Auditory and Vestibular Research

Central Auditory and Cognitive Processing Impairment in Adults with Normal Hearing Exposed to Industrial Noise and Leisure Noise

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Mainpoints

Industrial noise damages auditory and cognitive systems, excluding reaction time

PLD leisure noise harms speech-in-noise perception, memory, and selective attention

Industrial noise exposure correlates with speech-in-noise deficits

Abstract:
Background and Aim: Noise can lead to temporary or permanent changes in the structure and function of the peripheral and central auditory systems when experienced at high sound pressure levels over time. This study aimed to examine the effects of industrial noise and leisure noise—specifically from Personal Listening Devices (PLDs)—on central auditory and cognitive processing in adults with normal hearing.
Methods: In this cross-sectional study, 136 males aged 20–40 were divided into three groups: 45 exposed to leisure noise from PLDs, 46 exposed to industrial noise (average [Leq]<90 dB (A)/ 8 hours), and 45 with no history of noise exposure (control group). All participants had normal audiograms. To evaluate central auditory processing, the Dichotic Digits Test (DDT), Duration Pattern Sequence Test (DPST), and Quick Speech-in-Noise Test (Q-SIN) were used. Cognitive abilities were assessed using the Ray Auditory Verbal Learning Test and the Semantic Stroop Test.
Results: The results showed that the industrial noise group performed significantly worse on all central auditory and cognitive tests—except reaction time—compared to both the PLD and control groups. The PLD group also showed impairments in speech-in-noise perception, short-term memory, and selective attention relative to the control group. Additionally, a negative correlation was found between noise exposure and speech-in-noise performance.
Conclusion: These findings suggest that both industrial and PLD-related leisure noise can impair central auditory and cognitive functions in individuals with normal hearing, highlighting the need for broader assessments in noise exposure monitoring.
Keywords: Leisure noise exposure, personal listening devices, Occupational noise exposure, cognitive ability, central auditory processing disorders, attention

Introduction

Noise, typically defined as "unwanted sound," can have substantial adverse effects on the auditory system, even if the sound is subjectively considered pleasant or desirable when above certain thresholds of intensity and duration. Noise exposure is classified into three main categories: environmental, occupational, and leisure noise [1] . Industrial or occupational noise has long been recognized as a significant health risk. The World Health Organization (WHO) attributes approximately 16% of disabling hearing loss to occupational noise exposure

[2]. Beyond hearing loss, industrial noise has been linked to impaired cognitive performance, increased workplace errors and accidents, and elevated risks of Alzheimer's disease, social isolation, psychological distress, and cardiovascular disease [3].
Recreational noise (Leisure), particularly from the use of Personal Listening Devices (PLDs), presents a rising global challenge. WHO reports that 1.1 billion young people are at risk of hearing loss from unsafe listening behaviors, with nearly half of youth in middle- and high-income countries exposed to harmful sound levels via PLDs [4]. Loud music, though subjectively enjoyable, can be addictive and damaging. Prolonged exposure through PLDs has been associated with transient threshold shifts (TTS), tinnitus, hyperacusis, abnormal pitch perception, and ultimately, permanent hearing loss [5].
Safety standards attempt to mitigate these risks. NIOSH recommends workplace noise exposure not exceed 85 dB(A) time-weighted average (TWA) over 8 hours, with exposure duration halved per 3 dB(A) increase. Neither standard fully prevents tinnitus, hyperacusis, or speech-in-noise deficits despite normal audiograms [6]. OSHA extends this limit to 90 dB(A) for 8 hours. For leisure noise, WHO and the International Telecommunications Union (ITU) in 2019 recommend the WHO-ITU H.870 standard, which suggests that noise levels remain under 80 dB (A) for a maximum of 40 hours weekly [1]. PLDs can reach sound levels of 101–107 dB(A) at full volume. and even moderate volume can be harmful in under an hour [7].
Emerging research reveals that even sound levels at or below 80 dB SPL can lead to physiological damage at multiple levels of the auditory pathway—including the cochlea, midbrain, thalamus, and cortex. Brattico et al. demonstrated that 70–80 dB SPL industrial noise over five years can alter brain hemispheric organization and degrade speech recognition and attention in subjects with clinically normal hearing [8]. Kujala et al. suggest that noise above 80 dB(A) may result in TTS as well as synaptic damage at inner hair cells, leading to cochlear synaptopathy, hidden hearing loss, and central auditory processing deficits, which may go undetected by standard audiograms [9]. Normal-hearing individuals exposed to industrial noise often present with deficits in speech-in-noise recognition [8], attention [10], temporal processing [11], binaural hearing [12], and memory [13]. These effects are dose-dependent, influenced by both intensity and duration of exposure. Even noise exposure below 80 dB SPL induces central auditory system alterations, including changes in central gain within the midbrain, thalamus, or cortex, and reorganization of tonotopic maps [14], driven by homeostatic plasticity. Animal studies show 65 dB SPL noise affects the medial geniculate body and auditory cortex, altering midbrain frequency responses and lateral inhibition [15]. In humans, non-damaging noise intensities (below 95 dB A) impair performance on mismatch negativity (MMN) and central temporal processing tests, indicating deficits in attention and temporal processing [9].
Leisure noise exposure similarly impairs speech-in-noise perception, attention, and memory [16, 17], causing functional deficits masked by normal audiograms [18]. However, Yeend et al. found no direct link between lifetime noise exposure and speech-in-noise ability, suggesting cognitive factors like attention and working memory primarily determine performance [19]. This implies long-term noise exposure may selectively disrupt higher-order auditory processing, with central deficits occurring independently of peripheral damage [20].
Critically, industrial and leisure noise engage distinct neurophysiological pathways. Music that commonly used in PLD usage activates emotion-linked systems enhancing memory encoding [21], and improving spectral/temporal processing. Conversely, industrial noise activates thalamic fear/emotion circuits and the amygdala-HPA axis, triggering stress hormones and defensive responses [22, 4]. This differential neural impact may explain variations in observed central auditory deficits.
This study tested whether recreational (PLD users) and industrial noise exposure impair central auditory processing and cognition more than controls, hypothesizing greater deficits from industrial noise. Speech-in-noise perception, binaural hearing, temporal processing, memory, attention, and reaction time were compared across industrial workers, frequent PLD users, and non-exposed controls. Findings can highlight the necessity of central auditory assessments alongside standard audiometry in noise-exposed populations.

