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RESEARCH ARTICLE

Comparison of auditory reaction time in noise and quiet in tinnitus subjects

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Abstract

Background and Aim: Tinnitus is perception of sound in absence of external source. Reaction time is the time between sensory stimuli and a behavior. Alternation of auditory reaction time has been shown in the literature in patients with tinnitus. This study has investigated the auditory reaction time in quiet and noise to different frequencies.

Methods: Fifteen subjects with chronic tinnitus participated in this study. Basic auditory test and tinnitus evaluations were carried out. In order to measure auditory reaction time, the participants were instructed to press a button after hearing the target sound. Xnote Stopwatch software measured reaction times and data were collected.

Results: Auditory reaction time to the tinnitus frequency stimulus decreases significantly ($p<0.05$) in tinnitus subjects in both quiet and noise conditions. This alternation is significantly different in noise compared to the quiet condition ($p<0.05$).

Conclusion: Based on the results, noise can reduce auditory reaction time significantly. Also, alternation of auditory reaction time to the tinnitus frequency –especially in noise –ould suggest different central processing of the tinnitus frequency in tinnitus subjects.

Keywords: Auditory reaction time; noise; tinnitus

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Introduction

Tinnitus is perception of a sound in absence of any external source [1]. The quality of sound could be sensation of buzzing, ringing, clicking, pulsations, and other noises in the ear [2]. 15 percent of all population and 22 percent of 50 year olds and above experience tinnitus in the United State [3]. 30-40 percent of patients with hearing loss report tinnitus, while 90% of tinnitus subjects have a degree of hearing loss [4]. The quality of life in subjects with tinnitus and hearing loss decreases from moderate to severe [5]. Subjects with severe tinnitus experience a degree of depression and anxiety disorder or even commit suicide [6]. About 4.1 percent of subjects visit specialists for their attention deficits, sleep disturbance and psychological problems [7]. Currently, no definitive treatment offered for tinnitus. Specialists try to reduce the reaction of tinnitus subjects to their tinnitus [8].

Lack of definitive protocol for tinnitus may be due to its unknown neurophysiology. Many specialists believe that the origin of tinnitus is impairment in the cochlea or auditory nerve, but recent researches suggest a central mechanism as the main mechanism of tinnitus [7]. Recent studies focus on attention network in tinnitus subjects [8]. Most of subjects with tinnitus complain of decreased attention. Additionally, neurophysiologic examinations indicate that cognitive deficits can decrease attention control in tinnitus subjects especially in attention inhibition tasks. Partial or no habituation to tinnitus may be the most problematic condition in tinnitus subjects. Although auditory habituation mechanism is not known well in the brain, it is mostly believed to be related to thalamus and brainstem [9].

Attention is a factor which cannot simply be measured. Attention is a part of more complex mechanism which includes top-down and bottom-up processing [9]. Tinnitus can occur due to defects in both top-down and bottom-up processing, and in most cases it starts with one processing deficits and then continues to the other one [9].

According to "effortfulness theory", hearing loss and tinnitus can also reduce attention sources; tinnitus acts as a "line busy" mechanism, and hearing loss affects attention by sending "noisy" signals to the central nervous system [7].

Effect of tinnitus on attention and concentration discussed extensively in the literature [10] and also attention problems were included in most tinnitus questionnaires [11]. Hearing loss also has correlation with attention in different ages [12]. Neurologic imaging studies focus on cortical areas of the brain and its connection to short term memory and attention centers; tinnitus is a multi-modal processing, but it seems that cingulo-frontal-parietal network controls reaction in tinnitus subjects. Positron emission tomography (PET) scan studies indicate tempro-parietal regions of the brain –which has a role in short-term memory –activate the perception of tinnitus. Similar studies show plasticity of neural networks at visual area of the frontal, parietal and temporal cortex in tinnitus subjects [13].

Psychomotor vigilance task (PVT) is a tool of measuring attention. Reaction time (RT) as a PVT can be measured in animal and human at threshold and supra-threshold levels. RT can be measured both in normal and in hearing loss patients [14,15]. Evaluation of simple reaction time is at the level of talamo-cortical which represents sustained attention [16]. Simple auditory reaction time (not complex in which subjects should response to one stimulus between a set of stimuli) evaluates subject's sustained attention. To perform the test, participants were explained what to do but cognitive learning is not required and also, other factors such as intelligence, IQ, university degree etc. do not affect reaction time [17].

