Development of Auditory based application Software for Tinnitus Treatment

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Abstract

Background: Frequency Discrimination Treatment (FDT) is being used to reduce the tinnitus percept but the participants report boredom due to the repeated task. In the present study an interactive software was developed in which FDT is introduced in a game format with the purpose of increasing the client's motivation and attention. In addition, to use the software consistently and regularly to use it to reduce their tinnitus percept. Thus, the objectives formulated were to a) develop FDT in game format b) find the pre-post treatment effects on tinnitus characteristics and c) investigate the association between tinnitus severity with the handicap and functionality from tinnitus.

Method: A total of thirty participants who have had subjective tinnitus and normal hearing sensitivity were included. Each participant was provided FDT for 15 days. Outcome measures included quantitative tinnitus pitch and loudness and qualitative THI and TFI. The quantitative measures carried out in each day of treatment and baseline sessions, whereas the qualitative measure was performed at the baseline, day-1 and at each week during treatment session.

Results: A Friedman test revealed a significant reduction in handicap from tinnitus reflected in THI and reduced the functionality impairment from tinnitus reflected in TFI across sessions. A similar result was observed in each group on THI and TFI. In addition, a significant association was observed in Chi-Square test between severity and each qualitative measure of THI and TFI after 15 days of frequency discrimination training.

Conclusion:

To conclude the active discrimination of target frequency from tinnitus pitch achieved habituation of perception and reaction.

Key words: perceptual task, ringing, tinnitus,

Chapter -1

Introduction

Tinnitus is a ringing sound in the ear or head despite absence of acoustic event. The prevalence of tinnitus is 25.7% in individuals with geriatric aged 60 years and above, hearing loss was reported in 97.5% of these individuals (Thirunavukkarasu & Geetha, 2013) and it is considered to be a serious health care burden (El-Shunnar et al., 2011) Several of the auditory management strategies for tinnitus have emerged based on models and theories causing tinnitus. Currently a gold standard approach in treating tinnitus is through providing passive sound stimulation to mask it. However recent studies on active sound stimulation in suppressing tinnitus have shown convincing positive outcome over gold standard approach ((Hoare et al., 2014; McNeill, Tavora-Vieira, Alnafjan, Searchfield, & Welch, 2012; Tyler, Stocking, Secor, & Slattery, 2014; K. Wise, Kobayashi, & Searchfield, 2015) as these researchers based their hypothesis on selective attention to a target non-tinnitus sound from tinnitus sound which eventually results in reversal of old maladaptive cortical remap.

An active form of sound enrichment to treat tinnitus is frequency discrimination task (FDT). Hoare, Stacey, & Hall, (2010) reported that perceptual training interrupts tinnitus generation there by changes function reorganization through active listening condition. Hoare, Kowalkowski, & Hall, (2012) investigated the effect of FDT on tinnitus handicap on 70 adults with sloping hearing loss who had chronic subjective tinnitus. Three groups of participants were randomly trained with FDT on either a) at the frequency of normal hearing portion b) within frequency region of hearing loss and c) a high pass harmonic complex tone within the region of hearing loss. They observed no change in tinnitus handicap between groups after training. In addition, during the course of each therapy session many clients had reported that the task is repetitive and bored after a few minutes of usage. Their findings suggest merely acoustic mechanism is not helpful for tinnitus remediation. However, non-specific pattern of improvement reflected in psychoacoustic characteristic suggestive of FDT impact on contributory mechanism such as selective attention or emotional state.

Hoare et al., (2014) sought solution to this by developing FDT software into game by incorporating interactive modules to maintain motivation and attention towards task. This was considered with the premise that cognitive deficit such as attention and working memory are often and if FDT improves attention then it may be useful for tinnitus. A total of 60 participants were randomly assigned to either a) star b) treasure hunter and c) submarine games for span of four weeks. At the end of four weeks each of the participants were trained with all these games. They documented a) intrinsic motivation such as challenge, control and curiosity, b) usability and game preference c) tinnitus handicap d) psychoacoustic measures and d) attention. The results reveled that motivation in engaging with the three games was same and had measurable enjoyment under game usability. Analyses of THI subscale on 'health and psychological well being' revealed a small (7% reduction) significant difference between before and after treatment. However, no difference on the THI subscale of 'hearing difficulty' was noted. This reflects overall change observed only in psychological rather than functional handicap of tinnitus. The studies of Hoare, Gander, Collins, Smith, & Hall, (2012); Hoare et al., (2014) failed to document pitch and loudness during the course of therapy session. Failure to document tinnitus pitch perhaps leads to training at incorrect frequencies for discrimination, leading to negate outcome of tinnitus remap. Wise (2016) hypothesized that the perceptual task in game format with intentionally reducing an attention to tinnitus expected to change the perception of tinnitus by breaking strong neural path of previous tinnitus precept. In this task clients were instructed to locate the target pulsating sound (dissimilar with respect to tinnitus) in an attempt to ignore distracter sounds through the use of target sound intensity cue. Thematic analyses revealed that the perceptual task in game format encompassing auditory attention found to be feasible for training patient to treat tinnitus. In yet another study by Wise, Kobayashi, Magnusson, Welch, & Searchfield, (2016) on perceptual task revealed there was a significant reduction in Tinnitus Functional Index (TFI) and reduction in THI. Frequency discrimination perceptual task had shown positive outcome in reduction of tinnitus precept but was confined to the participants who had mild tinnitus handicap, irrespective of pitch. This evidence suggests documenting subjective profile on tinnitus relief might shed light on extent of effective treatment approach to treat clients having tinnitus.

Thus, in present study clients having tinnitus handicap of different degree were recruited. The outcome was measured using qualitative analyses such as tinnitus handicap index (THI) and tinnitus functional index (TFI) questionnaires and quantitative measures using psychoacoustic tests utilizing tinnitus pitch and loudness at pre- and post- treatment sessions in interactive perceptual training software to avoid bore some and eliminate monotonocity.

1.2. Need for the study

Every month on an average 70 to 100 clients report to clinic with the complaint of tinnitus. The line of audiological management provided to clients having tinnitus is sound enrichment which works on masking principle. This strategy is found to be beneficial only during sound enrichment. Unfortunately, in quiet condition or during no conversation, majority of clients have reported tinnitus. Hence the objective of tinnitus treatment should be, to make the client experience either habituation to reaction or habituation to perception of tinnitus.

In addition, in our clinic a few clients who have underwent therapy for tinnitus showed a significant attrition because of ineffective training regime. They are merely provided with counseling and background therapy, requires no or minimal involvement from client. Though these approaches have been found to be effective to reduce tinnitus to beneficiaries, clients have reported that these treatments were repetitive and bore some over time. Moreover, behavioral treatments to treat tinnitus are nowadays becoming computerized such that it can be tailor made to individualize.

Computer assisted health interventions are gaining more prominence nowadays as it supports clients desire needs. In perceptual game, client was instructed to interact with the training program rather react to the stimulus presented from the software. That is, they have to discriminate the non-tinnitus target sound from distractors sound to frame a puzzle. Interactive training module incorporating a few elements in a game play such as decision making, strategy development and competition may enhance intrinsic motivation to use it regularly and consistently. In addition, perceptual discrimination task in game format to treat tinnitus is not currently available in market to procure.

In present day our clinic has no such treatment software to cater the client's desire need. Thus, in the present project we have proposed to develop software incorporated perceptual discrimination task in a game format to appreciate enjoyment and engagement with it to reduce over attention towards tinnitus. Further, treatment effect was documented considering individuals with wide spectrum of tinnitus handicap.

1.3. Specific objectives

1. Development of auditory based software for treatment of tinnitus.
2. Profiling of participant based on severity of tinnitus.

