Evaluation of Temporal Resolution Around the Tinnitus Frequency in Adults with Tonal Tinnitus

Prithivi Thanikaiarasu, Udhayakumar Ravirose, and Prashanth Prabhu

Abstract **Objective**: 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. For a complete assessment of tinnitus, central auditory processing abilities should be considered in addition to other routine evaluation. Temporal processing is one of the important auditory processing skills that is essential for complex higher level auditory processing. The gap detection test (GDT) and duration discrimination test are relatively simple psychoacoustic methods of measuring temporal resolution [1]. Hence, the present study is aimed at finding the duration discrimination threshold in tinnitus patients at the tinnitus frequency and half an octave above and below the frequency of tinnitus perception. **Method**: 15 participants with normal or minimal hearing loss with tinnitus in the age range of 18–40 years were enrolled in the present study. Duration discrimination test was administered on all the participants using MATLAB software (MLP toolbox) at the matched tinnitus frequency, half an octave below and above the frequency of tinnitus perception. **Results**: The results of the study revealed that there was a significant increase in duration discrimination thresholds at the tinnitus frequency compared to half an octave above and below the matched frequency. The result suggests that temporal resolution abilities are affected at the tinnitus frequency in individuals with tinnitus. **Conclusions**: The results of the study suggest that the temporal processing ability is affected in individuals with tinnitus especially at the frequency of tinnitus.

Keywords Tinnitus · Temporal resolution · Duration discrimination test

1 Introduction

Tinnitus is a perception of sound without an external source. It is a common disorder with prevalence estimates ranging from 7 to 20% among randomly selected populations [2]. Tinnitus is associated with a variety of disorders in the auditory system,

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whether generated peripherally or centrally, but may arise spontaneously, too. Studies have shown an association between the presence of tinnitus and neural activity disorders in the auditory central nervous system, from the peripheral level (dorsal cochlear nucleus) to the cortical level [3–6]. Evaluation of tinnitus may not be complete without assessing the effect of tinnitus on different auditory skills. For a complete assessment of tinnitus, central auditory processing abilities should be considered in addition to the routine psychological evaluation of tinnitus characteristics. Temporal resolution refers to the ability to detect changes in acoustic stimuli over 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 [2, 7–9].

Measurement of duration discrimination threshold has traditionally been used for the identification of temporal discrimination deficits in a variety of clinical populations. It was hypothesized that neural activity in tinnitus patients might create deficits in their ability in temporal processing when compared to those non-tinnitus individuals. A research work on temporal resolution abilities in individuals with tinnitus using gap detection in noise and duration pattern test at 1 kHz frequency revealed some amount of temporal processing ability being affected in individuals with the perception of tinnitus [10]. However, previous studies have assessed temporal resolution in tinnitus patients only using GDT [10]. There are no studies which have used duration discrimination task to assess temporal processing in individuals with tinnitus. In addition, none of the studies have attempted to evaluate temporal processing around the perceived tinnitus pitch. The results of such a study would provide important information regarding the relationship between peripheral and central mechanisms of tinnitus generation that may affect auditory processing. Hence, the present study aimed at finding the duration discrimination threshold in tinnitus patients at the tinnitus frequency, half an octave above and below the frequency of tinnitus perception.

2 Method

A total number of 15 participants were considered for the study with the complaint of tinnitus. Individuals having continuous tinnitus, tonal perception, and in age range 18–45 years, with normal hearing status and/or minimal hearing loss, were included in the study. After obtaining informed consent and local ethics committee approval, all participants underwent the test procedures as follows.

2.1 Instrumentation

- A calibrated audiometer (Madsen Astra) coupled with an acoustically matched headphone (TDH-39) and a bone conductor (B-71) was utilized to estimate pure tone threshold, speech recognition threshold, and speech identification score.

- Tympanometry and acoustic reflex thresholds (ART) were obtained using a calibrated immittance meter (GSI-Tympstar).
- An otoacoustic emission was done using ILO software to check for the functioning of outer hair cell functioning, DPOAE was done.
- A Dell laptop with maximum likelihood procedure (MLP) toolbox implemented in MATLAB software version 7.10 was used to carry out duration discrimination test.
- A TDH-39 headphone was calibrated for the output of the computer at 60 dB SPL which was used to present the stimulus through the computer.