Vernon measured auditory reaction time to different frequencies and different sound levels. They concluded abnormal loudness growth at tinnitus frequency can result in shorter auditory reaction time [18].

Chocholle [19], Fletcher and Munson [20] findings on three normal hearing subjects indicate loudness growth dose not differ in normal hearing and tinnitus subjects significantly.

Noise is one of the main reasons of hearing loss and tinnitus [21]. The aim of this study was to compare auditory reaction time to tinnitus and non-tinnitus frequency in quiet and noise. Auditory reaction time in quiet and in noisy environments such as traffic noise, noise at work etc. should be considered for safety of subjects with hearing loss (with and/or without tinnitus), thus frequency of alarm systems could be altered in order to have the fastest reaction in emergency situations especially in industrial settings.

Methods

Fifteen subjects with chronic tinnitus (more than 6 months) with moderate to severe score on Tinnitus Handicap Inventory [22] aged 26-45 (SD=6.89) and 15 non-tinnitus subjects with hearing loss (HL) participated in this study. Only subjects with simple pure tone tinnitus perception were included in this study (Table 1). Non-interventional analytical case study research was performed on volunteer subjects.

Otoscopy was done to ensure normal external ear and tympanic membrane. Pezhvak Ava portable audiometer (model: ultimate, Iran) was

Table 1. Descriptive statistics of age in tinnitus and hearing loss groups

	Age (years)			
Group	N	Mean (SD)	Min	Max
Tin	15	36.40 (6.89)	26	45
HL	15	34.73 (5.58)	28	43

N; number, Tin; tinnitus group, HL; hearing loss group

used to evaluate hearing thresholds. After completion of tinnitus handicap and back depression inventory, tinnitus loudness and pitch match was performed using Cool Edit software and audiometric standard headphone. Residual inhibition factor in tinnitus subjects was not measured, because stimuli used in the study and the test –babble noise and white noise vs. narrow band noise –differed in nature (spectrum) and loudness.
Subjects were instructed to press a bottom as soon as they hear a target sound. The first two tasks were done for training and then data collection was started.
The sound stimuli was presented monaurally and at the most comfortable level of the subject. Random inter-stimulus interval was used in order to reduce the probability effect. The duration of target stimuli (tinnitus frequency, one octave above and one octave below in tinnitus (Tin) group and matched frequencies in control group) was considered one second and presented in random order.
Three types of noise were used in this study: 6 talkers babble noise [23], 12 talkers babble noise [24] and white noise. The first frequency in each trial was not included in analysis because of its prolonged reaction time. Signal to noise ratio maintained 5 dB sensation level (SL) in all noisy conditions.
Xnote Stopwatch software was used in order to collect data from participants. Finally, data was analyzed using statistical software.
All disruptive items kept away from the subject and only a white screen was shown during the test.
A Quite test environment was chosen in order to maintain subject's attention on the test and also, supra-aural headphone was used in order to reduce background noise.
An exploratory data analysis was conducted to determine if the reaction time was normally distributed. Results for the Kolmogorov-Smirnov test for normality indicated that the reaction time distribution did not deviate significantly from a normal distribution.
The statistical comparison of the reaction time for the Tin and the HL group was conducted using SPSS 24. The analysis employed a t-test for independent groups, with alpha set at the 5% level, two tail test; and tested the null hypothesis that the groups performed statistically equal on the reaction time test for all analysis.

Results

Auditory reaction time to target frequencies was measured in this study. Mean auditory reaction time in quiet condition was measured 261 ms (SD=28.95) and 267 ms (SD=28.85) in Tin group and in HL group, respectively. In noise conditions, mean auditory reaction time was measured 258 ms (SD=21.69) in tinnitus subjects and 266 ms (SD=18.41) in the HL group. Table 2 shows mean auditory reaction time measured in Tin and HL groups in all test conditions.
The mean auditory threshold of the HL and Tin subjects in tinnitus frequency, one octave above and one octave bellow (and equivalent frequency in control group) in Tin and HL groups illustrated in Fig. 1.
Results for the mean comparison test indicated that the mean reaction time of the tinnitus group was significantly lower to their tinnitus frequency in both noise and quite conditions ($p<0.05$).
Also, reaction time in quite was significantly longer compared to three noise conditions in both Tin and HL groups ($p<0.05$).