3. To evaluate the treatment effect using qualitative THI and TFI measures on study participants.

4. To determine the association between tinnitus characteristics and severity of tinnitus, after FDT treatment.

1.4. Aim of the study

Aim of the study was to develop frequency discrimination task to treat tinnitus and further to investigate its effect on individuals with tinnitus.

Chapter -2

Method

The present study aimed to investigate the treatment effect for tinnitus using frequency discrimination training in a game play format. The treatment effect was quantified using quantitative measures (pitch, loudness and attention task) and qualitative measures (THI and TFI) on study participants.

2.1. Participants

A total of 30 participants were involved in the study with in the age range of 20 years to 60 years (Mean age = 42.26 years). Those participants who had unilateral continuous bothersome tinnitus were included in the study. All the participants had hearing sensitivity with in normal limit ≤ 15 dB HL in both ears, except older adults where the hearing sensitivity was ≤ 25 dB HL at high frequencies at 4 kHz and 8 kHz. Participants who had normal middle ear as indicated by type A tympanogram were recruited. Further the study participants were grouped into four based on the severity of tinnitus a) mild (Group-1; N = 6) b) moderate (Group-2; N =18), c) severe (Group-3; N =3) and d) catastrophic (Group-4; N=3). The selected participants had no other neurological, psychological and cognitive issues. They were native speakers of Kannada and geographically located in and around Mysore. *An informed consent was obtained from each participant by explaining the procedure of treatment and time allocated for treatment.* All procedures performed in studies involving human participants were in accordance with the ethical standards of the AIISH institutional research committee

(SH/CDN/ARF-60/2016-17). A detailed characteristic of tinnitus and probable cause for each participant in four groups are tabulated in Table -2.1.

Table -2.1 Details of tinnitus characteristics of each participant

SI	Groups	Age	Tinnitus Ear	Tinnitus Pitch (Hz)	Loudness (SL)	THI	TFI	Probable Cause
1	Mild	25	Right	400	15	Mild	Small problem	Stress
2	Mild	30	Left	250	10	Mild	Small problem	Stress
3	Mild	40	Right	2000	15	Mild	Small problem	Noise exposure (>10 year, 8 hours 80 dB, EPD's)
4	Mild	30	Left	500	5	Mild	Small problem	Dental factor
5	Mild	50	Right	1500	10	Mild	Small problem	Stress
6	Mild	55	Left	200	10	Mild	Small problem	Accident
7	Moderate	44	Right	250	15	Moderate	Moderate problem	Stress
8	Moderate	60	Right	250	15	Moderate	Moderate problem	Stress
9	Moderate	40	Left	125	10	Moderate	Moderate problem	Stress
10	Moderate	20	Right	200	5	Moderate	Moderate problem	Stress
11	Moderate	40	Left	300	10	Moderate	Small problem	Accident
12	Moderate	25	Left	6000	15	Moderate	Moderate problem	Noise exposure (>5 mnt year, 7 hours 65 dB)
13	Moderate	25	Right	120	15	Moderate	Moderate problem	Stress
14	Moderate	40	Right	7000	10	Moderate	Moderate problem	Stress
15	Moderate	43	Left	250	15	Moderate	Moderate problem	Stress
16	Moderate	54	Right	3000	10	Moderate	Moderate problem	Stress
17	Moderate	61	Left	2500	15	Moderate	Moderate problem	Noise Exposure
18	Moderate	44	Left	7000	10	Moderate	Moderate problem	Noise Exposure

								(>20 year, 8 hours 70 dB, EPD's)
19	Moderate	35	Right	950	10	Moderate	Moderate problem	Stress
20	Moderate	22	Left	7000	10	Moderate	Moderate problem	Stress
21	Moderate	45	Left	6500	15	Moderate	Moderate problem	Stress
22	Moderate	40	Right	1000	15	Moderate	Small problem	Stress
23	Moderate	45	Left	200	10	Moderate	Moderate problem	Stress
24	Moderate	60	Right	5000	10	Moderate	Moderate problem	Noise exposure(>1 year, 30 hours 60 dB, EPD's)
25	Severe	50	Right	250	10	Severe	Moderate problem	Accident
26	Severe	25	Left	750	15	Severe	Moderate problem	Stress
27	Severe	35	Left	4000	10	Severe	Big problem	Stress
28	Catastrophic	65	Right	3000	10	Catastrophic	Very big problem	Stress
29	Catastrophic	60	Right	8000	10	Catastrophic	Very big problem	Stress
30	Catastrophic	30	Left	3000	15	Catastrophic	Very big problem	Accident

2.2. Development of software – Perceptual frequency discrimination task

The developed software has two modules. An evaluation module and the other one is a treatment module.

2.2.1. Evaluation module. Evaluation module consists of both qualitative and quantitative methods to measure the severity of tinnitus and to estimate tinnitus pitch and loudness respectively.

2.2.1.1. Qualitative measures. The qualitative measures comprised of **Tinnitus handicap inventory (**THI) and **Tinnitus Functional Index** (TFI). Questions pertained to each measure are loaded in 'outcome measurement module of Software for presenting and documenting the data from study participants. It was used for pre-, during- and post-therapy assessment to determine the effectiveness of treatment.

2.2.1.1.1. Tinnitus handicap inventory (THI). Tinnitus handicap inventory (THI) developed by Newman and colleagues (1996) and its Kannada version adopted by Dwarkanath et al (2016) was utilized. It comprised of 25-items inventory that evaluate the functional and emotional implications of tinnitus and probes the severity of tinnitus in a patient. The patient must answer to each question with "yes" (4 points), "sometimes (2 points) or "no" (0 points). Responses are summed to determine the patient's score which ranges from 0 to 100 points. The patient's total score is then compared to the THI grade levels to interpret the level of tinnitus severity. The scoring patterns are as follows2-16 slight, 18-36 mild, 38-56 moderate, 58-76 severe and 78-100 catastrophic.

2.2.1.1.2. Tinnitus Functional Index (TFI). TFI was developed by Henry et al., (2014). It is a 25-items inventory tool that uses a 10-point scale ('0' represented as less effected and '10' represented as extremely effected) to measure and classify tinnitus severity. It comprises of eight subscales which includes i) the intrusiveness of tinnitus, ii) sense of control the patient has, iii) cognitive interference, iv) sleep disturbance, v) auditory issues, vi) relaxation issues, vii) quality of life and viii) emotional distress. Each of the 8 subscales consists of 3 items except for the Quality of life subscale, which consists of 4 items. For valid sub scale scores, no more than 1 item should be omitted. Subscales are computed to arrive at final TFI score. Sum of all subscales divided by number of questions answered multiplied by 10. This procedure generates a score in the range of 0-100. A total score on TFI received from each patient was classified as -

not a problem (range 0-17); small problem (range 18-31); moderate problem (range 32-53); big problem (range 54-72); and very big problem (range 73-100).

2.2.1.2. Quantitative measures. The quantitative measures comprised of pitch and loudness matching task and attention task. These tasks are computerized for effective presentation of stimulus and documenting results from each study participant. The pitch and loudness were assessed from ten participants in conventional method and from the software. It was found ± 5 dB and 7 Hz difference in loudness and pitch and these differences are within intra-subject reliability.