2.2 Pure Tone Audiometry

Participants were subjected to audiometric testing using Madsen Astra audiometer at the frequencies of 0.25, 0.5, 1.0, 2.0, 4.0, and 8.0 kHz for air conduction and between 0.25 and 4.0 kHz for bone conduction to confirm normal hearing status and/or with minimal hearing loss.

2.3 Immittance Audiometry and Otoacoustic Emissions

Immittance audiometry was done using GSI-Tympstar to carry out tympanometry and reflexometry to rule out any middle ear pathology and distortion product otoacoustic emissions were done using ILO software to check for outer hair cell functioning and to confirm the diagnosis of normal hearing sensitivity and/or minimal hearing loss.

2.4 Tinnitus Psychoacoustic Assessment

The psychoacoustic characteristics of the tinnitus were evaluated in all patients in order to define the pitch and loudness of the perceived tinnitus. Pitch matching attempts to quantify tinnitus in terms of its possible frequency, in that, pure tones were presented to the patient and the patients were asked to choose which one most closely matches the tinnitus that they hear. This matched frequency was taken as a reference signal for loudness matching.

In loudness matching, the intensity of the tone varied in 5 dB steps until the subject heard the sound equally loud as that of tinnitus perceived. This was helpful in recruiting participants with tonal perception of tinnitus and the matched tinnitus frequency was considered for carrying out duration discrimination test.

2.5 Duration Discrimination Test

The minimum difference in duration which a participant can discriminate was assessed. Duration discrimination thresholds (DDT) were measured for a pure tone of three frequencies which included at the matched tinnitus frequency, half octave and below the tinnitus frequency. The tone had raised cosine onset and offset gates of 10 ms. The minimum and maximum values of duration deviation used were 0.1 ms and 200.1 ms. On each trial of three blocks, two blocks had pure tones at a standard duration and other blocks selected at random contained a pure tone of variable duration, which was always longer than the standard duration. The participant's task was to identify the variable block. A 3AFC procedure was used by implementing MLP toolbox in the MATLAB software version 7.10 which was used to estimate the duration difference.

3 Statistical Analysis

Statistical analysis was done using SPSS software version 20.

4 Results

The mean and standard deviation of duration discrimination thresholds were determined and shown in Fig. 1. The figure shows that the duration discrimination thresholds were higher at tinnitus frequency compared to half octave above and below the tinnitus frequency.

Shapiro–Wilk test of normality was done to determine if the data was normally distributed. The result of test of normality shows that the data was not normally distributed ($p < 0.01$). Hence, non-parametric inferential statistics were done. Friedman's test was done to determine if there is any significant difference in DDT across the three conditions. The results of Freidman's test [$\chi^2\ (2) = 28.09, p < 0.01$] showed that there was significant difference across the conditions. Hence, Wilcoxon signed rank tests were done to separately compare two conditions. The results show that there was a significant increase ($p < 0.01$) in duration discrimination thresholds at the tinnitus frequency compared to half octave above [$Z = -4.04, p < 0.01$] and below the matched frequency [$Z = -4.04, p < 0.01$]. There was no significant difference [$Z = -1.08, p > 0.05$)] in DDT between half octave above and half octave below tinnitus frequency conditions. The result suggests that temporal resolution abilities are affected at the tinnitus frequency in individuals with tinnitus. The consequences of poor temporal resolution in individuals with tinnitus are discussed.

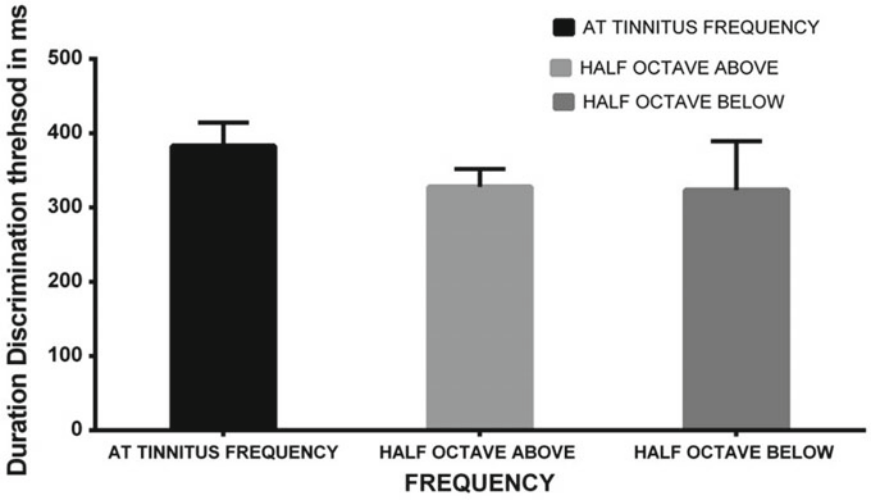

Fig. 1 Mean and SD of duration discrimination threshold at tinnitus frequency, half octave above and half octave blow the tinnitus frequency

