The Journal of International Advanced Otology

J Int Adv Otol 2019; 15(2): 253-6 • DOI: 10.5152/iao.2019.6698

Original Article

Evaluation of Differential Sensitivity for Frequency, Intensity, and Duration around the Tinnitus Frequency in Adults with Tonal Tinnitus

Udhayakumar Ravirose, Prithivi Thanikaiarasu, Prashanth Prabhu

Department of Audiology, All India Institute of Speech and Hearing, Mysuru, India

ORCID IDs of the authors: U.R. 0000-0002-3042-1514; P.T. 0000-0002-7267-5846; P.P. 0000-0002-9878-4733.

Cite this article as: Ravirose U, Thanikaiarasu P, Prabhu P. Evaluation of Differential Sensitivity for Frequency, Intensity, and Duration around the Tinnitus Frequency in Adults with Tonal Tinnitus. J Int Adv Otol 2019; 15(2): 253-6.

OBJECTIVES: The perceptual characteristics of tinnitus are usually assessed by a matching procedure, where loudness and pitch of an external sound are matched to those of the tinnitus percept. The duration discrimination test (DDT), differential limen for intensity (DLI) and differential limen for frequency (DLF) are relatively simple psychoacoustic methods of measuring differential sensitivity.

MATERIALS and METHODS: 15 participants with normal or minimal hearing loss with tinnitus in the age range of 18 to 40 years were enrolled in the present study. Pure tone audiometry (PTA), immittance audiometry and otoacoustic emissions were done to diagnose the degree of hearing loss. Duration discrimination test (DDT), differential limen for intensity (DLI) and differential limen for frequency (DLF) was administered on all the participants using MATLAB software (MLP toolbox) at the matched tinnitus frequency, half an octave below & above the frequency.

RESULTS: The results show that there was a significant increase in DDT, DLI and DLF thresholds at the tinnitus frequency compared to half an octave above and below the matched frequency. The result suggests that differential sensitivity abilities regarding frequency, intensity, and duration are affected at the tinnitus frequency in individuals with tinnitus.

CONCLUSION: The results of the study suggest that the differential sensitivity ability is affected in individuals with tinnitus especially at the frequency of tinnitus.

KEYWORDS: Differential sensitivity, tonal tinnitus, normal hearing

INTRODUCTION

Perception of sound inside the human ears without any external source is called the tinnitus, which is a commonly prevalent disorder ranging from 7% to 20% in randomly selected individuals [1]. Tinnitus is associated with different peripheral hearing-related problems or central spontaneous perception may also occur without any abnormalities. Even then some research work exhibits association between tinnitus and co-occurring neural activities at the peripheral and central auditory systems till the level of cortex. This tinnitus is usually evaluated by an individual's perceptual characteristics in which usually the procedure employed was the matching of pitch and intensity of perceived tinnitus by the individual [2, 3].

Temporal resolution is often referred to as an individual's ability to detect the smallest change in acoustic events concurrent to time. It is important for resolving brief dips in the intensity of the interfering noise and, therefore, is critical for understanding speech in these situations. Duration discrimination test (DDT), difference limen for intensity (DLI), and difference limen for frequency (DLF) are relatively simple psychoacoustic methods of measuring differential sensitivity [4]. Measurements from the above-mentioned tests have been used traditionally for identifying a deficit in frequency, intensity, and temporal resolution. It is to be believed that in individuals with tinnitus, the co-occuring neural activity might create disturbances in the measurement of these differential sensitivities when compared to individuals with no tinnitus. Temporal resolution abilities in individuals with tinnitus are affected with poor performance of temporal processing skills, assessed by duration pattern test and gap detection in noise [5].

This study was presented at the 50th Annual Convention of the Indian Speech and Hearing Association, 5-7 January 2018, Mysuru, India.

