural activity: Moller (1984) showed that a certain forms of tinnitus can be related to abnormal neural phase locking phenomenon. He explains the reason behind the tinnitus perception was the artificial synapses, which occur as a result of damaged nerve and leads to emphatic transmission between nerve fibers. Such cross talk between nerves results in phase locking of spontaneous activity which results in tinnitus.

2.2.2.2 Cortical re-organization: In intact auditory cortex the tonotopic representation of spectral frequencies are ordered from caudal-to-rostral direction

which reflect the place coding of frequencies in basilar membrane. Roberts et al. (2010) reported that damage to cochlea results in increased spontaneous firing rate (SFR) which is a result of imbalance in inhibitory and excitatory functions at different levels of auditory systems. This imbalance in neural activity reaches DCN, VCN which are the auditory brainstem region (Kaltenbach, 2006; Eggermont & Kenmochi, 1998). This result in a diminished thalamocortical input in the region of impaired hearing due to the de-afferentation of a specific portion of the cochlea. Eventually the adjacent intact neurons extend their functionality to the damage neurons. The damaged characteristic neurons are now replaced by adjacent frequency (Salvi, Lockwood, & Burkard, 2000). In discriminating the frequency in treatment approach, an attempt was made to realize neurons in what frequency are supposed to tune for. In making constant discriminating the edge frequency (intact neurons) and the damaged neurons, a reverse map in cortical region are formed due to plasticity (Mulnickel, Elbert, Taub & Flor, 1998; Dietrich, Nieschalk, Stoll, Rajan & Pandey, 2001).

2.3 Effect of frequency discrimination task on tinnitus perception

Several studies have revealed different origin for tinnitus generation. The heterogeneity of cause for tinnitus generation does not allow to practice a single, specific and definite treatment for all cases. There are different methods of treating the tinnitus which includes sound based therapy, habituation therapy and counselling but these techniques take longer duration for treating tinnitus. These treatment strategies are passive, meaning it does not involve the active participation of response. Moreover, it is hard to measure whether patient have heard the stimuli in passive sound therapy. An alternative use of sound requires active listening in the form of various perceptual training paradigms (Hoare et al., 2010). Perceptual training has a base of evidence that auditory cortex is plastic and can be modified by the targeted auditory stimulation

(Hoare et al., 2010; Searchfield et al., 2007). One of the widely published perceptual training method for tinnitus is Frequency discrimination training (FDT) (Hoare et al., 2010).

FDT assumes that the tinnitus is caused by the maladaptive over-representation of tinnitus pitch frequencies in the cortical tonotopic map which caused plastic reorganization of the central auditory system (Hoare et al., 2012; Eggermont & Roberts, 2004). The reorganization can be induced not only by the peripheral damage, but also by the external sound stimulation (Recanzone, Schreiner, & Merzenich, 1993). Recanzone et al. (1993) in his study on adult owl monkeys found that, there was an increase in the discrimination thresholds for frequency discrimination task after training for the several weeks. He also found that there was a changes in the frequency representation of the AI region of auditory cortex which was noted in electro-physiological measures. This indicate that the auditory cortical representations are modifiable through external sound stimulation. A study by Amitay, Irwin, & Moore, (2006) found an improved frequency discrimination threshold over the training sessions in normal hearing individuals. He recruited 120 subjects with normal hearing and assigned the individuals to ten different groups. One group was given no task who acted as a control group. Other groups had varying difficulty levels. The result showed there was a significant improvement in the training groups compared to control group. He also found that the groups with lesser difficulty level had more improvement than the groups with higher difficulty levels.

Herraiz, Diges, Cobo, Plaza, & Aparicio, (2006) administered auditory discrimination training on 35 individuals suffering from tinnitus. They used Visual analogue scale (VAS) of intensity and Tinnitus handicap inventory (THI) to note the severity of the tinnitus. The result showed an improvement in tinnitus severity among

43% of the samples. There was a significant improvement seen in VAS and THI scores after administering auditory discrimination training. In the similar line of study Flor, Hoffmann, Struve, & Diesch, (2004) found that the frequency discrimination training had improved the tinnitus for the group who had regularly trained for more sessions, whereas the increase in tinnitus severity was noted for the individuals who are trained for less number of sessions and they were irregular. A review article by Hoare, Stacey, & Hall, (2010) found ten articles related to auditory discrimination training and found that nine out of ten reported some significant change in self-reported scale of tinnitus and/or psychoacoustic outcome measures after auditory training. The possible reason is that auditory training capture the cortical neurons from the tinnitus generating network and allocate them to the network supporting the representation of tinnitus frequencies (Flor et al., 2004).

Herraiz, Diges, Cobo, Aparicio, and Toledano, (2010) administered FDT treatment for individuals suffering from tinnitus. After administering the FDT treatment, they found a significant improvement in tinnitus severity. The reason for improvement in severity was attributed to the concept of lateral inhibition. They suggest that, FDT stimulates the specific frequency region with in the A1 in range close to the tinnitus frequency but not within the specific region of tinnitus. This would have resulted in strengthening of lateral inhibitory activity which disrupt the pathological synchronous activity. The other reason accounted here is that the FDT strengthens the synapses in the region of hearing loss in the higher auditory system (Tugumia, Samelli, Matas, Magliaro, & Rabelo, 2016).In active listening condition to discriminate the sounds in tinnitus patients have reported boredom due to monotonous task in it. There was an absence of intrinsic motivation to attend to the stimulus over a period of time. Even though the FDT had shown an improvement in the tinnitus percept it is less used

in clinical trials due to its repetitive nature of the task. FDT losses the attention and motivation of the patients during the treatment due to the time consuming nature. These factors have led to significant attrition from therapy. Thus, a treatment platform should have the factor of intrinsic motivation for sustained attention to perform the task.

2.4 FDT in game environment

To over-come the disadvantages of the FDT, Hoare et al., (2014) developed a gaming software to administer FDT treatment on tinnitus patients. He developed three different gaming platform which includes STAR 2, TREASURE HUNTER and SUBMARINE. The patients reported a greater intrinsic motivation to train in the game based platforms with the compliance of 70% in all three games. But he found no significant difference in the tinnitus severity and psycho-acoustical characteristics of tinnitus after treatment. In yet another study Wise, Kobayashi & Searchfield, (2015) tried to find the effect of game based training program on tinnitus percept. Terrane gaming software was used to administer FDT treatment for 20 days. The results showed that, there was a significant improvement of 6.25 points in THI questioner.

Wise, Kobayashi, Magnusson, Welch, & Searchfield, (2016) compared the two gaming platform that uses FDT in different modalities to treat Tinnitus. An auditory attention training game “terrain” and the visual sustained attention task “tetris”. The results revealed a greater reduction in Tinnitus Functional Index (TFI), Tinnitus Handicap Inventory (THI) and rating scales pertained to ability to ignore and tinnitus annoyance were obtained for the ‘terrain’ compared with the ‘tetris’. Thus, involving an intrinsic motivation of patients through gamification encourages them using the task consistently and effectively for prolonged period (Hemanth et al., 2017 ongoing). A project on gamification of FDT in treating tinnitus is under progress. The results of pilot study had shown tinnitus reduction over a period of time. However, relapse of treatment

effect on tinnitus is not considered in their study. Thus, in the present study treatment and replace effect of FDT on symptoms of tinnitus is documented.

Chapter -3

METHOD

A single subject ABA design was utilized to document the treatment effect of FDT and its replace on tinnitus symptoms.

3.1 Participants

Six patients who had subjective tinnitus were recruited for the study. The detailed report on hearing ability and tinnitus characteristics were discussed in case report. All the participants had normal middle ear status. All had experience in handling computer and play a game in it. None of participants had physical dexterity problem.

3.2 Instrumentation

1. Diagnostic Audiometer Inventis Piano was utilised to assess hearing sensitivity.
2. GSI Tympstar immittance meter was used to check the middle ear status of participants.
3. The Tinnitus manager (Version 1.0) software was used for treatment. It comprised of tinnitus evaluation and Frequency discrimination training (FDT) treatment in the game format. This was installed in the personal laptop HP and the output was routed headphone with mic having frequency response of 20 Hz to 20 KHz.

3.3 Procedure

A detailed audiological evaluation was performed on each participants. A baseline and treatment of FDT on perception of tinnitus was documented and in addition relapse of treatment effect on tinnitus perception was estimated.

3.3.1 Subject Selection Criteria

The participants underwent routine audiological evaluations. A detailed case history was administered. In addition, the pure tone audiometry was assessed using standardized Hughson and Westlake procedure. Immittance and reflexometry evaluations was used to assess middle ear status. Oto-acoustic emissions and auditory brainstem response was assessed if required. The details of each participant is given in case report section.

3.3.2 Treatment Regime

3.3.2.1 Phase-1: Baseline. Five baselines (B1, B2, B3, B4 and B5) on tinnitus loudness and pitch were considered for five consecutive days (Figure-1). At the fifth day of baseline, two questionnaires focused to severity and functionality on tinnitus were documented.

Tinnitus evaluation using alternative force choice method developed by Jastreboff (2002) was performed to document pitch and loudness of patient's tinnitus. Stimulus presented to the ear contralateral to tinnitus, if participant have unilateral tinnitus whereas ipsilateral matching was carried out for subjects with bilateral tinnitus. Loudness matching was carried out at octave frequencies from 125 Hz to 8 KHz. The initial presentation level was presented at 5 dB SL and varied with 1 dB step till the loudness matches. For pitch matching, a pair of loudness matched tones are presented sequentially and patients are instructed to report the tone closer to his/her tinnitus. This procedure was continued till the patient gets the tone closest to his/her tinnitus.