2.2.1.2.1. Pitch and loudness matching task. To assess tinnitus pitch and loudness an adaptive method given by (Jastreboff & Jastreboff, 2000) was adopted. The ear contra-lateral to the tinnitus was used for matching of tinnitus pitch and loudness, if the subject had unilateral tinnitus. Whereas, the ipsi-lateral matching was done for individuals with bilateral tinnitus. The loudness matching was identified first before the pitch matching. Loudness matching was performed at octave frequencies from 125 Hz to 8000 Hz (above 8 kHz if required). For loudness matching the initial presentation level was presented at 5 dB SL (Jastreboff & Jastreboff, 2000) and it was varied in 1 dB step till the patient was able to match the loudness. In order to match the pitch, participants were presented with a pair of loudness matched tones sequentially and instructed to report the tone that is closer to his/her tinnitus. This procedure continued for consecutive octave frequencies till the participant was able to match the pitch. For example, we presented the loudness matched tones at 1 kHz and 2 kHz and asked the patient which one was nearer to his/ her tinnitus pitch. If the patient matched his/her tinnitus with 1 kHz tone, then the same procedure was repeated with 1 kHz and 500 Hz

(2 kHz and 4 kHz if the patient matches with 2 kHz instead of 1 kHz). The procedure continued till the patient gets to the frequency closest to his/ her tinnitus. It was ensured that the tones presented did not exceed the loudness discomfort level of the participant.

2.2.2. Treatment module. A training game module adopting frequency discrimination task was used as the treatment approach to provide relief from tinnitus. Frequency discrimination training attempted to alter the central frequency map of tinnitus by training sound discrimination near tinnitus pitch regions. It's an activity to shift the tinnitus frequency to its neighboring frequency (in the multiples of 1/3rd octave of the tinnitus frequency) by conditioning the individual to memorize the neighboring frequency corresponding to the tinnitus pitch. Tinnitus pitch may change naturally, and would lead to tonotopic reorganization at auditory cortical level.

2.2.2.1. Stimuli in perceptual frequency discrimination task. Once the evaluation was completed and was saved the software would automatically generate target and distracter stimuli based on the tinnitus pitch using MATLAB. The tinnitus pitch and loudness of test ear was estimated using adaptive method (Jastreboff & Jastreboff, 2000) in the evaluation module of software. A 1/3rd octave below the frequency of tinnitus was considered as target (T), frequency of tinnitus was considered as distracter1 (D1). A 2/3rd octave below tinnitus frequency was considered as distracter 2 (D2). A 1/3rd octave above tinnitus frequency was considered as D3. A 2/3rd octave above tinnitus frequency was considered as D4. Each of these stimuli were presented through iball headphone Rk25 which has frequency response within 0.125 kHz to 10 kHz.

Most comfortable level:

Intensity of target tone and distracters were set at MCL for each ear individually before the actual game of FDT was administrated. The software has facility to present stimulus to both ears simultaneously. If the participant had asymmetric hearing loss, the MCL in both ears were optimized by subjectively matching the loudness level in both the ears to avoid ambiguity in identification of target sound.

The target tone intensity was played at MCL+7dB and the other distracters were played at MCL. This added as a cue to identify target over other distracters.

2.2.2.2. Target familiarization. Target familiarization involved presentation of target sounds to both ears in different patterns. The target familiarization should be successfully completed to move on to target identification. Each participant was made to identify targets along with the presence of distracters. Participates was instructed to discriminate between the tones and identify the target tone correctly and consistently in the presence of distracters.

Training was carried out using direction pattern test. In direction pattern test, the participants are asked to lateralize the sound to either right or left which was presented in sequence at MCL level. The participants were instructed to write/tell the pattern of presentation of stimulus. There were six combination of patterns in which the target tone was presented to either right or left ear. Six patterns were repeated five times randomly (6x5=30 trails). In total there were 30 set of stimuli, where each set consisted of a pattern of presentation as follows.

RLR, RLL, LRR, LRL, RRL, LLR

R- right ear and L- Left ear

To complete the target familiarization task, the participant is asked to identify the pattern 70% of the time correctly i.e., among 30 trails the participant is said to have correctly identified the target in 21 trails. This task was administered in the presence of clinician and in every trail the feedback was given to the corresponding response. If the score is less than 70 % then client has to undergo the training until target score (70 %) attained in the task.

2.2.2.3. Target identification:

Level 1: Once the tone familiarization was achieved during the training mode, the participants were moved to level 2 and it consisted of one target and one distracter D1. The client was asked to find the target tone correctly and consistently with the presence of one distracter

Level 2: Two distracters i.e., distracter 1 and distracter 2 was introduced along with the target tone. The client was asked to find the target tone correctly and consistently with the presence of two distracters.

Level 3: As the game level increased the complexity of the game also increased. Three distracters were present in level 4. Distracter 1, distracter 2, distracter 3 were introduced along with the target. The client had to find the target tone correctly and consistently with the presence of three distracters.

Level 4: Four distracters were present in level 4. Distracter 1, distracter 2, distracter 3 distracter 4 were introduced along with the target tone with the presence of four distracters. Eventually target and distracters varied as the tinnitus pitch varied.

Puzzle game: 9 or 16 pieces puzzles were given to the participants after the tone familiarization. Pieces in the puzzle were associated with an audio file of target and distracter sounds and they were played sequentially in random order. If the target was correctly identified, the image appears. If not, message "wrong" appears on the screen. Each participant was asked to identify the target sounds correctly to complete the puzzle. The images used were unrepeated to avoid monotonicity in the game. The game was sufficiently difficult to maintain interest and attention while being sufficiently manageable to minimize fatigue. The game provided the patient with feedback regarding progress or lack of progress. Once the puzzle was complete, the patient was moved to next level with a fresh puzzle to complete. Similarly, patient was asked to complete all four levels by completing the puzzles at each level.

2.2.2.4. Training regime. Each participant was tested with two baselines with time interval of one week. During the course of pre training time participants were given sound therapy and counseling which are the component of tinnitus retraining therapy. A training session of three weeks was provided using game format of FDT to obtain tinnitus relief from study participants. Each day of training session lasted for 30 minutes. End of each week of training the qualitative and quantitative measures were documented to see the effect of training on over all tinnitus relief.

2.3. Analyses

Tinnitus characteristic was profiled based on tinnitus pitch, loudness, THI and TFI using descriptive statistical analysis. In addition, to investigate the treatment effect across sessions a Friedman test was administered. This was administered for each group. If any significant difference was observed, then Wilcoxon signed rank test was performed. Further to assess the association between treatment effect and characteristic of tinnitus a Chi Square test was used.

Chapter -3

Results

A tinnitus pitch, loudness, THI and TFI of baseline and for the three weeks of treatment data were obtained from each participant of four groups who were classified based on severity of tinnitus.

3.1. Profiling of tinnitus characteristics in each group

The range of loudness and pitch at baseline and after 15 days of treatment using FDT were described for participants of each group. In addition, the data on THI and TFI at baseline and after treatment were also described.

3.1.1. Mild group. There are six participants in the mild group. The THI at baseline was mild and after treatment the THI was reported to be slight severity of handicap from tinnitus in five participants. A remaining one participant stated habituation of perception after three weeks of treatment. The pitch ranged from 200 Hz to 2000 Hz at the baseline and after three weeks of treatment except on one participant the pitch ranged from 125 Hz to 1000 Hz. In addition, the loudness of tinnitus in mild participants ranged from 5 to 15 dB SL at baseline and after treatment except on one participant the loudness changed from 5 to 10 dB SL. Further, the TFI at baseline was reported to be a ‘small problem’ and after the treatment TFI had changed to ‘not a problem’ from all six participants of mild group.