Corresponding Address: Udhayakumar Ravirose E-mail: udhayakmr9@gmail.com

Submitted: 17.01.2019 • **Revision Received:** 17.04.2019 • **Accepted:** 23.05.2019

Available online at www.advancedotology.org

There are no studies that have used duration discrimination, pitch discrimination, and intensity discrimination tasks to assess differential sensitivity in individuals with tinnitus. In addition, none of the studies have attempted to evaluate differential sensitivity around the perceived tinnitus pitch. Thus, studies using these measures can provide some insight regarding the involvement of central and peripheral auditory mechanisms on perception of tinnitus, which may impact the auditory processing abilities. Hence, the present study aimed at determining the DDT, DLI, and DLF thresholds in patients with tinnitus at the tinnitus frequency and half an octave above and below the frequency of tinnitus perception.

MATERIALS AND METHODS

Fifteen participants in the age range of 18 to 40 years (mean=29.47 and standard deviation=7.20) with their hearing thresholds at normal limits or minimal hearing loss with tinnitus were included in the present study. All the participants had tonal tinnitus, which was continuous in nature. The demographic data of the participants with the duration of tinnitus and location of tinnitus are provided in Table 1.

Pure tone audiometry (PTA) and immittance audiometry were carried out to diagnose the degree and type of hearing loss. Tinnitus evaluation was done to determine the frequency and intensity of tinnitus. Assessment of tinnitus was carried out to define the perceived pitch and intensity of the tinnitus. In the pitch matching procedure, the participants were presented with pure tones and they were instructed to match the frequency with the one that closely resembles their perceived pitch of the tinnitus. This matched frequency was taken as a reference signal for loudness matching. In loudness matching, the intensity of the tone was varied in 5-dB steps until the subject heard the sound equally loud as that of the perceived tinnitus. This was helpful in recruiting participants with the tonal perception of tinnitus, which is continuous in nature, and the matched tinnitus frequency was considered for carrying out the following tests.

Table 1. Demographic data of the participants recruited in the study

S.No.	Age (in years)	Gender	Ear with tinnitus	Duration of the tinnitus (in months)
1	23	Female	Left	6
2	38	Male	Left	11
3	29	Male	Both	5
4	25	Male	Both	10
5	24	Female	Both	22
6	40	Male	Left	4
7	35	Male	Right	13
8	40	Male	Both	17
9	33	Male	Left	8
10	36	Female	Left	15
11	29	Female	Both	7
12	28	Female	Both	20
13	18	Male	Both	16
14	24	Female	Right	12
15	23	Female	Left	6

DDT, pitch discrimination test (PDT), and intensity discrimination test (IDT) were carried out on all the participants using MATLAB software (Mathworks, R2014b, Standford University, California) using an MLP toolbox at the matched tinnitus frequency, half an octave below and above the frequency. In the duration discrimination task, the minimum time difference required to differentiate between two sounds as different was assessed in which it had three blocks with two having a standard stimuli and one being a variable stimuli of 250 ms long pure tone with raised cosine ramps at an onset and offset of 10 ms [6]. Among the three blocks, the block with varied stimuli has a variable duration from 0 to 25 ms from the standard and the task of the patient was to identify the block containing the variable stimulus. A three-down, one-up rule was used to estimate the difference equivalent to the 79.4% psychometric function. Likewise, the pitch discrimination and intensity discrimination tasks focused on estimating the minimum frequency and minimum intensity required to differentiate between two sounds. In the pitch discrimination task, on each trial of three blocks, two blocks had standard frequency pure tones, and another block contained a pure tone of variable frequency, which is always greater than the standard frequency and the participant was instructed to identify the block containing variable frequency. The three-down, one-up rule was used to approximate the frequency difference equivalent to the 79.4% psychometric function. In the intensity discrimination task, the minimum intensity required to differentiate two sounds as different was estimated. For the variable stimuli, the intensity was varied from 0.99 dB and 10 dB as a minimum to maximum deviation in the stimuli. The participant's task was to identify the variable block. The three-down, one-up rule was used to estimate the intensity difference equivalent to the 79.4% psychometric function.

Statistical Analysis

The data were collected and subjected to statistical analysis using The Statistical Package for the Social Sciences (SPSS) v20 software for Windows (IBM Corp.; Armonk, NY, USA).