In addition, participants was instructed to complete two self-report tinnitus questioners i.e., Tinnitus handicap inventory (THI) developed by Newman et al., (1996) and Tinnitus functional index (TFI) developed by Meikle et al., (2012).

The tinnitus handicap inventory (THI) in Kannada developed by Dwaranath et al (2012) was adopted in the study. The questioner consists of 25 questions which focus on functional and emotional implication of tinnitus. Each question has three options with points associated to it i.e., “yes” (4 points), “sometime” (2 points) and “no” (0 points). The patient response to all questions are summed up to determine the patient’s score which range from 0 to 100 points. The patient’s score is then compared with the THI severity scale to document the tinnitus severity of the patients. The severity scale is as follows- 0-16 (Slight or no handicap), 18-36 (Mild handicap), 38-56 (Moderate handicap), 58-76 (Severe handicap), 78-100 (Catastrophic handicap).

Tinnitus functional index (TFI) is a 25-item inventory characterized by eight subscale which address on negative impact of tinnitus. The subscale includes 1) Intrusiveness, unpleasantness and persistence of tinnitus, 2) Sense of control, 3) Cognitive interference, 4) Sleep disturbance, 5) Auditory difficulties attributed to tinnitus, 6) Interference with relaxation, 7) Quality of life and 8) Emotional distress. Each question in the subscale was rated in ten point rating scale (‘0’ indicate less effected and ‘ten’ indicate extremely effected) to document the tinnitus severity. For determining the severity of tinnitus, Sum of all subscales divided by number of questions answered multiplied by ten was taken which range from ‘0-100’. The resultant score was compared with the TFI severity scale to document the severity of tinnitus. The score range and its functional severity are as follows - “0-17” (not a problem), “18-31” (small problem), “32-53” (moderate problem), “54-72” (big problem) and “73-100” (very big problem).

The baseline obtained from the evaluation and questioner was saved in the tinnitus manager software.

3.3.2.2 Phase-2: Treatment - Frequency Discrimination Task. The software automatically generates the stimulus based on pitch of the tinnitus and the participant's MCL. The treatment module includes target familiarization and the target identification game.

Stimulus: The software automatically generates the target and distracter stimuli based on the saved pitch and loudness of the tinnitus. The 1/3rd octave frequency below the tinnitus frequency was considered as the target sound. The distractors stimuli were tinnitus frequency, 2/3rd octave below the tinnitus frequency, 1/3rd octave above the tinnitus frequency and 2/3rd octave above the tinnitus frequency were considered.

The most comfortable level (MCL) was estimated using bracketing method with initial presentation level of 40 dB and it was done individually for each ears and saved in the software. The target sound is presented at 7 dB above the MCL and distracters are presented at the level of MCL.

Target familiarization: It includes presentation of target stimulus between the ears sequentially and the participants were asked to lateralize the sound between the ears and report the pattern of presentation. The target was presented in six patterns either to right or left ear (RRL, RLR, LRR, RLL, LRL and LLR) and each pattern was repeated five times in random sequence. The patient was moved to training level when he/she achieves 70% of correct score in familiarization task.

Frequency Discrimination game: It includes a target stimulus and a distractor. Participant was trained to identify the target in the presence of distractor. The target identification task was performed in four levels. Level-1 consists of a target tone and one distractor. The target was presented to either of the ears randomly and distracter (Tinnitus pitch) is presented always to the ear with tinnitus. The target and distractor

stimuli are presented in a game. The puzzle game includes a gird of concealed squares that appears on the computer screen. These square are the pieces of pictures which is associated with an audio files of target and distracter stimuli. A participant needs to identify the target sound associated to a particular square (pieces of puzzle) by ignoring the distracter sound. For every correct response a piece of picture unfolds. Playing with the game a unfold piece of pictures build on to form a complete picture. If response is incorrect, the massage "wrong" displays on the computer screen.

A new distracter was added to increase the complexity of the game at level-2, 3 and 4. In each level participant task was to identify the target sound (1/3rd below the tinnitus) by ignoring the distracter sound (Tinnitus pitch + other generated stimuli). In each level, the picture in the puzzle was changed in order to maintain the interest of the patient in the game. The FDT training was given for 30 minute per session. Training was carried out five times a week for a period of two weeks (10 session) (Figure 3.1). Prior and after the FDT treatment, tinnitus evaluation was carried out and saved in the software to monitor the pitch and loudness of the tinnitus. In addition, THI and TFI questionnaires were administered at the end of each week.

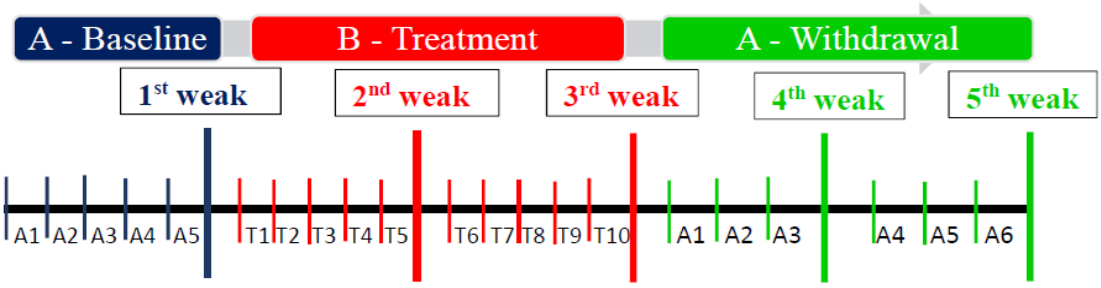

Figure 3.1. Schematic representation of research design

3.3.2.3 In phase-3: Relapse. The treatment was withdrawn for the duration of two weeks and the relapse was noted in this period. To see relapse, tinnitus evaluation includes pitch and loudness of the patient was documented. Tinnitus evaluation was carried out three times in a week for a period of two weeks (Figure 3.1). In addition, questionnaires of THI and TFI were administered at the end of each week.

Chapter 4

CASE REPORTS

4.1 Case 1:

A 36 years old male reported with a complaint of difficulty to hear soft sounds and ringing sensation in left ear since seven months. The onset of the problem was sudden and it is progressive in nature. These symptoms were started when client met with a road traffic accident resulted injury to his head and neck. The client also reports of exposure to industrial noise for eight hours a day for the duration of five years. Ontological evaluation and a detailed audiological evaluation were completed. Otoscopic examination revealed cone of light visible in both ears. A pure tone audiometry revealed a minimal sensorineural hearing loss in both ears (Figure 4.1). A notched audiogram at 4 kHz was noted. Tympanometric evaluation revealed 'A' type tympanogram indicated normal middle ear functioning. Ipsilateral and contralateral reflexes were present at the octave frequencies 500 Hz, 1 kHz & 2 kHz. Oto-acoustic emissions (OAE's) testing showed absence of both transient and distortion product OAE's.

A case history of tinnitus revealed a sudden onset and progressive in nature. The episode of tinnitus was continuous. The subject suffers from subjective tinnitus and the tonal type was continuous. The case reported a high pitched perception of tinnitus. Tinnitus evaluation was performed using alternative force choice method (Jastreboff, 2002). The case matched the pitch at 7000 Hz with loudness matched to 40 dB. A positive result was obtained in the residual inhibition test.

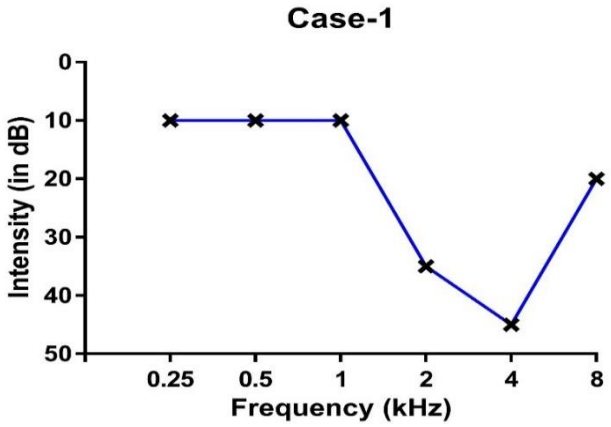

Figure 4.1. Audiogram of the ear with tinnitus in case-1.

4.1.1 Frequency Discrimination Treatment

4.1.1.1 Baseline: Tinnitus pitch was matched at 7000 Hz (Figure 4.2) and loudness at 40 dB (Figure 4.3) which were noted stable across five sessions of baseline. In addition, client reported severe handicap and a big problem in functionality from Tinnitus Handicap Inventory (THI) and Tinnitus Functional Index (TFI), respectively (Figure 4.4).

4.1.1.2 Treatment: Within the treatment phase, the median of pitch was 4800 Hz and range bar was 7000 Hz (minimum) and 4000 Hz (maximum) (Figure 4.2). In addition, the loudness across treatment phase documented median value of 45; range bar were 45 dB (minimum) and 35 dB (maximum) (Figure 4.3). The tinnitus pitch changed linearly across treatment sessions. In addition, soon after the treatment his pitch subjected to change after three sessions indicated immediacy effect. However, loudness found to have cyclicity pattern. That is, when the treatment was started the client tinnitus loudness was high and then at 10^{th} treatment session his loudness declined back to the baseline. Severity of handicap and functionality index were reduced after treatment. In baseline to treatment condition (between phase condition),

the presence of potential of contrast was noted in terms of pitch of the tinnitus which reduced from 7000 Hz to 4000Hz (Figure 4.2) [Baseline median = 7000 Hz, treatment median = 4800 Hz]. Further, the potential of contrast was found in THI and TFI scores where THI scores reduced from severe handicap to moderate handicap and TFI scores reduced from big problem to moderate problem (Figure 4.4). However, the potential of contrast was noted to be absent for tinnitus loudness (Figure 4.3).