Method

Participants

This cross-sectional study included 136 male participants divided into three groups: Leisure Noise Exposure Group (L-NEG, n=45), Industrial Noise Exposure Group (I-NEG, n=46), and a Control group (n=45). Due to gender-related risk factors, only males were included. Groups were comparable in age (18-40 years) and

hearing level. Inclusion criteria comprised: normal pure-tone hearing thresholds (<25 dB HL, 250–8000 Hz), Type A tympanograms, right-handedness, absence of academic/attention deficits, and no history of ototoxic drug or sedative use. Exclusion criteria included absent acoustic reflexes or elevated acoustic reflex thresholds (>95 dB HL). Both noise-exposed groups (L-NEG and I-NEG) had ≥2 years of noise exposure [9]. The I-NEG comprised workers from furniture construction and aluminum production industries, exposed to occupational noise levels ≥85 dB(A), involving continuous, impact, and vibration noise. Interviews confirmed inconsistent use of hearing protection. Demographic characteristics are presented in Table 1.
L-NEG participants reported using Personal Listening Devices (PLDs) for music for ≥22 minutes daily at ≥80% volume for ≥2 years [23]. Total usage time at maximum volume (100%) was capped at ≤1.5 hours. To estimate PLD sound exposure levels, participants reported their most frequently used volume level (percentage of maximum device output). The Calculated Listening Level (CLL) was determined. As direct measurement was unfeasible, the regression equation by Portnuff et al. (0.6143x + 39.395, where x = reported volume percentage) was applied to estimate the dB SPL equivalent for earbuds [23]. Finally, equivalent sound pressure levels (Leq(8h) and Leq(24h)) were calculated using established methods:

$$leq\ (dB) = 10\log[\frac{1}{T}\sum_{i=1}^{N} ti\ 10\frac{LPi}{10}]$$

The key parameters of this study are defined as follows: T denotes the reference time (8 or 24 hours), LPi signifies the sound pressure level of exposure, and ti indicates the duration of exposure in hours"[24]. The volume of PLDs in the L-NEG and decibel equivalent based on PLD volume percentage is reported in Table 1.
Regarding the control group, all entry conditions for the two groups, other than noise exposure, met the mentioned criteria. Therefore, none of the subjects in the control group were exposed to industrial noise, and none of them met the inclusion criteria of the group using PLD in this study.