Ethics Consideration

In the present study, all the testing procedures were carried out using non-invasive techniques, adhering to the conditions of the Ethics Approval Committee of the institute. All the procedures were explained to the patients and informed consent was taken from all the participants of the study.

RESULTS

The mean and standard deviation of duration discrimination thresholds, difference limen intensity, and difference limen frequency were determined and are shown in Figures 1, 2 and 3, respectively. The figures show that the DDT, DLI, and DLF were higher at the tinnitus frequency compared to half an octave above and below the tinnitus frequency.

The Shapiro-Wilk test of normality showed that the data were not normally distributed ($p<0.01$). Hence, non-parametric inferential statistics were done. The Friedman test was carried out to determine

if there is any significant difference in DDT, DLI, and DLF across the three conditions. The results of Freidman's test showed that there was significant difference across the conditions for DDT, DLI, and DLF. The results of Friedman's test are shown in Table 2.

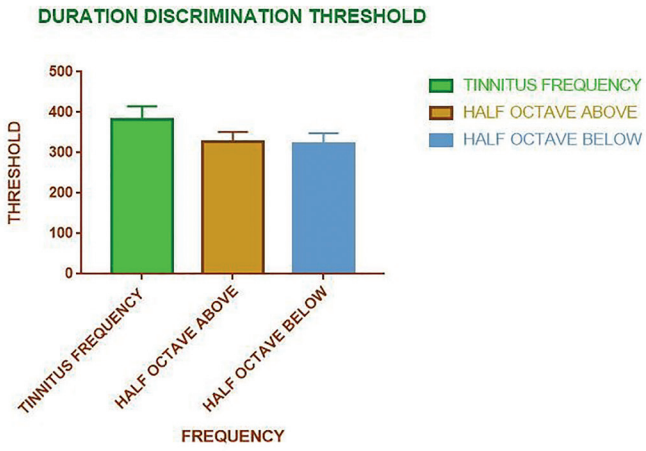

Figure 1. Mean and SD of duration discrimination threshold at the tinnitus frequency, half an octave above, and half an octave below the tinnitus frequency.

Hence, the Wilcoxon signed-rank test was carried out separately to compare two conditions. The results show that there was a significant increase in DDT, DLI, and DLF thresholds at the tinnitus frequency compared to half an octave above and below the matched frequency. There was no significant difference in DDT, DLI, and DLF thresholds between half an octave above and half an octave below the tinnitus frequency conditions. The power of the test (effect size) was calculated using the formula $Z/\sqrt{N}$. The power of the test ranged from 0.73 to 0.77, suggestive of moderate to strong effect. The results of the Wilcoxon signed-rank test and the power of the test are shown in Table 3.

Table 2. The results of Friedman's test to compare across three conditions for DDT, DLI, and DLF separately

Psychoacoustic test	Result of Friedman's test
DDT	χ^2 (2)=121.32, p<0.001
DLI	χ^2 (2)=108.59, p<0.001
DLF	χ^2 (2)=143.47, p<0.001

DDT: duration discrimination test; DLI: differential limen for intensity; DLF: differential limen for frequency

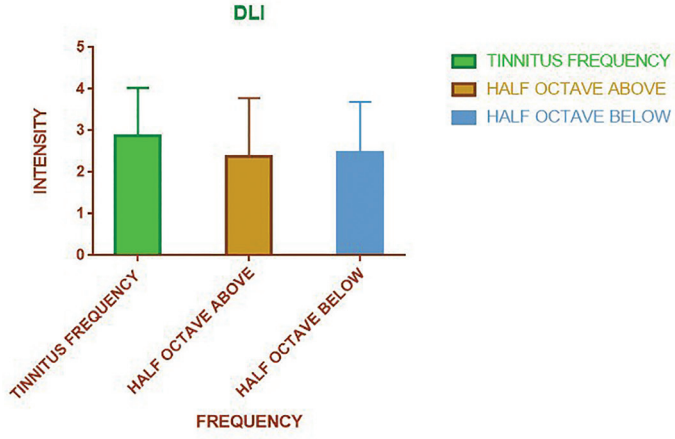

Figure 2. Mean and SD of duration difference limen of intensity at the tinnitus frequency, half an octave above, and half an octave below the tinnitus frequency.