4.1.1.3 Relapse: Within the relapse phase the median of pitch was 4250 Hz and range bar was 4500 Hz (minimum) and 4000 Hz (maximum) respectively (Figure 4.2). In addition, the loudness across relapse phase documented stable value of 40 dB (Figure 4.3). In addition, the moderate severity in THI and moderate problem in TFI remained same in the relapse phase (Figure 4.4). In between treatment and relapse phase the absence of potential of contrast was noted in each of the tinnitus characteristics. It indicates that each characteristic of tinnitus noted during the treatment was same even after cessation of it.

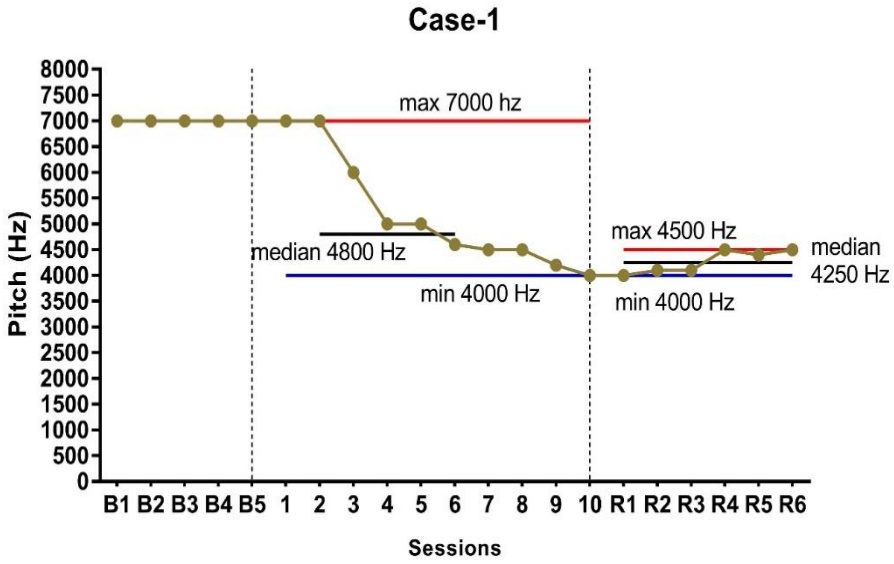

Figure 4.2. Tinnitus pitch across baseline, treatment and relapse sessions in case-1. (B- Baseline, T- Treatment and R- Relapse)

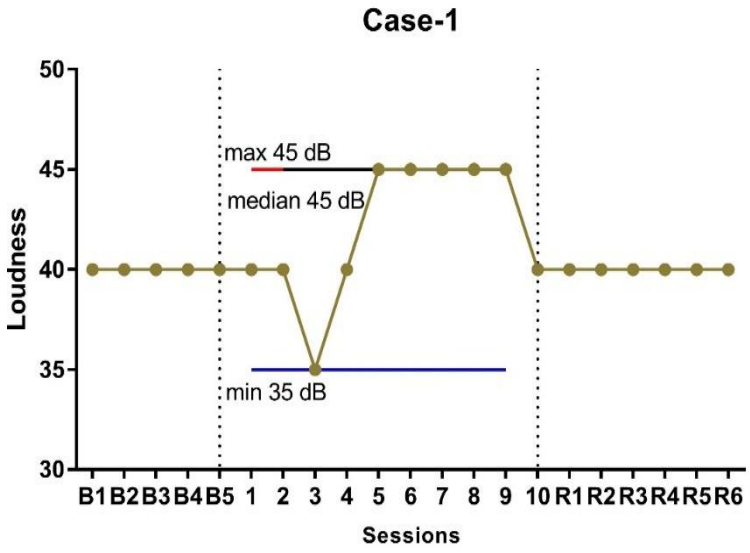

Figure 4.3. Tinnitus loudness across baseline, treatment and relapse sessions in case-1 (B- Baseline, T- Treatment and R- Relapse)

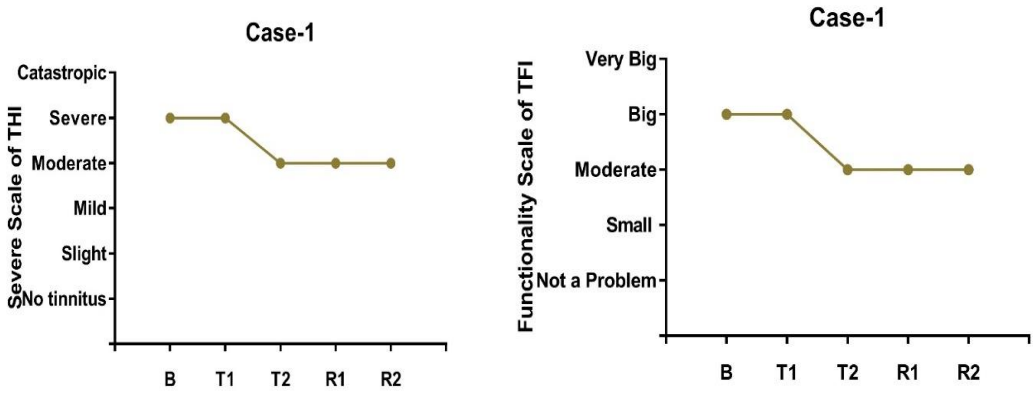

Figure 4.4. THI and TFI across baseline, treatment and relapse sessions in case-1. (B- Baseline, T- Treatment and R- Relapse)

Table- 4.1. *Summary of tinnitus characteristics across sections in case-1*

Phase	Tinnitus Characteristics	Basline	Treatment	Replase
Within Phase	Pitch	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Variable
	Loudness	Stable	Cyclicity	Stable
	THI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
	TFI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
		Baseline and Treatment		Treatment and Relapse
Between phase	Pitch	Potential of contast observed		Overlap of scores between treatment and relapse phase
	Loudness	Variable		Overlap of scores between treatment and relapse phase
	THI	Potential of contast observed		Overlap of scores between treatment and relapse phase
	TFI	Potential of contast observed		Overlap of scores between treatment and relapse phase

4.2 Case 2:

A 62 years male reported with the complaint of reduced hearing sensitivity in both ears and ringing sensation in left ear since six months. Tympanic membrane in both ear was visualized on otoscopic examination. Pure tone audiometry revealed minimal sloping hearing loss in left ear (Figure 4.5). Further, tympanometry finding revealed bilateral 'A' type tympanogram with elevated ipsilateral and contralateral reflexes indicated normal middle ear status in both ears. Both transient evoked and distortion product OAEs were absent.

The case history of tinnitus revealed gradual onset and static in nature. The episode of tinnitus was continuous. The subject suffers from subjective tinnitus and the tonal type was continuous. Further, patient reported the perception of tinnitus as whistling sound. The detailed case history revealed idiopathic cause for his tinnitus perception. Tinnitus evaluation was carried out using alternative force choice method wherein the subject matched the tinnitus pitch at 5500 Hz and loudness matched to 70 dB. Positive result was obtained in the residual inhibition test.

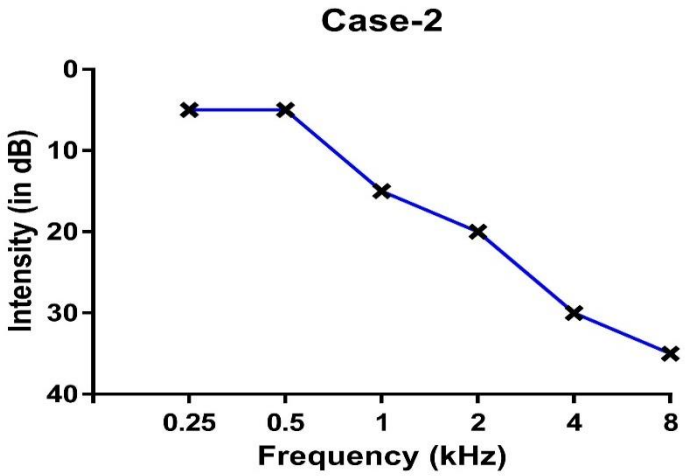

Figure 4.5: Audiogram of the ear with tinnitus in case-2.

4.2.1 Frequency Discrimination Treatment:

4.2.1.1 Baseline: Tinnitus pitch was matched at 5500 Hz (Figure 4.6) and loudness at 70 dB (Figure 4.7) which were noted stable across five sessions of baseline. In addition, client reported a moderate handicap from Tinnitus Handicap Inventory (THI) and moderate problem in functionality reflected in Tinnitus Functional Index (TFI) (Figure 4.8).

4.2.1.2 Treatment: Tinnitus pitch was varied as a function of treatment session. Within the treatment phase, the median pitch was 4050 Hz and range bar was minimum at 2400 Hz and maximum at 5500 Hz (Figure 4.6). Handicap from tinnitus documented moderate degree at first instance and then the THI reduced to mild degree (Figure 4.8). Tinnitus loudness of 70 dB and moderate functionality impairment were observed and it did not change as a function of treatment sessions (Figure 4.7).