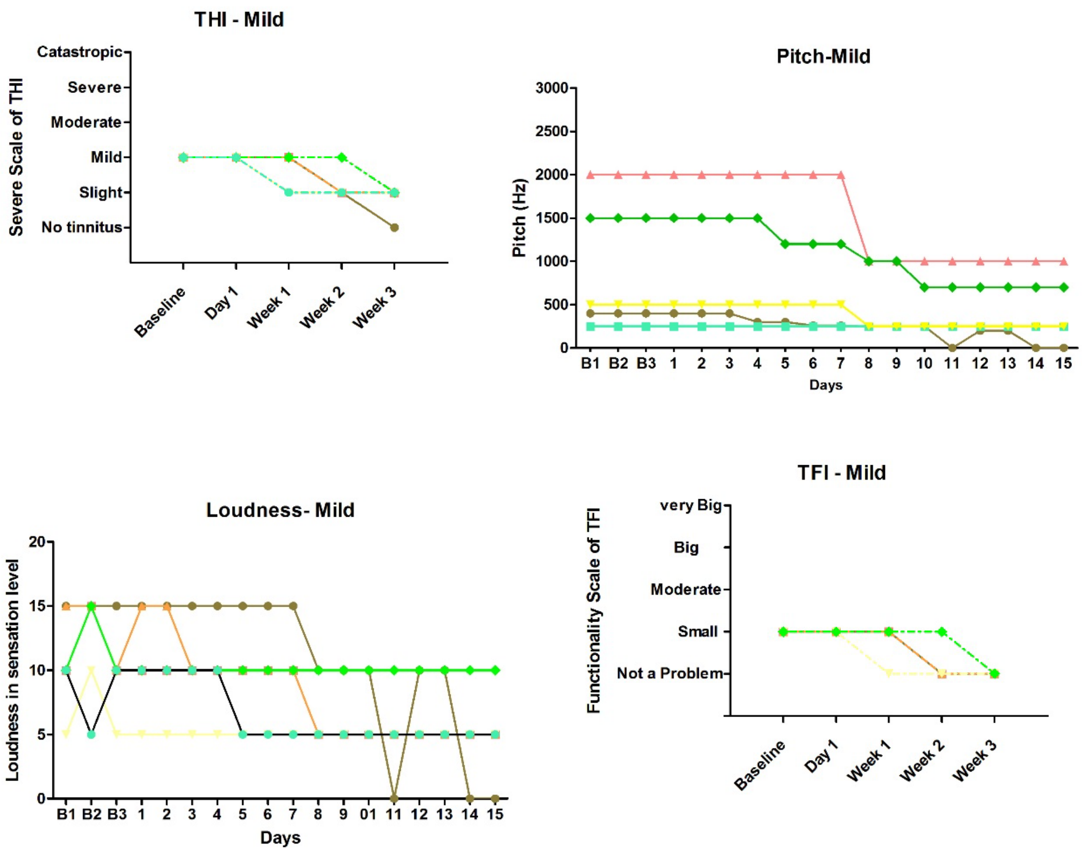

Figure-3.1 Characteristics of tinnitus from each participant of mild group.

The characteristics of tinnitus from each participant of mild group is shown in Figure-3. 1. It was observed that though the participants had mild severity of handicap from tinnitus, the loudness followed no pattern as a function of treatment for 15 days. This was same for other characteristics of tinnitus such as pitch, severity of handicap (THI) and functionality (TFI). At the end of 15 days of treatment, only one participant in mild group reported no experience of tinnitus. Four participants reported there was a change in pitch and loudness of tinnitus. Only one participant reported no change in either pitch or loudness of tinnitus.

3.1.2. Moderate Group. The characteristics of tinnitus from each participant of moderate group is shown in Figure-3. 2. There are 18 participants in the moderate group. The THI at baseline was moderate and after treatment the THI was reported to be mild severity of handicap from tinnitus in 11 participants and remained unchanged in three participants. the remaining four participants stated no experience of tinnitus after three weeks of treatment. except four participants the pitch ranged to 90 Hz to 7000 Hz after three weeks of treatment where whose pitch ranged from 120 Hz to 7000 Hz at the baseline. In addition, the loudness in moderate participants ranged from 5 to 15 dB SL at baseline and after treatment except on four participants the loudness ranged 5 to 10 dB SL. Further, the TFI at baseline was ranged 'mild - moderate problem' and after the treatment TFI had changed and which ranged 'moderate - not a problem'.

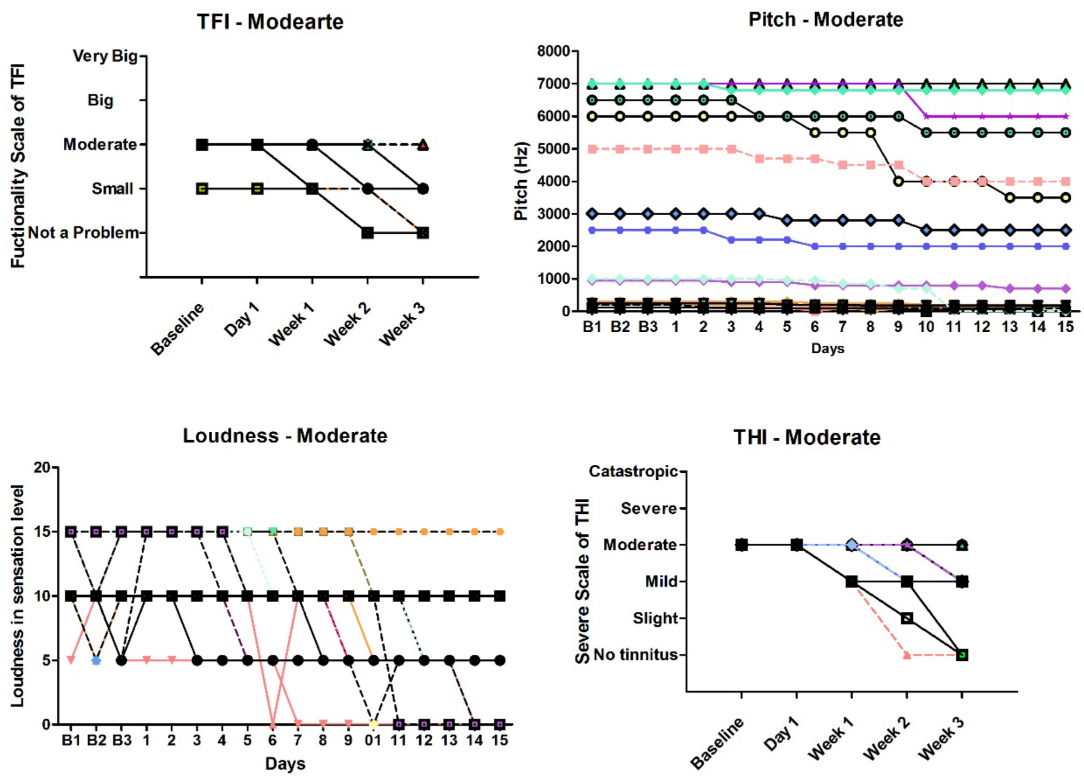

Figure-3.2. Characteristics of tinnitus from each participant of moderate group.

It was observed that though the participants had moderate severity of handicap from tinnitus, the loudness followed no pattern as a function of treatment for 15 days. This was same for other characteristics of tinnitus such as pitch, severity of handicap (THI) and functionality (TFI). At the end of 15 days of treatment, four participants in moderate group reported no experience of tinnitus. In addition, thirteen participants reported change in pitch and ten participants reported a change in loudness. Further, only one participant reported no change in pitch of the tinnitus and four of them experienced no change in loudness.

3.1.3. Severe Group. The characteristics of tinnitus from each participant of severe group is shown in Figure-3.3. There are three participants in the severe group. The THI at baseline was severe and after treatment the THI was reported to be mild to moderate severity of handicap from tinnitus. The pitch ranged from 250 Hz to 4000 Hz at the baseline and after three weeks of treatment the pitch ranged from 70 Hz to 3000 Hz. In addition, the loudness in severe group participants ranged from 10 to 15 dB SL at baseline and after treatment the loudness ranged 5 to 10 dB SL. Further, the TFI at baseline was ranged ‘moderate - big problem’ and after the treatment TFI had changed to ‘small problem’.