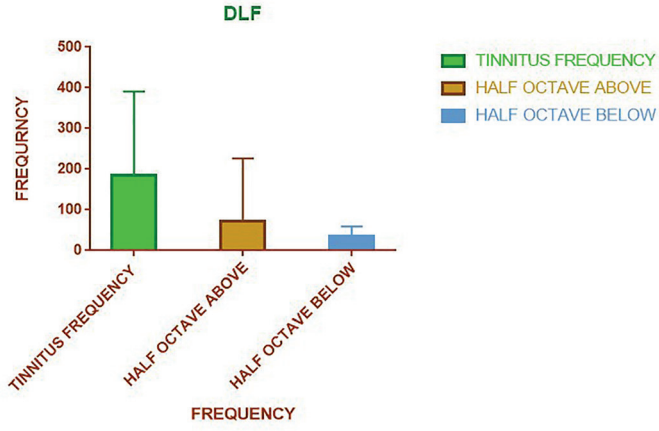

Figure 3. Mean and SD of duration difference limen of frequency at the tinnitus frequency, half an octave above, and half an octave below the tinnitus frequency.

Table 3. The results of the Wilcoxon signed-rank test and power of the test (r) for all the pair-wise comparisons (tinnitus F indicates tinnitus frequency)

Psychoacoustic test	Pairs for comparison	Results of the Wilcoxon signed-rank test	Power of the test (effect size)
DDT	At tinnitus F vs. below tinnitus F	Z=-4.04, p<0.01,	0.74
	At tinnitus F vs. above tinnitus F	Z=-4.01, p<0.01	0.73
	Below tinnitus F vs. above tinnitus F	Z=-1.08, p>0.05	-
DLI	At tinnitus F vs. below tinnitus F	Z=-4.14, p<0.01,	0.76
	At tinnitus F vs. above tinnitus F	Z=-4.11, p<0.01	0.75
	Below tinnitus F vs. above tinnitus F	Z=-1.88, p>0.05	-
DLF	At tinnitus F vs. below tinnitus F	Z=-4.04, p<0.01,	0.75
	At tinnitus F vs. above tinnitus F	Z=-4.17, p<0.01	0.77
	Below tinnitus F vs. above tinnitus F	Z=-1.58, p>0.05	-

DDT: duration discrimination test; DLI: differential limen for intensity; DLF: differential limen for frequency

DISCUSSION

Tinnitus is defined as a perception of sound without the presence of external sound stimuli and the exact physiology behind it is still unclear. Some researchers hypothesized that this perception is basically associated to the background nerve activities at the neural level of an individual's auditory mechanism. Some research works depict that the perception of tinnitus may be a result of deficit in the neural structures anywhere at the level of the central auditory mechanism. At this level, the generation of tinnitus may be due to altered afferent input to the system which in turn initiates a complex sequence of events at the level of central auditory mechanism [7]. A cochlear disorder undiagnosed by PTA may also initiate a series of processes in the nervous system, which in turn exhibits tinnitus. Temporal processing is an essential skill for processing complex auditory signals, and these skills are basically referred to as the minimum time required to segregate or analyze an auditory event. The most commonly employed psychophysical tests to assess these skills are the gap detection test (GDT), DDT, PDT, IDT, and the temporal modulation transfer function test (TMTF).

The present study assessed the ability of the duration discrimination (DDT), pitch discrimination (DLF), and intensity discrimination (DLI) tests at and around the tinnitus frequency in individuals with normal hearing sensitivity and/or minimal hearing loss with tinnitus. To attain good temporal resolution abilities, the auditory system requires a balanced neuronal firing at the level of excitatory and inhibitory synapse. However, in individuals with tinnitus at the tinnitus frequency, there may be a possible influence, which impairs the processing skills at the tinnitus frequency compared to one octave above and below it.