In baseline to treatment condition, presence of potential of contrast was noted in tinnitus pitch and THI questionnaire. The tinnitus pitch changed from 5500 Hz to 2400 Hz (Figure 4.6) and the severity of tinnitus reduced from moderate handicap from tinnitus to mild (Figure 4.8). Whereas, the potential of contrast was absent for both tinnitus loudness (Figure 4.7) and functional impairment from tinnitus reflected in TFI questionnaire (Figure 4.8).

4.2.1.3 Relapse: The tinnitus pitch was slightly varied with a minimum of 2000 Hz and maximum of 2200 Hz with a median value of 2050 Hz (Figure 4.6) across the relapse period. The tinnitus loudness and questionnaires documenting severity of handicap and functional impairment from tinnitus showed stable across the relapse period (Figure 4.7 and 4.8). In between phases (treatment to relapse conditions), there was an absence of potential contrast in each characteristics of tinnitus.

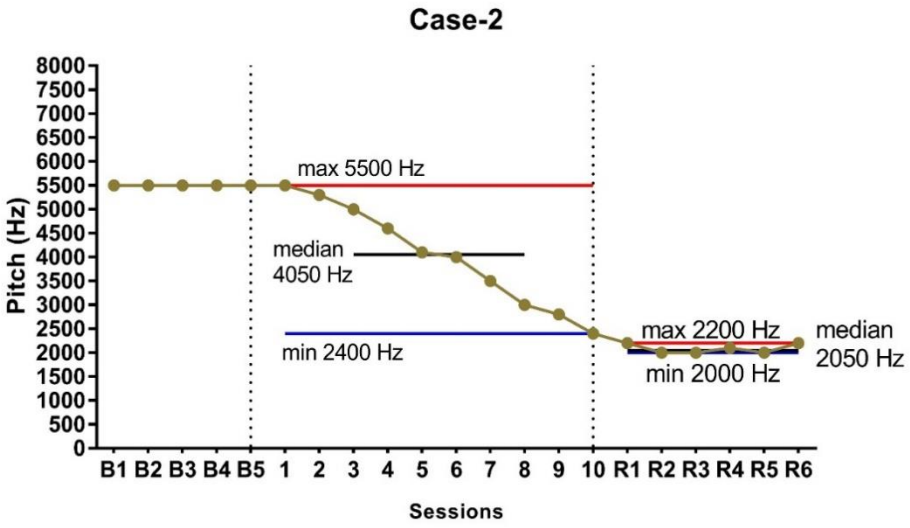

Figure 4.6: Tinnitus pitch across baseline, treatment and relapse sessions in case-2.

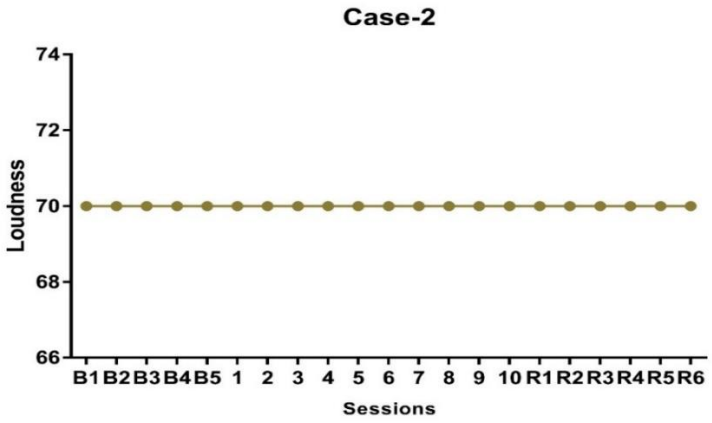

Figure 4.7: Tinnitus loudness across baseline, treatment and relapse sessions in case-2

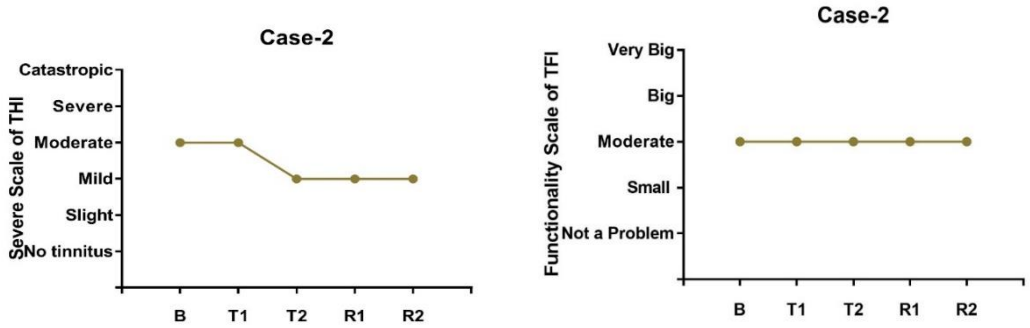

Figure 4.8: THI and TFI across baseline, treatment and relapse sessions in case-2

Table- 4.2. *Summary of tinnitus characteristics across sections in case-2*

Phase	Tinnitus Characteristics	Basline	Treatment	Replase
Within Phase	Pitch	Stable	Trend obsereved; Immediacy effect not seen ; dramatic change suggest strong treatment	Variable
	Loudness	Stable	Stable	Stable
	THI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
	TFI	Stable	Stable	Stable
		Baseline and Treatment		Treatment and Relapse
Between phase	Pitch	Potential of contast observed		Overlap of scores between treatment and relapse phase
	Loudness	Stable		Overlap of scores between treatment and relapse phase
	THI	Potential of contast observed		Overlap of scores between treatment and relapse phase
	TFI	Stable		Overlap of scores between treatment and relapse phase

4.3 Case 3:

A 52 years male reported with the complaint of reduced hearing sensitivity in both ears and ringing sensation in left ear. The medical history revealed that the patient is under medication for hypertension since five years. After taking case history and ontological examination a detailed audiological evaluation was performed. Pure tone audiometry revealed minimal sloping hearing loss in both ears (Figure 4.9). Immittance evaluation showed a bilateral 'As' type of tympanogram with elevated ipsilateral and contralateral reflexes indicated normal middle ear status. OAE's test showed an absent TEOAEs and DPOAEs in both ears.

Tinnitus onset was gradual and progressive in nature. The subject suffers from subjective tinnitus and the tonal type was continuous. The patient reported the tinnitus percept as tone. Tinnitus evaluation was performed wherein the subject matched the tinnitus pitch at 8500 Hz and loudness matched to 70 dB. A negative result was obtained in the residual inhibition test.

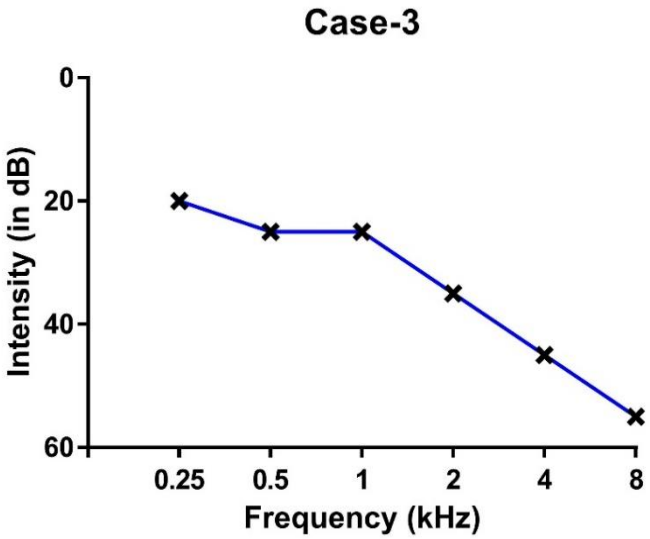

Figure 4.9: Audiogram of the ear with tinnitus

4.3.1 Frequency Discrimination Treatment:

4.3.1.1 Baseline: A stable baseline was obtained with the tinnitus frequency of 8500 (Figure 4.10) Hz and tinnitus loudness of 70 dB (Figure 4.11). Within the baseline phase the median pitch was 8500 Hz and range bars was 8000 Hz (minimum) and 8500 Hz (maximum) respectively (Figure 4.10). In addition, the loudness across baseline phase documented median value of 70 dB and range bars was 70 dB (minimum) and 75 dB (maximum) respectively (Figure 4.11). The questionnaire documented moderate handicap in THI and moderate problem in TFI questionnaire (Figure 4.12).

4.3.1.2 Treatment: Tinnitus pitch showed immediacy effect and later pitch was stable after 3rd session of treatment. Within the treatment phase the median of pitch was 3350 Hz and range bar was 2800 Hz (minimum) and 6100 Hz (maximum) respectively (Figure 4.10). Tinnitus loudness showed a cyclicity pattern of response but at the end of treatment phase it showed constant change as a function of treatment sessions. The loudness across treatment phase documented median value of 60 dB; range bar was 75 dB (minimum) and 85 dB (maximum) respectively (Figure 4.11). The handicap from tinnitus and functionality index lessened across the treatment phase (Figure 4.12).

In baseline to treatment condition, a potential of contrast was observed across the tinnitus characteristics and tinnitus severity. The tinnitus pitch changed from 8500 Hz to 3300 Hz (Figure 4.10) and loudness was changed from 70 dB to 60 dB (Figure 4.11). The THI questionnaire showed reduction in tinnitus severity from moderate handicap to mild. The TFI questionnaire showed lessened functionality index from moderate problem to small problem (Figure 4.12).