Discussion

Tinnitus is a phantom sensation which is perceived without any mechanical or vibration in the cochlea. Epidemiologic studies show one third of the population experience tinnitus at least one

Table 2. Descriptive statistics of auditory reaction time in tinnitus and hearing loss groups

	Tin group			HL group			
Test condition	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**p**
RT1B	295.93 (32.836)	252	392	300.27 (38.16)	260	389	0.741
RTTF	269.40 (22.280)	226	317	293.60 (28.45)	259	373	0.015
RT1A	287.00 (16.222)	256	319	298.47 (34.79)	257	374	0.257
RT-12T-1B	266.00 (24.966)	221	314	263.67 (21.74)	224	311	0.787
RT-12T-TF	249.33 (21.067)	220	279	268.40 (31.03)	220	360	0.047
RT-12T-1A	269.27 (36.364)	224	383	269.13 (34.08)	222	371	0.992
RT-6T-1B	262.27 (18.626)	238	291	262.13 (17.41)	237	293	0.984
RT-6T-TF	246.40 (19.515)	220	284	266.73 (13.89)	243	289	0.003
RT-6T-1A	263.67 (17.078)	233	288	265.87 (14.87)	234	289	0.710
RT-WN-1B	263.67 (20.632)	211	289	265.33 (19.38)	215	283	0.821
RT-WN-TF	243.27 (19.808)	215	279	267.87 (22.00)	212	299	0.003
RT-WN-1A	268.80 (23.791)	210	290	268.27 (23.49)	212	293	0.951

Tin; tinnitus group, HL; hearing loss group, RT; reaction time (in milliseconds), TF; tinnitus frequency, 1A; 1 octave above tinnitus frequency, 1B; 1 octave below tinnitus frequency, 12t; 12 talkers babble noise, 6t; 6 talkers babble noise, WN; white noise

time during their lifespan and 1-5 percent exhibit psychological related symptoms caused by tinnitus. Tinnitus usually coexists with hearing loss. The etiology of tinnitus is unknown in most of subjects; however, it is believed that the central nerves system mechanism changes cause tinnitus especially in subjects with normal hearing [2].

MsShane et al. reported the prevalence of tinnitus to be 34% in subjects who are exposed to noise for less than 10 years. In subjects who are exposed to noise for 11 to 30 years, the prevalence of tinnitus raised to 54% and it is reported to be 50% in subjects who are exposed to noise for 31 to 50 years. Except those who have experienced noisy situations for less than 10 years, the prevalence of tinnitus due to noise remains consonant. They reported that noise induced hearing loss occurred prior to noise induced permanent tinnitus in industrial worker’s population, especially in those who were in continuous noise [25]. We studied tinnitus subjects with falling high tone sensory-neural hearing loss mostly occurred due to exposure to noisy environments. Target stimuli are within normal and pathologic frequencies of the subjects’ hearing. Also, background noises used in this study contain wide spectrum (white noise) and are similar to everyday noise (babble noise) which are very likely to be present in different situations.

Statistical analysis in this study indicates that auditory reaction time is significantly shorter (faster) in noise condition compared to quiet ($p<0.05$). Data analysis also suggests a faster auditory reaction time to tinnitus frequency compared to one octave above and below it in tinnitus subjects.

Goodwin and Johnson [19] results are similar to this study but only in quiet condition. They