In the field of audiology, assessing the central auditory processing is a scope of practice. It is also well reported in the literature that the temporal processing abilities are affected in individuals with tinnitus [5]. A research work also showed a statistically significant increase in the gap detection threshold in individuals who had deficit in the central auditory nervous system, and hence this psychophysical measure can be considered as an effective tool for assessing the temporal resolution clinically [8]. A research work on 18 individuals with tinnitus and 23 normal hearing individuals using the GIN test reports a normal identified gap with shorter time intervals compared to that of individuals with tinnitus, and hence it is postulated that the ongoing tinnitus masks the gap and exhibits difficulty in processing the gaps at both the high and low frequency background [9, 10]. In addition, it is also reported that individuals with tinnitus needed longer duration of time to identify gaps compared to that of non-tinnitus individuals and it is postulated that the neuronal activity may prolong the thresholds of GDT [11]. Thus, the poorer performance at the tinnitus frequency indicates a processing deficit of differential sensitivity at the frequency of tinnitus.

CONCLUSION

The results of the study suggest that the differential sensitivity for frequency, intensity, and duration are affected in individuals with tinnitus, especially at the frequency of tinnitus. This suggests abnormal auditory processing at the tinnitus frequency, which needs to be explored further.

Ethics Committee Approval: Ethic committee approval was received for this study from the Ethics Committee of All India Institute of Speech and Hearing.

Informed Consent: A written Informed consent was taken from all the participants of the study prior to the data collection.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – U.R., P.T., P.P.; Design – U.R., P.T., P.P.; Supervision – U.R., P.T., P.P.; Resource – U.R., P.T., P.P.; Materials – U.R., P.T., P.P.; Data Collection and/or Processing – U.R., P.T., P.P.; Analysis and/or Interpretation – U.R., P.T., P.P.; Literature Search – U.R., P.T., P.P.; Writing – U.R., P.T., P.P.; Critical Reviews – U.R., P.T., P.P.

Acknowledgements: The authors would like to acknowledge all the participants of the study.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Hoffman HJ, Reed GW. Epidemiology of Tinnitus BT-Tinnitus: Theory and Management. In: Tinnitus: Theory and Management. 2004. p. 16-41.
2. Tyler RS. Considerations when evaluating a tinnitus patient for compensation. Aust New Zeal J Audiol 2002; 24: 85-91. [CrossRef]
3. Holgers KM. [Tinnitus treatment is guided by etiology. Noise, stress or anxiety/depression plausible causes]. Lakartidningen 2003; 100: 3744-9.
4. Florentine M, Buus S, Scharf B, Zwicker E. Frequency Selectivity in Normally-Hearing and Hearing-Impaired Observers. J Speech Lang Hear Res 1980; 23: 646-69. [CrossRef]
5. Gilani VM, Ruzbahani M, Mahdi P, Amali A, Khoshk MHN, Sameni J, et al. Temporal processing evaluation in tinnitus patients: Results on analysis of gap in noise and duration pattern test. Iran J Otorhinolaryngol 2013; 25: 221-5.
6. Grassi M, Soranzo A. MLP: A MATLAB toolbox for rapid and reliable auditory threshold estimation. Behav Res Methods 2009; 41: 20-8. [CrossRef]
7. Bartels H, Staal MJ, Albers FWJ. Tinnitus and neural plasticity of the brain. Otol Neurotol 2007; 28: 178-84. [CrossRef]
8. Musiek FE, Shinn JB, Jirsa R, Bamiou DE, Baran JA, Zaida E. GIN (Gaps-In-Noise) Test Performance in Subjects with Confirmed Central Auditory Nervous System Involvement. Ear Hear 2005; 26: 608-18. [CrossRef]
9. Sanches SGG, Sanchez TG, Carvallo RMM. Influence of cochlear function on auditory temporal resolution in tinnitus patients. Audiol Neurotol 2010; 15: 273-81. [CrossRef]
10. Hebert S, Fournier P, Norena A. The Auditory Sensitivity is Increased in Tinnitus Ears. J Neurosci 2013; 33: 2356-64. [CrossRef]
11. Haas R, Smurzynski J, Fagelson M. The effect of tinnitus on gap detection. Tinnitus Today 2012; 37: 10-30.