4.3.1.3 Relapse: The tinnitus pitch was varied across the relapse period. Within the relapse phase the median of pitch was 3450 Hz and range bar was 3300 Hz

(minimum) and 4000 Hz (maximum) respectively (Figure 4.10). The tinnitus loudness was noted to have stable except at short spike in loudness on 3rd session after cessation of treatment. The loudness across relapse phase documented the median value of 60 dB; range bar was 60 dB (minimum) and 65 dB (maximum) (Figure 4.11). In addition, between treatment and relapse phase there was an absence of potential of contrast in the tinnitus characteristics (Pitch and loudness, THI, and TFI).

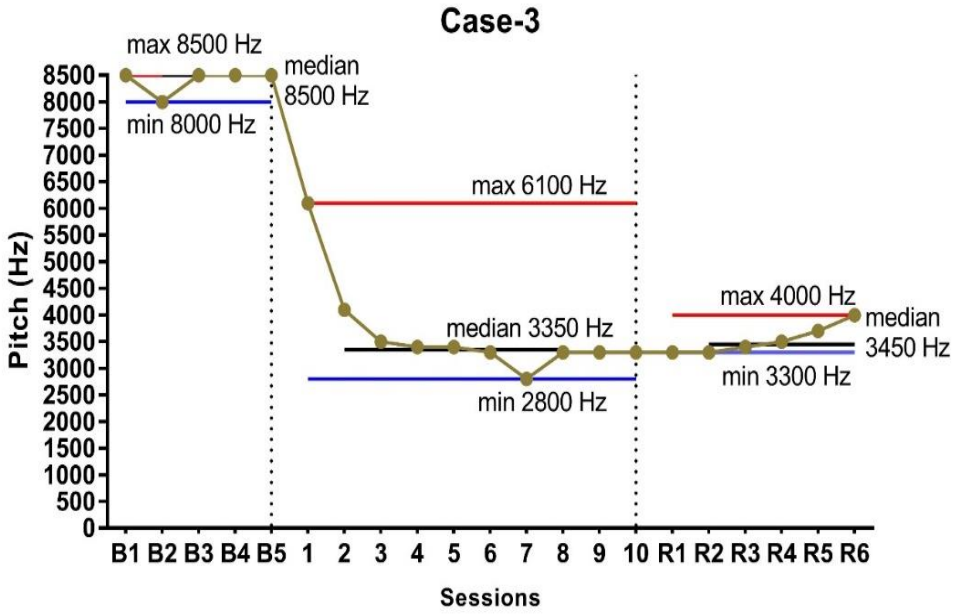

Figure 4.10: Tinnitus pitch across baseline, treatment and relapse sessions in case-3.

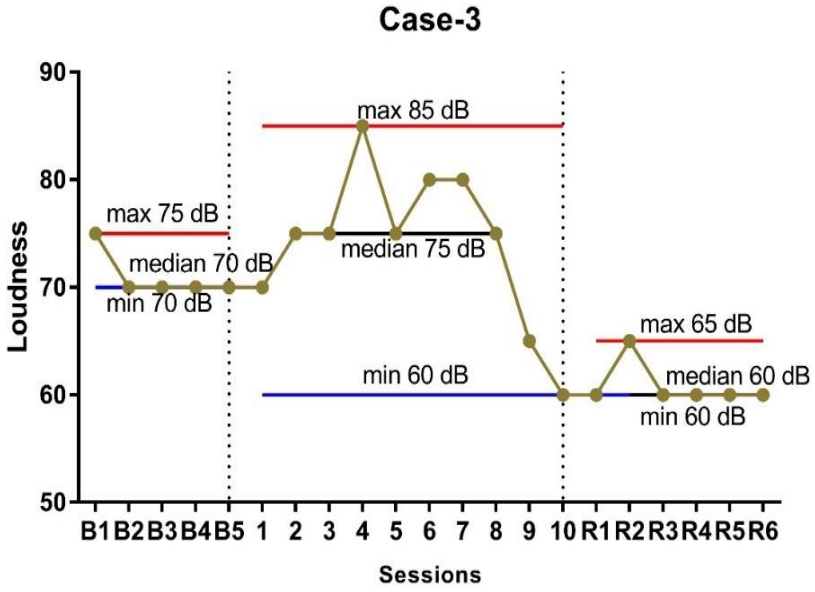

Figure 4.11: Tinnitus loudness across baseline, treatment and relapse sessions in case-3.

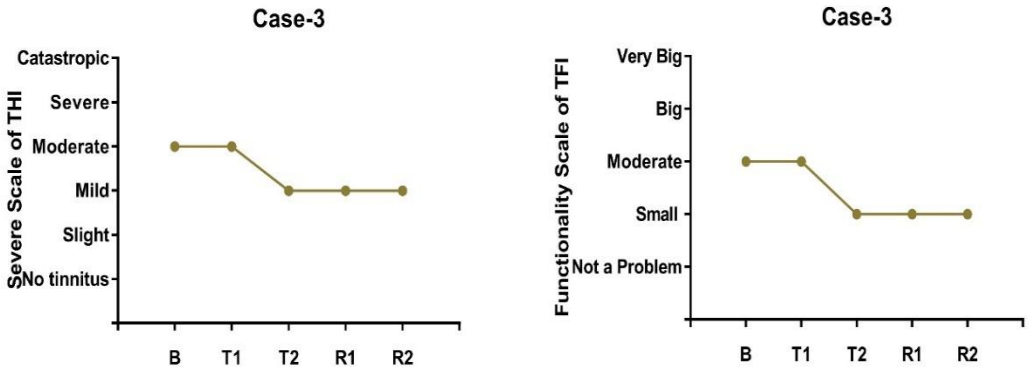

Figure 4.12: THI and TFI across baseline, treatment and relapse sessions in case-3.

Table- 4.3. *Summary of tinnitus characteristics across sections in case-3.*

Phase	Tinnitus Characteristics	Basline	Treatment	Replase
Within Phase	Pitch	Variable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Variable
	Loudness	Variable	Cyclicity	Variable
	THI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
	TFI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
		Baseline and Treatment		Treatment and Relapse
Between phase	Pitch	Potential of contast observed		Overlap of scores between treatment and relapse phase
	Loudness	Potential of contrast observed		Overlap of scores between treatment and relapse phase
	THI	Potential of contast observed		Overlap of scores between treatment and relapse phase
	TFI	Potential of contast observed		Overlap of scores between treatment and relapse phase

4.4 Case 4:

A 35 years male reported with the complaints of reduced hearing sensitivity in both ears and ringing sensation in left ear since six months. The onset and nature of tinnitus were noted to be gradual and static, respectively. The client also reports a history of industrial noise exposure of eight hours a day for the duration of two years. A pure tone audiometry revealed a minimal hearing loss in the both ears (Figure 4.13). Immittance results showed 'A' type tympanogram with presence of ipsilateral and contralateral reflexes indicated normal middle ear status. The OAEs test revealed reduced SNR for TEOAEs and presence of DPOAEs in both the ears.

Case history of tinnitus revealed a gradual onset and static in nature. The subject suffers from subjective tinnitus and the tonal type was continuous. The patient reported the tinnitus percept as tone. Tinnitus evaluation was performed and pitch was matched to 2000 Hz and the loudness was matched at 80 dB. The test for residual inhibition showed positive results on tinnitus perception.

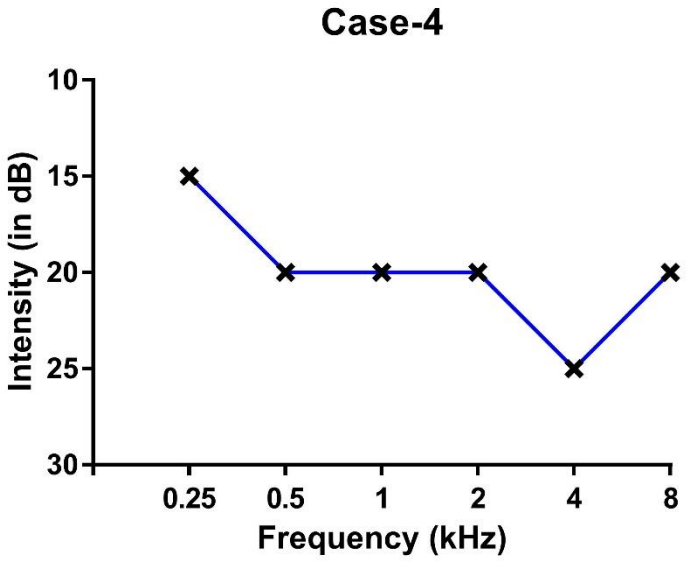

Figure 4.13: Audiogram of the ear with tinnitus

4.4.1 Frequency Discrimination Treatment:

4.4.1.1 Baseline: A baseline tinnitus pitch of 2000 Hz and loudness of 80 dB were noted. Within the baseline phase the median pitch was 2000 Hz and range bar was 2000 Hz (minimum) and 2500 Hz (maximum) respectively (Figure 4.14). In addition, the loudness across baseline phase documented median value of 80 dB; range bar was 75 dB (minimum) and 80 dB (maximum) respectively (Figure 4.15). The questionnaires documented the sever handicap from tinnitus in THI questionnaire and a big problem in TFI questionnaire (Figure 4.16).