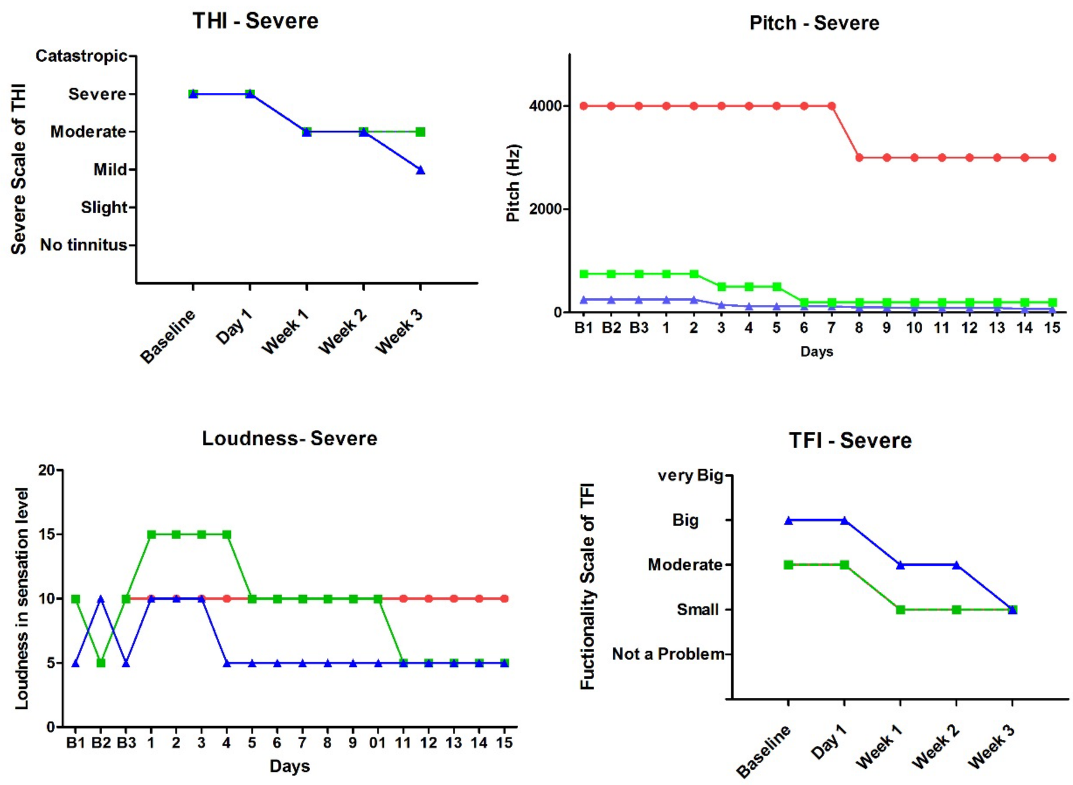

Figure-3.3. Characteristics of tinnitus from each participant of severe group.

It was observed that though the participants had severe degree of severity in handicap from tinnitus, the loudness and pitch followed no pattern as a function of treatment for 15 days. Whereas, in both THI and TFI an observable linear change was noticed as a function of treatment from all three participants. At the end of 15 days of treatment, three participants in severe group reported change in pitch of their tinnitus. In addition, two participants reported change in loudness and one participant reported no change in loudness.

3.1.4. Catastrophic Group. The characteristics of tinnitus from each participant of catastrophic group is shown in Figure-3.4. There are three participants in the catastrophic group. The THI at baseline was catastrophic and after treatment the THI was reported to be moderate to severe degree of severity in handicap from tinnitus. The pitch ranged from 3000 Hz to 8000 Hz at the baseline and after three weeks of treatment the pitch ranged from 2000 Hz to 8000 Hz. In addition, the loudness in catastrophic group of participants ranged from 10 to 15 dB SL at baseline and after treatment the loudness changed to 5 dB SL. Further, the TFI at baseline was 'very big problem' and after the treatment the TFI had changed which ranged from to 'very big problem - moderate problem'.

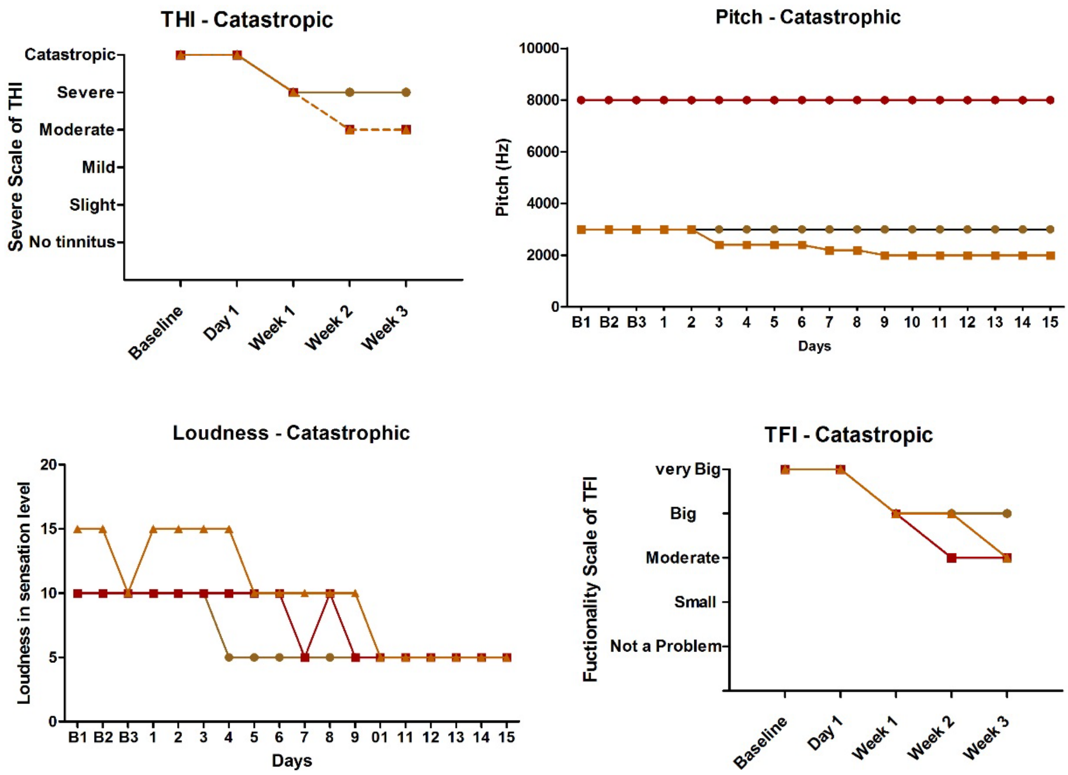

Figure-3.4. Characteristics of tinnitus from each participant of catastrophic group.

It was observed that though the participants had catastrophic degree of severity in handicap from tinnitus, the loudness followed no pattern as a function of treatment for 15 days. Whereas, in both THI and TFI an observable linear change was noticed as a function of treatment from all three participants. At the end of 15 days of treatment, three participants in catastrophic group reported change in loudness of their tinnitus. In addition, two participants reported change in pitch and one participant reported no change in pitch.

3.2. To determine the treatment effect on THI and TFI.

In each group, the ordinal data of THI from participants across five sessions (bassline, day-1, week -1 week-2 and week-3 of post treatment) were subjected to Friedman's test. This was performed for each group separately. Further, Wilcoxon signed rank test was conducted as a post hoc if significant arises in Friedman's test on data of THI. A similar test was conducted on the data of TFI.

3.2. 1. Treatment effect on Tinnitus severity index. Figure-3.5. presents the mean rank of THI in each group. Using Friedman's chi-square test, we found a significant difference in the mean rankings of the THI across sessions in mild group $X^2(4, N = 6) = 18.41$, $p = 0.001$, moderate $X^2(4, N = 6) = 18.41$, $p = 0.001$, severe $X^2(4, N = 6) = 18.41$, $p = 0.001$and catastrophic group $X^2(4, N = 6) = 18.41$, $p = 0.001$, respectively.