5 Discussion

Tinnitus by definition is a phantom perception of sound without external source. Tinnitus is an otologic symptom and despite the great amount of research on this subject, the exact pathophysiological process of tinnitus remains unclear. Involvement of the whole auditory system, either peripheral or central, should be considered in the development of tinnitus. Some authors postulated that the presence of tinnitus has been associated with a disorder in the neural activity of the auditory system. A cochlear disorder, even when undiagnosed by pure tone audiometry, may initiate a series of processes in the nervous system that may result in tinnitus [11]. Temporal processing is one of the important auditory processing skills that are essential for complex higher level auditory processing. Temporal resolution is an auditory temporal processing skill that refers to the minimal time required to segregate or resolve acoustic events. The gap detection test (GDT) and duration discrimination test are relatively simple psychoacoustic methods of measuring temporal resolution [1].

Additionally, according to some published data, deficits in neural structures in the central auditory nervous system may result in the perception of tinnitus [12]. Bartels et al. [13] stated that an altered afferent input to the auditory pathway may be the initiator of a complex sequence of events, conclusively resulting in the generation of tinnitus at the central level of the auditory nervous system [13].

The present study investigated the ability of the duration discrimination test to differentiate between a group of patients with tinnitus who showed normal hearing sensitivity and/or minimal hearing loss. Good performance in auditory temporal

resolution requires precise neuronal firing with the balance of the excitatory and inhibitory synapses, which can be impaired in individuals with tinnitus and/or hearing loss at the tinnitus frequency compared to half octave above and below the tinnitus frequency.

Assessment of central auditory processing in a different group of patients is one of the audiologist's scopes of practice. Gilani et al. [10] studied temporal resolution abilities in individuals with tinnitus using gap detection in noise and duration pattern test [10]. They reported that temporal processing is affected in individuals with tinnitus. Musiek et al. [14] performed GIN in subjects with confirmed central auditory nervous system involvement and reported a statistically significant increase in gap detection thresholds, indicating that the GIN test holds promise as a clinically useful tool in the assessment of temporal resolution, one of the central auditory abilities, in the clinical arena [14]. Sanches et al. [15] applied GIN test to assess the auditory temporal resolution skill in 18 tinnitus patients and 23 normal participants and reported that control group detected gaps with a shorter time interval than the patient's group [15]. Haas et al. [16] also pointed out threshold values of gap detection in tinnitus patients were longer in duration than non-tinnitus subjects and hypothesized that some changes in neural activity in tinnitus patients might prolong gap detection threshold (GDT) [16]. Fournier and Hebert [1] assessed gap detection in human with tinnitus and postulated that tinnitus group displayed a consistent deficit in gap processing at both low and high background noise frequencies, assuming that ongoing tinnitus masks the gap and results in their impaired gap detection [1].

In several studies, gap detection test and gap-in-noise test were done to assess temporal processing ability and whereas they have not attempted to assess using duration discrimination test and also at the frequency of tinnitus, half an octave below and above the tinnitus frequency. Hence, in the present study, reveals that the higher approximate threshold that the tinnitus patients required to detect tones of varying gap in order to discriminate tones detection, and is in accordance with the literature data, which revealed poorer temporal acuity abilities, especially at the tinnitus frequency.

6 Conclusions

In the present study, temporal processing difficulties were found in individuals with tinnitus having normal hearing and/or minimal hearing loss. The thresholds were poor especially at the tinnitus frequency when compared to that of the half octave frequency above and below of the tinnitus frequency. Thus, the implication of our study indicates the need for assessing the central auditory processing difficulties in individuals with tinnitus in addition to the routine testing of evaluating tinnitus. Further studies can use other tests of evaluating various auditory processing difficulties to incorporate a comprehensive test battery for more precise diagnosis for better remediation measures.

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