4.4.1.2 Treatment: The tinnitus pitch showed a variable response across the treatment phase. Within the treatment phase the median pitch was 1300 Hz and range bar was 900 Hz (minimum) and 1800 Hz (maximum) respectively (Figure 4.14). In addition, the loudness across treatment phase documented median value of 80 dB; range bar was 75 dB (minimum) and 80 dB (maximum) respectively (Figure 4.15). Tinnitus pitch did not show any immediacy effect rather showed changing pattern of response across the treatment phase. The tinnitus severity showed an improving pattern in terms of both THI and TFI and there was an immediacy effect seen in THI (Figure 4.16).

In baseline to treatment condition, there was an absence of potential of contrast in tinnitus pitch and loudness. The severity of the tinnitus and functionality index showed a potential of contrast. The severity of the tinnitus reduced from severe handicap to moderate handicap in THI questionnaire and from big problem to moderate problem in TFI questionnaire.

4.4.1.3 Relapse: Within the relapse phase the median of pitch was 1300 Hz and range bar was 800 Hz (minimum) and 1300 Hz (maximum) respectively (Figure 4.14). In addition, the loudness across relapse phase documented median value of 72.5 dB;

range bar was 70 dB (minimum) and 80 dB (maximum) respectively (Figure 4.15). The TFI questionnaire documented stable functionality index across the relapse period whereas, THI showed a reduced tinnitus severity from moderate handicap to mild handicap (Figure 4.16). In treatment to relapse condition, absence of potential of contrast was noted in tinnitus characteristics.

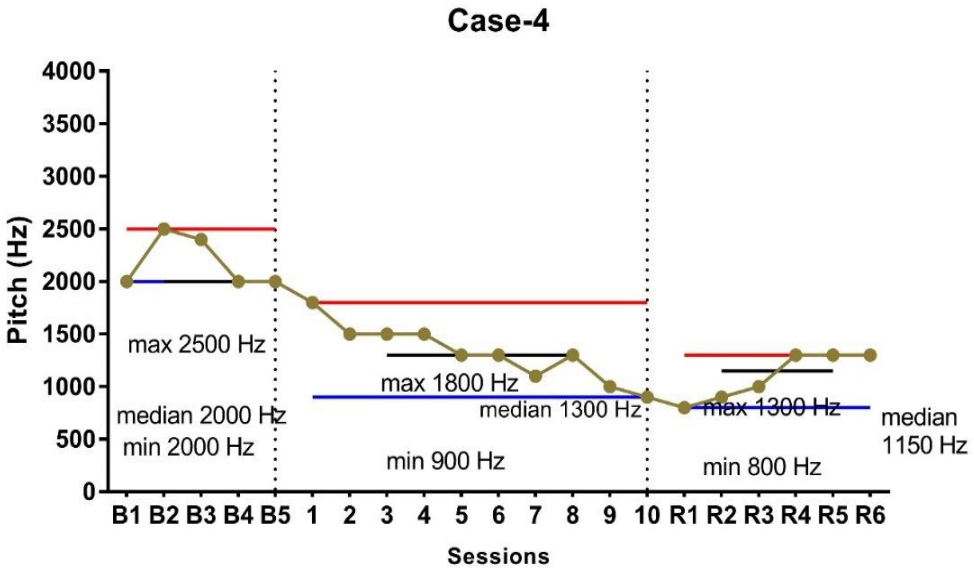

Figure 4.14: Tinnitus pitch across baseline, treatment and relapse sessions in case-4.

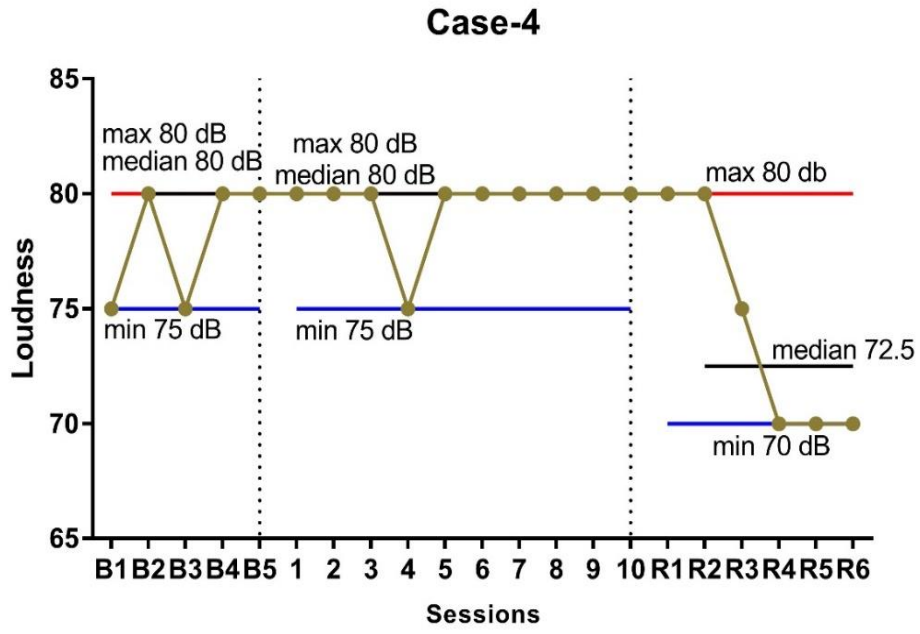

Figure 4.15: Tinnitus loudness across baseline, treatment and relapse sessions in case-4.

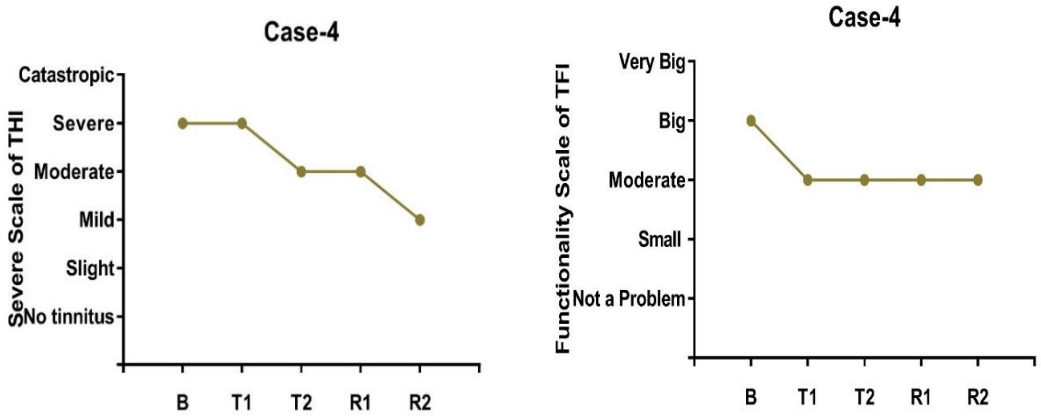

Figure 4.16: THI and TFI across baseline, treatment and relapse sessions in case-4.

Tabe- 4.4. *Summary of tinnitus characteristics across sections in case-4.*

Phase	Tinnitus Characteristics	Basline	Treatment	Replase
Within Phase	Pitch	Variable	Trend obsereved; Immediacy effect not seen; Gradual change suggest treatment effect.	Variable
	Loudness	Cylicity	Stable	Variable
	THI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Variable
	TFI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment. Later functionality index become stable	Stable
		Baseline and Treatment		Treatment and Relapse
Between phase	Pitch	Absence of potential of contast observed		Overlap of scores between treatment and relapse phase
	Loudness	Variable		Overlap of scores between treatment and relapse phase
	THI	Potential of contast observed		Overlap of scores between treatment and relapse phase
	TFI	Potential of contast observed		Overlap of scores between treatment and relapse phase

4.5 Case 5:

A 66 years male reported with the complaint of difficult to hear soft sounds and ringing sensation in both the ears since one year. The onset of both the problems were gradual and static in nature, respectively. The detailed case history revealed a cardiovascular problem and emotional instability. Pure tone audiometry revealed a bilateral mild sensorineural hearing loss with sloping configuration (Figure 4.17). Immittance evaluation showed 'As' type of tympanogram with elevated ipsilateral and contralateral reflexes indicated normal middle ear status in both ears. OAEs test revealed an absent TEOAEs and DPOAEs.

Tinnitus revealed a gradual onset and static in nature, respectively. The subject suffers from subjective tinnitus and the tonal type was continuous. The patient reported the tinnitus percept as tone. Tinnitus evaluation documented a tinnitus pitch and loudness which was matched at 6500 Hz and 60 dB, respectively. A positive result was obtained in residual inhibition test.

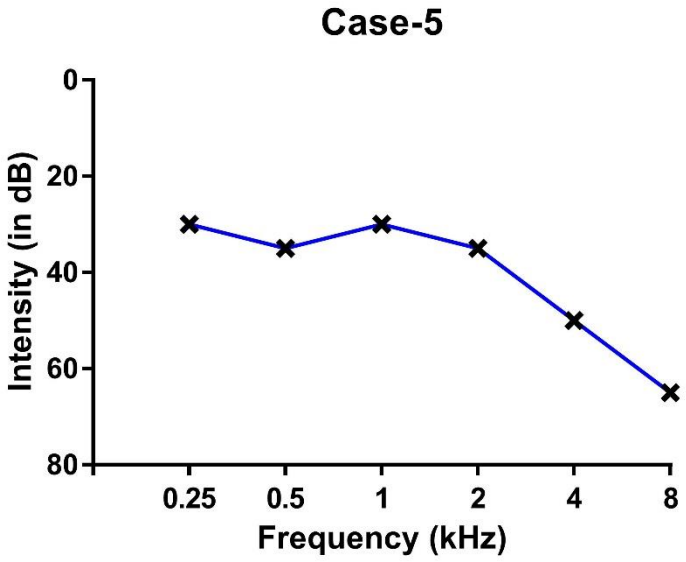

Figure 4.17: Audiogram of the ear with tinnitus.