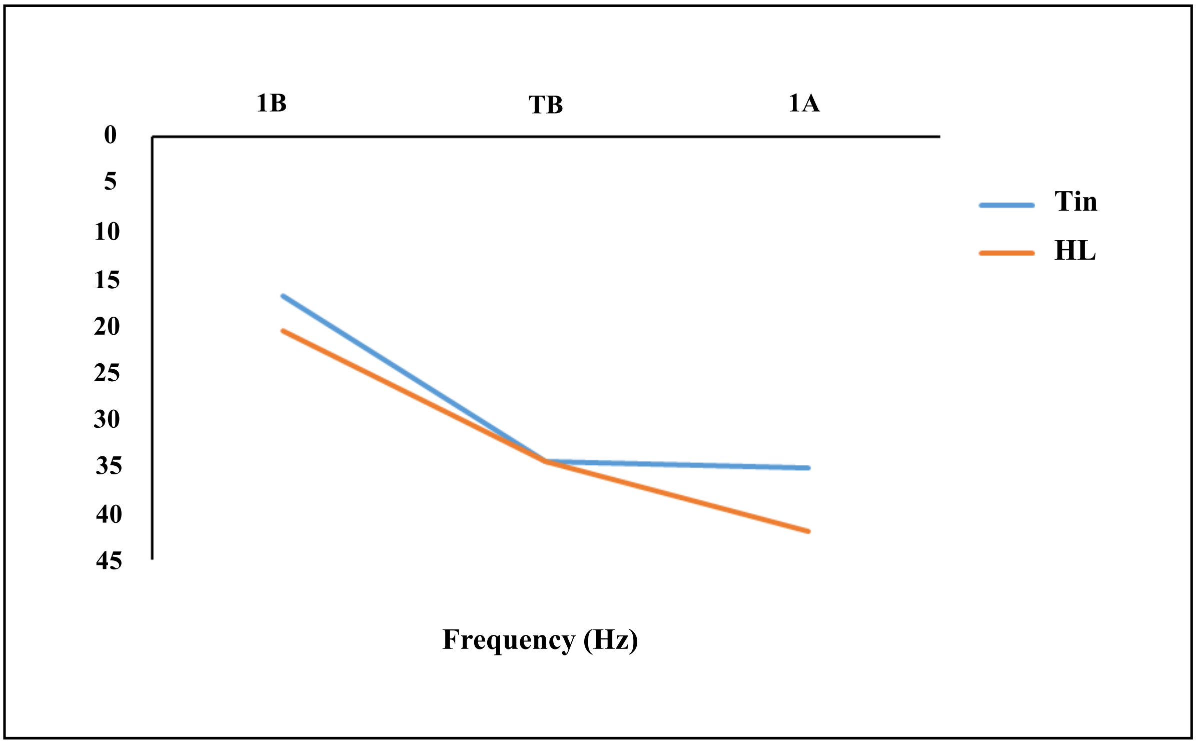

Fig. 1. Mean hearing thresholds in tinnitus frequency (TF) and equivalent frequency in hearing loss group, one octave above (1A) and one octave bellow (1B) in tinnitus group (Tin) and hearing loss group (HL).

investigated auditory reaction time to tinnitus frequency, subject's normal hearing threshold frequency and pathologic frequency (frequency with hearing loss). Husain et al. [7] findings are similar to Goodwin and Johnson results but visual reaction time is also included in their study. They concluded visual reaction time is similar to auditory reaction time in tinnitus subjects.

In this study, three frequencies containing tinnitus frequency and one octave above and below that frequency were used not only in quiet but in three noise conditions, 12 talkers babble noise (12t), 6 talkers babble noise (6t) and white noise (WN)) and it was shown that reaction time in all three noise situations have similar pattern to different frequencies but have statistically shorter time compared to quiet condition. As most cases in this study had falling slight to mild sensory-neural hearing loss (Fig. 1), it is not surprising that findings on auditory reaction time to one octave below tinnitus frequency and above frequency show similar results compared to normal hearing threshold frequency and pathologic frequency respectively in Goodwin and Johnson study [19].

One other factor which influences auditory reaction time is stimulus intensity. Stimulus with more sound pressure level (SPL) activates more auditory hair cells in the cochlea and as a result more neural activity and synchrony. Sound intensity in this study was considered to be at the most comfortable level (MCL) of each subject; more neural synchrony could be considered only for one octave below the tinnitus frequency not one octave above, as it has hearing loss and loss of neural synchrony.

Based on "edge theory", frequencies near the tinnitus frequency and in normal hearing thresholds have less neural activity compared to the tinnitus frequency [26]. Shorter reaction time in this study and similar studies can support this theory; this is true in both noisy and quiet conditions.

Noise can alter performance on many cognitive behaviors. Noise not only stimulates more hair cells in the cochlea and therefore causes more neural activity, but it also affects central mechanism in the brain. More neural activation synchrony can cause the shorter reaction time in noise conditions in this study.

At the level of physiology, Saha et al. measured catecholamine hormone in noise induced hearing loss subjects. Catecholamine hormone which can activate the limbic system is suggested to have a role in faster reaction time in these subjects [27].

Conclusion

In this study, auditory reaction time was investigated in tinnitus subjects in different frequencies in noise and in quiet. Data analysis indicates there is a significantly lower auditory reaction time to the tinnitus frequency in subjects with tinnitus and also, in three different noise conditions, significant alternation of auditory reaction time (lower) occur in both tinnitus group and hearing loss control group.

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