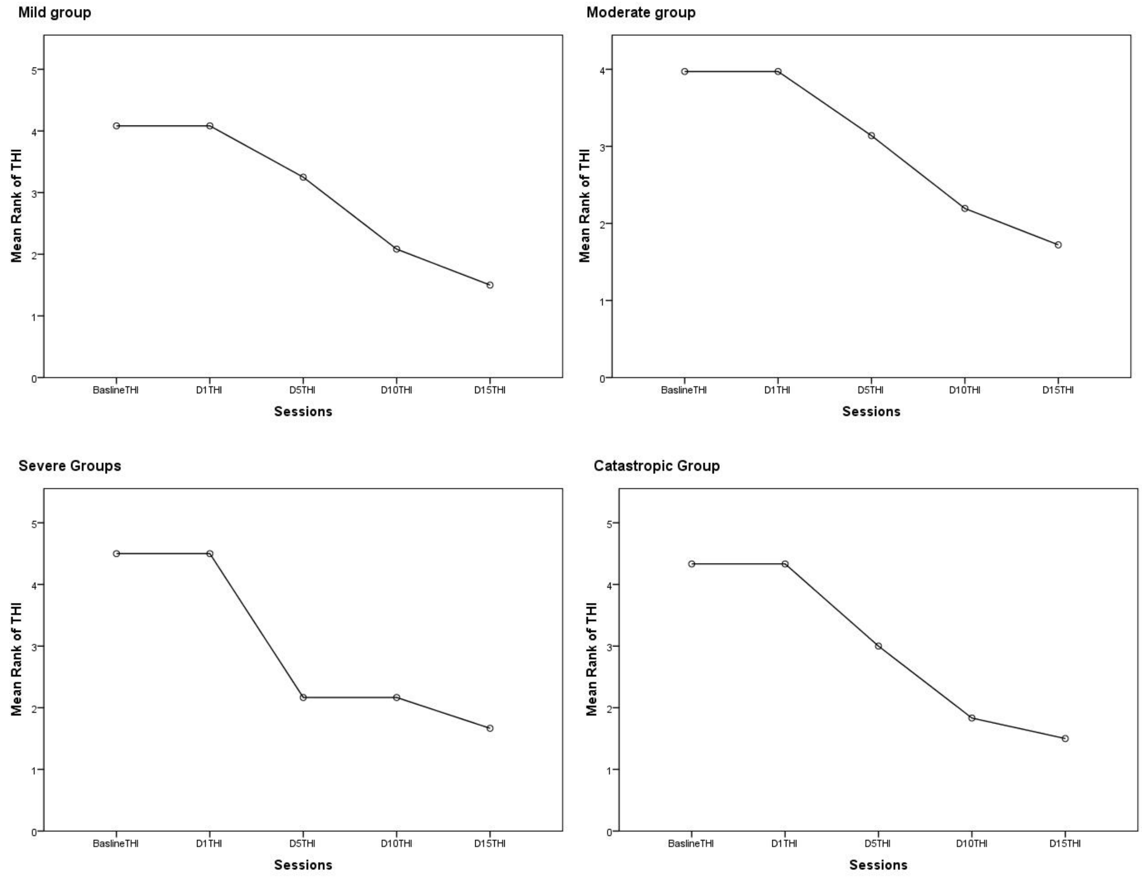

Figure-3.5-line graph showing the mean rank of THI across sessions in each group.

Further, a Wilcoxon signed rank test was administered on mean rank data of THI across sessions. This was performed separately in each group. It was observed that mean rank of THI reduced as a function of session, although there was no difference between baseline and day 1 THI value in each group. From Table-3.1. showing the Z value and of p value of Wilcoxon signed rank test for the data of THI.

1. Mild group: The mean rank of THI in day 10 and day 15 were significantly reduced from baseline. Further, the mean rank of THI was significantly reduced from day 10; and day 15 compared to day 1.

2. Moderate group: Expect mean rank of THI between the baseline and day 1, a significant difference was noticed between sessions in which THI was reduced as a function of sessions.
3. In both severe and catastrophic groups, a significant mean rank of THI was reduced from day 5; day 10; and day 15 compared to bassline.

Table-3.1. The Z and p values of Wilcoxon signed rank test for the data of THI in each group.

Groups →	*Mild*		*Moderate*		*Severe*		*Catastrophic*	
Sessions ↓	*Z value*	*P value*	*Z value*	*P value*	*Z value*	*P value*	*Z value*	*P value*
D1THI - BaslineTHI	.000	1.000	.000	1.000	.000	1.000	.000	1.000
D5THI - BaslineTHI	-1.414	.157	-2.646	**.008**	-1.732	**.050**	-1.414	**.045**
D10THI - BaslineTHI	-2.236	**.025**	-3.418	**.001**	-1.732	**.050**	-1.633	**.050**
D15THI - BaslineTHI	-2.333	**.020**	-3.578	**.000**	-1.633	**.050**	-1.633	**.030**
D5THI - D1THI	-1.414	.157	-2.646	**.008**	-1.732	**.049**	-1.414	**.039**
D10THI - D1THI	-2.236	**.025**	-3.418	**.001**	-1.732	**.048**	-1.633	**.048**
D15THI - D1THI	-2.333	**.020**	-3.578	**.000**	-1.633	**0.46**	-1.633	**.020**
D10THI - D5THI	-1.732	.083	-2.714	**.007**	.000	1.000	-1.414	.157
D15THI - D5THI	-1.890	.059	-3.025	**.002**	-1.000	.317	-1.342	.180
D15THI - D10THI	-1.414	.157	-2.070	**.038**	-1.000	.317	-1.000	.317

3.2.2. Treatment effect on Tinnitus functional index. Figure-3.6. presents the mean rank of TFI in each group. A Friedman test was carried out to compare the mean rank of TFI across sections. There was found to be a significant reduction in functional index from tinnitus as a function of treatment in mild $X^2(4, N = 6) = 18.35$, $p = 0.001$, moderate $X^2(4, N = 6) = 52.00$, $p = 0.001$, severe $X^2(4, N = 6) = 11.50$, $p = 0.021$, and catastrophic $X^2(4, N = 6) = 11.29$, $p = 0.023$ groups, respectively.