4.5.1 Frequency Discrimination Treatment:

4.5.1.1 Baseline: Within the baseline phase the median pitch was 6000 Hz and range bar was 6000 Hz (minimum) and 6500 (maximum) respectively (Figure 4.18). A stable baseline was obtained for the tinnitus loudness which was matched at 60 dB (Figure 4.19). The questionnaires documented moderate severity of handicap in THI questionnaire and moderate problem on TFI questionnaire (Figure 4.20).

4.5.1.2 Treatment: Within the treatment phase, the median of pitch was 5400 Hz and range bar was 4800 Hz (minimum) and 6000 (maximum) respectively (Figure 4.18). In addition, the loudness across treatment phase documented median value of 50 dB; range bar was 50 dB (minimum) and 60 dB (maximum) respectively (Figure 4.19). In baseline to treatment condition, a slight potential of contrast was documented in respect to tinnitus pitch. Whereas, a clinically significant potential of contrast was documented for tinnitus loudness and tinnitus severity. Tinnitus severity reduced from moderate handicap to mild handicap in THI and from moderate problem to small problem in TFI (Figure 4.20).

4.5.1.3 Relapse: Within the relapse phase, the median pitch was 5000 Hz and range bar was 4800 Hz (minimum) and 5300 (maximum) respectively (Figure 4.18). In addition, the loudness across relapse phase documented stable value of 50 dB (Figure 4.19). In treatment to relapse condition, there was an absence of potential of contrast was noted in each tinnitus characteristic.

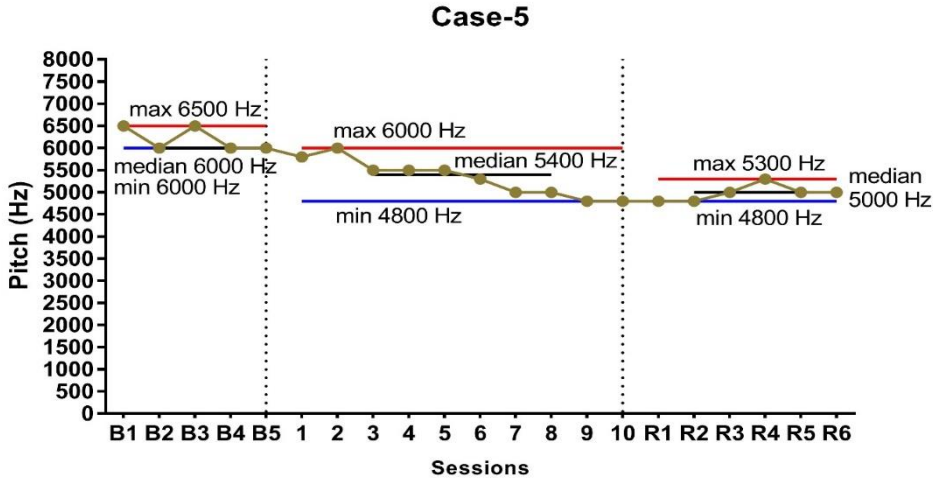

Figure 4.18: Tinnitus pitch across baseline, treatment and relapse sessions in case-5.

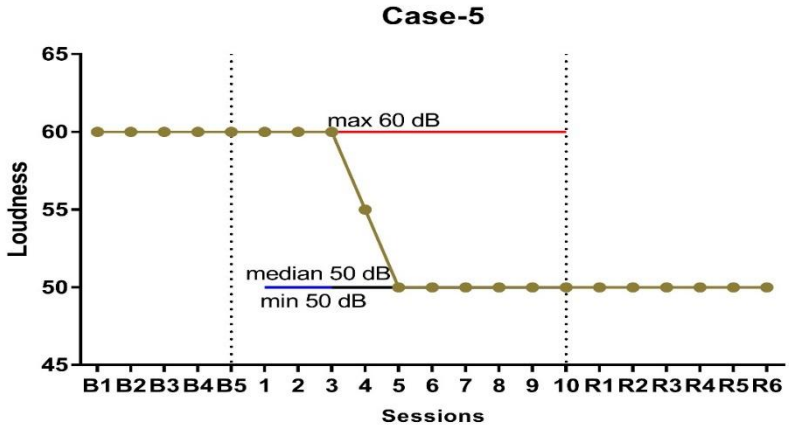

Figure 4.19: Tinnitus loudness across baseline, treatment and relapse sessions in case-5.

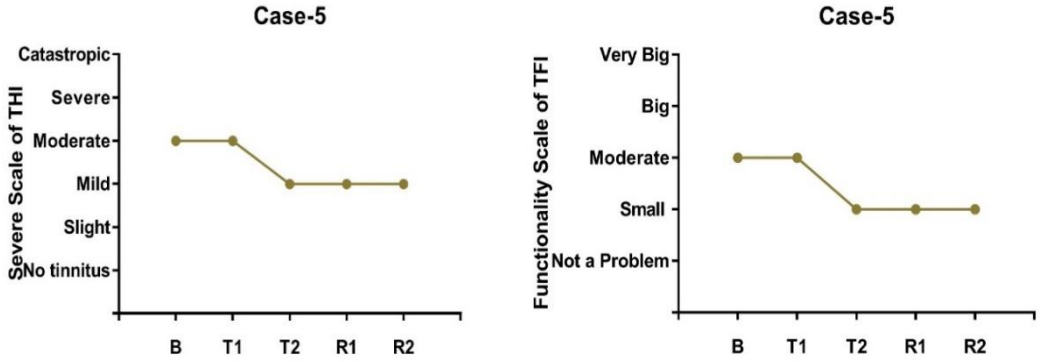

Figure 4.20: THI and TFI across baseline, treatment and relapse sessions in case-5.

Table- 4.5. *Summary of tinnitus characteristics across sections in case-5.*

Phase	Tinnitus Characteristics	Basline	Treatment	Replase
Within Phase	Pitch	Stable	Trend obsereved; Gradual change suggest treatment effect.	Variable
	Loudness	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
	THI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
	TFI	Stable	Trend obsereved; Immediacy effect seen ; dramatic change suggest strong treatment	Stable
		Baseline and Treatment		Treatment and Relapse
Between phase	Pitch	A slight of potential of contast observed		Overlap of scores between treatment and relapse phase
	Loudness	Potential of contast observed		Overlap of scores between treatment and relapse phase
	THI	Potential of contast observed		Overlap of scores between treatment and relapse phase
	TFI	Potential of contast observed		Overlap of scores between treatment and relapse phase

Chapter 5

DISCUSSION

The present study aimed to investigate FDT treatment and its relapse on tinnitus symptoms. Five subjects who have had subjective tinnitus with minimal to mild hearing loss were participated in the study. It was observed that each characteristic of tinnitus was stable in all the five cases reflected in baseline sessions. A clinically significant habituation to tinnitus was achieved in all the cases during the FDT treatment sessions.

Damage to specific region of cochlea reduces the input at central auditory cortex. Prior to damage the neurons were responding to the corresponding frequency but after damage the neurons of under stimulated region anticipates for sound and in turn increases synchronization of neural firing in extended region. Because of this each participant was instructed to discriminate the target tone which is 1/3rd below tinnitus pitch from distractors. In doing so, the cortical region receives the input from characteristic frequency rather than extended functionality of neighboring neurons. As a result, bottom-up input are activated from the neurons which were excited by the frequency they are originally tuned for and leads to reverse rewiring. Indicating so the pitch and loudness were constantly changed during the treatment phase, which made to break the neural pathway between source of generation of sound and interpretation of sound at auditory pathway. This in turn blocks the tinnitus related neural activity from reaching the limbic system and autonomic nervous system thereby reduces its negative reaction to tinnitus (habituation of reaction). Further, it weakens the conditioned reflex arc developed due to negative reaction associated to tinnitus, which was reflected in tinnitus handicap index and tinnitus functionality index. The symptoms of tinnitus relief from software is because of interactivity module. It maintains interest and attention

while being sufficiently manageable to minimize fatigue. It provided reinforcement to the client as soon they responded. In addition, it provided the patient with feedback regarding progress or lack of progress. In FDT game incorporated elements such as decision making, strategy development, competition, and rewards to discriminate the target tone from distractors. Further, at least 3-4 game modules with (n) difficult levels were used to hold the measurable enjoyment and encouragement to use the game regularly. Thus, there was no attrition in the study. These factors certainly yielded a clinically significant benefits in habituating to their tinnitus. Further, each of the tinnitus characteristics overlap between treatment and relapse sessions. It infers the breaking of conditioned reflex arc and established cortical reorganization was maintained, which was reflected in relapse phase.