Procedure

Basic audiologic and cognitive assessments were carried out for all participants. Duration Pattern Sequence Test (DPST), Persian version of Quick Speech in Noise Test (Q-SIN), Dichotic Digits Test (DDT) from central auditory processing as well as Ray Auditory Verbal Learning Test (RAVLT) and Semantic Stroop Test from cognitive assessment were performed. The presentation order of the assessments was randomized. Efforts were made to ensure adequate rest intervals between each assessment. In addition, assessments were conducted for employees outside of regular working hours.

Basic audiologic assessments

First, case history including noise exposure information and otoscopic examinations were performed. The immittance tests (Zodiac 901 model, Madsen CO, Denmark) to assess the middle ear status and audiometric tests to assess the hearing thresholds between 250–8000 Hz (Interacoustic AC 33 model, Madsen CO, Denmark) in the acoustic room were performed.

Cognitive assessments

The Montreal Cognitive Assessment (MoCA) is a cognitive screening test that was used to rule out cognitive impairment. This test evaluates attention/working memory, executive, episodic memory, language, and visuospatial skills. A cutoff score less than 25 is considered a referral for considered to diagnose mild cognitive impairment [25].

Central auditory processing tests

The DPST was chosen because it takes about 8 minutes and is easier than other temporal processing tests and has highly sensitive to cortical lesions (85.7% sensitivity, 92% specificity). Each DPST trial presented three 1000 Hz tones, each either long (500 ms) or short (250 ms), forming a sequence. Six unique duration patterns were used. Thirty trials were administered monaurally to each ear. Participants verbally reported the sequence (e.g., "long-short-long"). The percentage of correct responses per ear was calculated by multiplying the number of correctly identified sequences by 3.33 [26].
To minimize participant fatigue, an efficient speech-in-noise test was implemented. We used the Persian version of the Quick Speech-in-Noise (Q-SIN) test, validated for reliability in Iranian adults by Khalili et al. It

was administered at the participant's most comfortable level. Target sentences (male talker) were presented against multi-talker babble background noise. The signal-to-noise ratio (SNR) decreased progressively: the target started clearly audible but became increasingly difficult to understand as the background noise level rose relative to the target speech. Participants repeated each sentence. The total number of words correctly repeated across the test list was summed. The Speech-in-Nose Loss (SNR-Loss) in decibels (dB) was calculated using the equation: SNR-Loss = 27.5 – (Total Number of Correct Words) [27]
The Dichotic Digits Test (DDT) utilized monosyllabic Persian digits (1-10, excluding disyllabic 4). Its reliability exceeds 0.84, it is unaffected by peripheral hearing loss, and it is easy to administer. The test comprised 20 pairs of digits (40 items total per ear). Digit pairs on one channel of a CD were temporally aligned with pairs on the other channel to create dichotic stimuli. The CD was played on a dual-channel player, with channel one directed to the left ear and channel two to the right ear, per standard protocol. Participant responses were recorded on a worksheet. The total number of correct responses per ear was multiplied by 2.5 to derive a percentage score, rounded to the nearest digit [28]. All tests (DPST, Q-SIN, DDT) were conducted in a sound-treated room with stimuli delivered via headphones.

Cognitive processing tests

Cognitive function was assessed using software with the Semantic Stroop Test (Ravan Tajhiz Sina Co., Iran) and has a reliability of 0.71 for accuracy and 0.82 for reaction time. This test was used due to its simple administration, and on the other hand, the software provides us with individuals' data separately. In this test, neutral and target words were randomly presented with red and green colors on the computer screen. Two keys of the computer keyboard were marked with red and green color labels (? key, green and Z key, red). It was explained to the participant that he should press the green key for green words and the red key for red ones quickly. The number of correct answers, reaction time, and total time were determined by the software [29].
RAVLT does not require any special equipment and does not take a long time and its reliability is 0.80. In RAVLT, a 15 noun-word list was read to the participants. Then, participants were requested to recall as many words as possible. The number of words the participant remembered correctly was then recorded and determined as a score for the short-term performance. For the purposes here, the order in which the words are remembered is not important [30].

Statistical analyses

Statistical analyzes were performed using SPSS (version 17). To analyze the quantitative variables, the Kolmogorov-Smirnov test was used to check the normality of distribution. In this study, a Kruskal-Wallis test was performed to evaluate significant differences between DDT, DPST, RAVLT, Q-SIN, correct word scores, and reaction time in Stroop test between three groups. The Mann-Whitney test was used for pairwise comparisons between groups. Significance values were adjusted by Bonferroni correction for multiple testing and P adj was reported. $p<0.05$ was considered as statistically significant value.