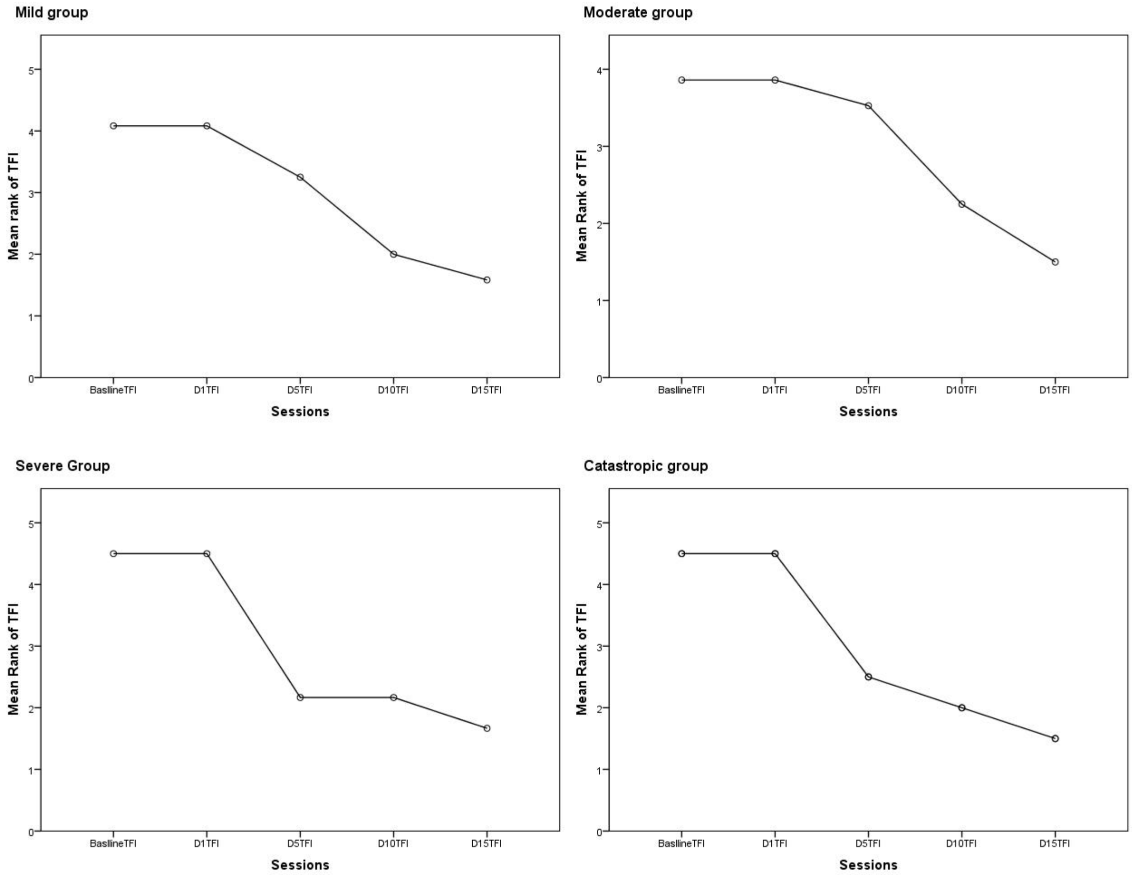

Figure-3.6-line graph showing the mean rank of TFI across sessions in each group.

Further, a Wilcoxon signed rank test was administered on mean rank data of TFI across sessions. This was performed separately in each group. It was observed that mean rank of TFI reduced as a function of sessions, although there was no difference between baseline and day 1 TFI value in each group. From Table-3.1. shows the Z value and of p value of Wilcoxon signed rank test for the data of TFI.

1. Mild group: The mean rank of TFI in day 10 and day 15 were significantly reduced from baseline. Further, the mean rank of TFI was significantly reduced from day 10; and day 15 compared to day 1.

2. Moderate group: Expect mean rank of TFI between the baseline and day 1, a significant difference was noticed between sessions in which TFI was reduced as a function of sessions.
3. In both severe and catastrophic groups, a significant mean rank of TFI was reduced from day 5; day 10; and day 15 compared to bassline.

Table-3.2. Showing the Z and p values of Wilcoxon signed rank test for the data of TFI in each group.

Groups →	*Mild*		*Moderate*		*Severe*		*Catastrophic*	
Sessions ↓	*Z value*	*P value*	*Z value*	*P value*	*Z value*	*P value*	*Z value*	*P value*
D1TFI – BasllineTFI	.000	1.000	.000	1.000	.000	1.000	.000	1.000
D5TFI – BasllineTFI	-1.414	.157	-1.732	.083	**-1.732**	**.043**	**-1.732**	**.042**
D10TFI –BasllineTFI	-2.236	**.025**	-3.357	**.001**	**-1.732**	**.033**	**-1.633**	**.032**
D15TFI –BasllineTFI	-2.449	**.014**	-3.704	**.000**	**-1.633**	**.022**	**-1.633**	**.022**
D5TFI - D1TFI	-1.414	.157	-1.732	**.043**	**-1.732**	**.043**	**-1.732**	**.053**
D10TFI - D1TFI	-2.236	**.025**	-3.357	**.001**	**-1.732**	**.033**	**-1.633**	**.022**
D15TFI - D1TFI	-2.449	**.014**	-3.704	**.000**	**-1.633**	**.022**	**-1.633**	**.032**
D10TFI - D5TFI	-1.732	.083	-3.162	**.002**	.000	1.000	-1.000	.317
D15TFI - D5TFI	-2.000	.046	-3.690	**.000**	-1.000	.317	-1.414	.157
D15TFI - D10TFI	-1.000	.317	-2.646	**.008**	-1.000	.317	-1.000	.317

3.2. To determine the association between tinnitus characteristics and severity of tinnitus after FDT treatment.

Test of Chi-square was used to assesses whether an association exists in pitch before and after therapy. This was performed by comparing the observed pattern of pitch or loudness responses (after 15 days of the therapy) to the baseline. Similarly, it was done for loudness of tinnitus. The null hypothesis (H_0) is stated has either pitch or loudness of the tinnitus has no effect on severity of handicap after 15 days of treatment. The results revealed no significant association between tinnitus pitch [X^2 (6, N = 30) = 9.98, p =0.12] and severity of handicap after 15 days of treatment. Similarly, there was no association between loudness of tinnitus and the severity of handicap from tinnitus [X^2 (6, N = 30) = 3.41, p =0.75] after 15 days of treatment (Figure-3.7). The result indicates ($p>0.05$) to accept the null hypothesis.

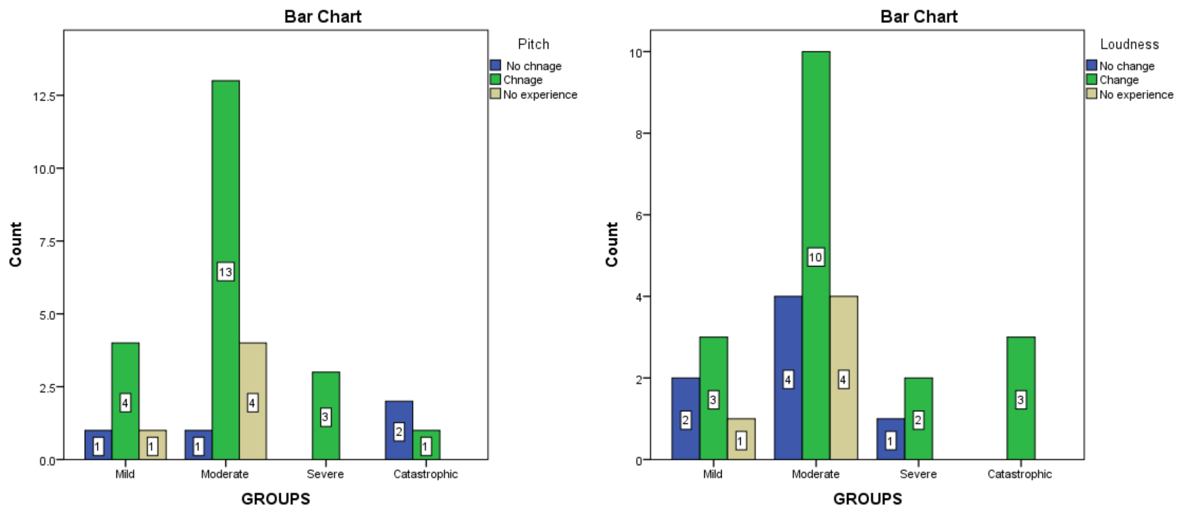

Figure-3.7 Bar graph showing the status of pitch and loudness after 15 days of treatment in each group.

Further, THI and TFI status after 15 days of treatment on participants who were grouped based on severity of handicap was assessed using Chi-Square Test. The null hypothesis (H_0) is stated as either THI or TFI has no effect on severity of handicap after 15 days of treatment. The results revealed a significant association between change in THI [X^2 (12, N = 30) = 42.54, p =0.001] and severity of tinnitus after 15 days of treatment. Further, a significant association was found between TFI and severity of tinnitus after 15 days of treatment [X^2 (9, N = 30) = 31.41, p =0.001] (Figure- 3.8). The result indicates ($p<0.05$) to reject the null hypothesis.