Chapter 6

SUMMARY AND CONCLUSION

Tinnitus is the conscious perception of a sound that originates in an involuntary manner. Frequency discrimination task is one among the treatment options available to reduce the tinnitus percept. This treatment approach was used on five clients. Five subjects having who have had subjective tinnitus with minimal to mild hearing loss were participated in the study. A single subject ABA research design was utilized to investigate the treatment effect and its relapse on tinnitus percept in five clients. The entire study comprised of three phases. In phase-1, a baseline of tinnitus characteristics (pitch and loudness of tinnitus) were assessed for a span of five sessions. In addition, at the last session THI and TFI were administered to document handicap and functional impairment from tinnitus. In pahse-2, treatment was administered for a span of ten sessions. In each session, the pitch and loudness were documented. In addition, at the end of each week, THI and TFI were administered. In phase-3, relapse of treatment was assessed for six sessions. Every alternative day in relapse phase, tinnitus pitch, loudness, THI and TFI were assessed. The results of the study showed that characteristics of tinnitus was stable in all the five cases which was reflected in baseline sessions. Clinically significant habituation to tinnitus was achieved in all the cases during the FDT treatment sessions, which was reflected in change in pitch, decreased in loudness, reduction in severity of handicap and functional impairment. Further, it was observed that each of the tinnitus characteristics overlap between treatment and relapse sessions. It infers that, breaking of conditioned reflex arc and established cortical reorganization was maintained. Thus, it can be concluded from the study that FDT treatment was found to be beneficial in reducing the tinnitus percept.

Clinical implication

1. Frequency discrimination treatment (FDT) in game format has reduced the tinnitus percept especially in those individuals with sloping hearing loss and subjective percept.
2. The study results shed light on persistence and or relapse of treatment effect on tinnitus after its withdrawal.
3. FDT in game environment is a good tool to implement in clinical setup to treat tinnitus.

REFERENCES

Amitay, S., Irwin, A., & Moore, D. R. (2006). Discrimination learning induced by training with identical stimuli. *Nature Neuroscience*, *9*(11), 1446–1448.

Axelsson, A., & Ringdahl, A. (1989). Tinnitus—a study of its prevalence and characteristics. *British Journal of Audiology*, *23*(1), 53–62.

Baguley, D. M. (2002). Mechanisms of tinnitus. *British medical bulletin*, *63*(1), 195-212.

Coles, R. R. A. (1984). Epidemiology of tinnitus: (1) Prevalence. *The Journal of Laryngology & Otology*, *98*(S9), 7–15.

Dietrich, V., Nieschalk, M., Stoll, W., Rajan, R., & Pantev, C. (2001). Cortical reorganization in patients with high frequency cochlear hearing loss. *Hearing Research*, *158*(1), 95-101.

Eggermont, J. J., & Kenmochi, M. (1998). Salicylate and quinine selectively increase spontaneous firing rates in secondary auditory cortex. *Hearing Research*, *117*(1-2), 149-160.

Eggermont, J. J., & Roberts, L. E. (2004). The neuroscience of tinnitus. *Trends in Neurosciences*, *27*(11), 676-682.

Flor, H., Hoffmann, D., Struve, M., & Diesch, E. (2004). Auditory Discrimination Training for the Treatment of Tinnitus. *Applied Psychophysiology and Biofeedback, 29*(2), 113–120.

Gold, T. (1948). Hearing. II. The physical basis of the action of the cochlea. *Proceedings of the Royal Society of London B: Biological Sciences*, *135*(881), 492-498.

Hemanth, N., Ajith, K.U., Mamtha, H.R., & Prashanth, S.S. (2017 ongoing). Development of computer based frequency discrimination treatment for tinnitus subjects. *AIISH research funds, Mysuru.*

Herraiz, C., Diges, I., Cobo, P., Aparicio, J. M., & Toledano, A. (2010). Auditory discrimination training for tinnitus treatment: the effect of different paradigms. *European Archives of Oto-Rhino-Laryngology*, *267*(7), 1067–1074.

Herraiz, C., Diges, I., Cobo, P., Plaza, G., & Aparicio, J. M. (2006). Auditory discrimination therapy (ADT) for tinnitus managment: preliminary results. *Acta Oto-Laryngologica*, *126*(sup556), 80-83.

Hoare, D. J., Kowalkowski, V. L., & Hall, D. A. (2012). Effects of Frequency Discrimination Training on Tinnitus: Results from Two Randomised Controlled Trials. *Journal of the Association for Research in Otolaryngology*, *13*(4), 543–559.

Hoare, D. J., Stacey, P. C., & Hall, D. A. (2010). The Efficacy of Auditory Perceptual Training for Tinnitus: A Systematic Review. *Annals of Behavioral Medicine*, *40*(3), 313–324.

Hoare, D. J., Van Labeke, N., McCormack, A., Sereda, M., Smith, S., Al Taher, H., Hall, D. A. (2014). Gameplay as a source of intrinsic motivation in a randomized controlled trial of auditory training for tinnitus. *PLoS One*, *9*(9), e107430.

Jastreboff, M. M., & Jastreboff, P. J. (2002). Decreased sound tolerance and tinnitus retraining therapy (TRT). *Australian and New Zealand Journal of Audiology*, *24*(2), 74.

Jastreboff, P. J. (1990). Phantom auditory perception (tinnitus): mechanism of generation and perception. *Neuroscience Research*, 8: 221–54

Jastreboff, P. J., & Hazell, J. W. (1993). A neurophysiological approach to tinnitus: clinical implications. *British journal of Audiology*, *27*(1), 7-17.

Kaltenbach, J. A. (2006). The dorsal cochlear nucleus as a participant in the auditory, attentional and emotional components of tinnitus. *Hearing Research*, *216–217*, 224–234.

Kemp, D. T. (1978). Stimulated acoustic emissions from within the human auditory system. *The Journal of the Acoustical Society of America*, *64*(5), 1386-1391.

Mazurek, B., Olze, H., Haupt, H., & Szczepek, A. J. (2010). The More the Worse: the Grade of Noise-Induced Hearing Loss Associates with the Severity of Tinnitus. *International Journal of Environmental Research and Public Health*, *7*(8), 3071–3079.

McFadden, D. (1982). Tinnitus: facts, theories and treatments. Report of working group 89. Committee on Hearing, Bioacoustics and Biomechanics. National Research Council.

Meikle, M. B., Henry, J. A., Griest, S. E., Stewart, B. J., Abrams, H. B., McArdle, R., & Folmer, R. L. (2012). The tinnitus functional index: development of a new

clinical measure for chronic, intrusive tinnitus. *Ear and Hearing*, *33*(2), 153-176.

Melo, J., Meneses, C., & Marchiori, L. (2012). Prevalence of tinnitus in elderly individuals with and without history of occupational noise exposure. *International Archives of Otorhinolaryngology*, *16*(2), 222–225.

Møller, A. R. (1997). Similarities between Chronic Pain and Tinnitus. *Am J Orol*, *18*, 577-585.

Moller, A. R. (1984). Pathophysiology of tinnitus. *Ann Otol Rhinol Laryngol*, 93, 39 - 44.

Mühlnickel, W., Elbert, T., Taub, E., & Flor, H. (1998). Reorganization of auditory cortex in tinnitus. *Proceedings of the National Academy of Sciences*, *95*(17), 10340-10343.

Newman, C. W., Jacobson, G. P., & Spitzer, J. B. (1996). Development of the tinnitus handicap inventory. *Archives of Otolaryngology–Head & Neck Surgery*, *122*(2), 143-148.

Nondahl, D. M., Cruickshanks, K. J., Wiley, T. L., Klein, R., Klein, B. E., & Tweed, T. S. (2002). Prevalence and 5-year incidence of tinnitus among older adults: the epidemiology of hearing loss study. *Journal of the American Academy of Audiology*, *13*(6), 323-331.

Recanzone, G. H., Schreiner, C. E., & Merzenich, M. M. (1993). Plasticity in the frequency representation of primary auditory cortex following discrimination training in adult owl monkeys. *The Journal of Neuroscience*, *13*(1), 87–103.

Roberts, L. E., Eggermont, J. J., Caspary, D. M., Shore, S. E., Melcher, J. R., & Kaltenbach, J. A. (2010). Ringing Ears: The Neuroscience of Tinnitus. *Journal of Neuroscience*, *30*(45), 14972–14979.

Salvi, R. J., Lockwood, A. H., & Burkard, R. (2000). Neural plasticity and tinnitus. *Tinnitus handbook*, *1*, 123-148.

Sanchez, L. (2004). The epidemiology of tinnitus. *Audiological Medicine*, *2*(1), 8–17.

Shargorodsky, J., Curhan, G. C., & Farwell, W. R. (2010). Prevalence and Characteristics of Tinnitus among US Aduls. *Am. J. Med*, *123*(8), 711–718.

Thirunavukkarasu, K., & Geetha, C. (2013). One-year prevalence and risk factors of tinnitus in older individuals with otological problems. *The International Tinnitus Journal*, *18*(2).

Tugumia, D., Samelli, A. G., Matas, C. G., Magliaro, F. C. L., & Rabelo, C. M. (2016, February). Auditory training program in subjects with tinnitus. In *CoDAS* (Vol. 28, No. 1, pp. 27-33). Sociedade Brasileira de Fonoaudiologia.

Wise, K., Kobayashi, K., & Searchfield, G. D. (2015). Feasibility study of a game integrating assessment and therapy of tinnitus. *Journal of Neuroscience Methods*, *249*, 1–7.

Wise, K., Kobayashi, K., Magnusson, J., Welch, D., & Searchfield, G. D. (2016). Randomized Controlled Trial of a Perceptual Training Game for Tinnitus Therapy. *Games for Health Journal*, *5*(2), 141–149

Zacharia, T., Naik, P. V., Sada, S., Kuniyil, J. G., & Dwarakanath, V. M. (2012). Development and standardization of tinnitus handicap inventory in Kannada. *International Tinnitus Journal*, *17*(2). 119-125