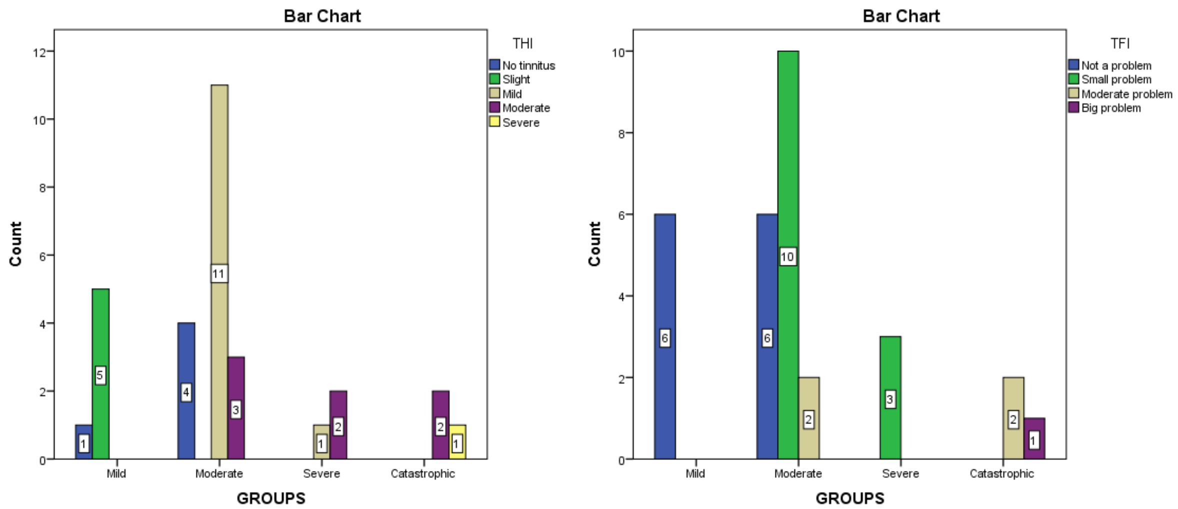

Figure-3.8 Bar graph showing the status of THI and TFI after 15 days of treatment in each group.

To summarise the pitch and loudness did not follow particular pattern as a function of severity of tinnitus. In each group, treatment of FDT did show a significant immediacy effect on reduced severity and lessened function impairment from tinnitus. In addition, there was a significant association between handicap and functionality index from tinnitus on severity of tinnitus after FDT treatment.

Chapter -4

Discussion

The participants of the study had normal hearing with tinnitus and had of absence OAE. We have speculated that the damage OHC and intact IHCs innervated by type-2 and type-1 fibers provide imbalance neural impulse at dorsal cochlear nucleus might have caused tinnitus resulted in mal adaptive cortical remap. The above explanation is in consonance with Chen & Jastreboff (1995) who reported increased spontaneous activity at the dorsal cochlear nucleus where excitation received by the IHC and not from the damaged OHC. During this process, with every new sound, the limbic and the autonomic nervous systems are activated to some extent and conditioned reflex might have developed. That is, a new pattern of sound unable to filter at auditory subawareness level due to irregular spontaneous activity. It reaches the auditory cortex compares with auditory memory. The participants might have focused their attention on tinnitus resulted in strengthened neuronal pathway. Consequently, limbic system evokes negative emotion and it is highly variable among individuals. Swanson (1987) reported that limbic system connects to all sensory system and to a certain sound evokes negative emotion. This self-reinforced negative reaction from limbic system reflected in the severity of handicap from tinnitus. Thus, the present study participants' had wide spectrum of severity though their hearing was normal irrespective of pitch and loudness. Meanwhile, autonomic nervous system would have prepared their body for an appropriate reaction needed and thus, functionality in a daily life varied from very big problem to small problem which was reflected in TFI.

We assumed that adjacent frequency with respect to tinnitus pitch extends their functionality leading spontaneous activity over relatively under functioned hearing receptors. After FDT treatment for a span of 15 days two patterns were observed. A significant change in tinnitus characteristics (pitch, loudness, THI and TFI) were noted irrespective of severity of tinnitus. In FDT training module, the participants were instructed to discriminate target 1/3 rd octave below tinnitus pitch which was presented to the ear having tinnitus by ignoring the distractors sounds. The focused attention towards the non-tinnitus target sound and discriminating it from distractors may cause two physiological changes. The neurons realize the frequency at which they are supposed to tune resulting in reduction in the extended spontaneous activity. In addition, constant discrimination of target sound from distractors breaks down the neuronal pathway between the source and auditory cortex. In such scenario the limbic system has to redefine the emotion and eventually reduce self-reinforcement of negative emotions. Thus, the study participants of the study have reported the reduced severity of handicap as a function of treatment sessions. Consequently, the para-sympathetic neuron of autonomic nervous system reacts and reduce the functionality impairment which was reflected in TFI as a function of treatment sessions, irrespective of severity of handicap from tinnitus. Perhaps in each treatment session constantly defining the tinnitus pitch from each participant in the software to discriminate target sound from distractors must have accentuated to break down the then conditioned reflex or strongest vicious neuronal pathway (auditory, limbic and autonomous nervous system). Moreover, the plasticity of the brain is the basis of learning and memory and needs continuous adjustment to the changing pitch and loudness over sessions, which was possible in the developed software. A few participants had experienced habituation to perception, that is, they were no longer aware of tinnitus, except when focused attention on it, which was revealed when THI was administered on them. A few of them reported habituation to reaction, that is, tinnitus was no longer evoked any emotion which was reflected when tinnitus handicap reduced from high to a low level on a rating scale.

Another pattern observed was a change in THI and TFI left no change in pitch and loudness of tinnitus. Tinnitus loudness match, pitch and the ability to suppress it with sound may be unchanged by habituation. The result of the present study is in consonance with the research reports of Hazell et al., (1985); Henry & Meikle, (2000) who have reported no relation between psycho-acoustical characterization of tinnitus (e.g., its pitch, loudness, suppressability) and handicap from tinnitus. However, it is not really important from a clinical point of view, as they were neither correlated with tinnitus severity nor with treatment outcome. The limbic system, which controls emotions such that participant might have perceived positive perception in reduction of tinnitus percept. Consequently, activation of the para sympathetic part of the autonomic nervous system results in mobilization of the whole body, making it ready for either habituation of reaction or perception.

To conclude the active discrimination of target frequency from tinnitus pitch is to achieve a neutral status over tinnitus there by tinnitus related neural impulse are blocked by subawarness level further making the signal fails to reach conscious awareness at auditory cortex. Eventually over a period with active focused attention and discriminating the target tone from distractors break down the conditioned reflex in brain and subsequently stops spreading of tinnitus-related neuronal activity to the limbic and autonomic nervous systems. The decreased activation of these systems (auditory, limbic and autonomic nervous system), facilitates habituation.

Implications of the study

The developed software reduced severity of handicap from tinnitus and improved the functionality index. Software installed into their personal device can be used effectively in their convenient time. In addition, a game format of perceptual discrimination task to treat tinnitus provides measurable enjoyment and engagement to use it regularly so that tinnitus relief can be realized from clients having tinnitus. Perhaps software reduces a significant attrition due to the factor of intrinsic motivation.

Summary and conclusion:

Each of the participant was provided frequency discrimination training for the span of 15 days. Outcome measures included quantitative tinnitus pitch and loudness and qualitative THI and TFI. A significant reduction in handicap from tinnitus reflected in THI and reduced the functionality impairment from tinnitus reflected in TFI across sessions. A similar result was observed in each group on THI and TFI. In addition, a significant association was observed between severity of tinnitus and each qualitative measure of THI and TFI after 15 days of frequency discrimination training. To conclude the active discrimination of target frequency from tinnitus pitch achieved habituation of perception and reaction.

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