Results

Characteristics of participants

A total of forty-five individuals in the L-NEG, with a mean age of 29.07 ± 3.31 years, and forty-six individuals in the I-NEG, with a mean age of 30.80 ± 5.45 years, along with forty-five participants having a mean age of 29.36 ± 5.45 years, took part in this study. Statistical analysis revealed no significant differences in age ($F(2, 133)=1.66$, $p=0.19$) or average hearing thresholds ($F(2, 133)=1.89$, $p=0.15$) among the groups. Information regarding each group, including age, hearing thresholds, intensity levels, and duration of noise exposure, is presented in Table 1. The frequency of the volume of personal listening devices in L-NEG participants is detailed in Table 2.

Temporal processing analysis with Duration Pattern Sequence Test

As shown in Table 3,The findings from the DPST indicated a statistically significant difference among the three groups concerning the left (H=82.37, df=2, p<0.001) and right (H=81.20, df=2, p<0.001) ears. Pairwise comparisons revealed that the scores for the left and right ears in the I-NEG were significantly lower than those of the L-NEG in both the left (p<0.001) and right (p<0.001) ears, as well as the control group in both ears (left: p<0.001; right: p<0.001). However, while the difference between the L-NEG and control groups in the right ear was significant (p<0.05), the difference in the left ear was not statistically significant (p>0.05).

Speech in noise perception with Quick Speech-in-Noise test

The results of the Q-SIN test showed that there was a significant difference between the three groups (H=34.567, df=2, p<0.001). Post-hoc analysis showed that the scores of the I-NEG were significantly poorer than the L-NEG (p=0.018) and the control group (p<0.001). Also, the L-NEG showed more SNR-Loss than the control group (p=0.006).

Binaural hearing analysis with The Dichotic Digits Test

The results of a Kruskal-Wallis test analysis in the DDT test showed a statistically significant difference between the three groups in the left (H=39.62, df=2, p<0.001) and right ears (H=15.66, df=2, p<0.001). Post-hoc analysis revealed that DDT results with I-NEG were significantly worse than with L-NEG in the left and right ears (p<0.001). The I-NEG achieved worse results than the control group in the left (p<0.001) and right ears (p=0.018). There were no significant differences between L-NEG and the control group (p>0.05).

Auditory short-term memory with Ray Auditory Verbal Learning Test

The analysis presented in Table 4 indicates a statistically significant difference among the three groups in the RAVLT (H=78.20, df=2, p<0.001). Post-hoc analysis revealed that the I-NEG scores were significantly lower than those of both the L-NEG and the control group (p<0.001). Additionally, a significant different was observed between the L-NEG and the control group (p<0.001).

Cognitive assessment with semantic stroop test

The correct percentage of neutral (H=41.14, df=2, p<0.001) and target (H=84.74, df=2, p<0.001) words were significantly difference between the three groups. Post-hoc analysis revealed the difference between the I-NEG and L-NEG was statistically significant in the neutral (p=0.018) and target (p=0.019) words. The score for neutral and target words in I-NEG were significantly poorer than the control group (p≤ 0.001). The difference in the correct answer of the neutral words and target words was statistically significant between L-NEG and the control group (p≤001).

Regarding reaction time, the result of the Kruskal-Wallis Test analysis showed no statistically significant difference between the three groups to neutral (H=4.46, df=2, p=0.10) and target (H=5.80, df=2, p=0.055) words.

The relationship between level of exposure and speech-in-noise perception

Spearmen correlation results showed a relation between Leq (8h) and SNR-Loss in the I-NEG (r= 0.54, p<0.001) and Leq and SNR-Loss in L-NEG (r=0.34, p<0.05). There was no correlation between temporal processing and binaural hearing with Leq (8) (p>0.05).

Discussion

This study aimed to compare central auditory processing (CAP) and cognitive functions among normal-hearing adults exposed to industrial noise, leisure noise, and those with no significant noise exposure. The investigation revealed significant detrimental effects of industrial noise exposure on dichotic hearing, auditory temporal processing, speech-in-noise perception, and cognitive domains including selective attention and working memory relative to both L-NEG and control groups. Furthermore, the L-NEG demonstrated measurable deficits compared to controls in critical areas such as speech-in-noise perception, auditory temporal processing, selective attention, and memory performance. The pathophysiological mechanisms and empirical evidence underlying these differential outcomes are systematically examined in the following sections. mechanisms.

Central auditory processing

Quantitative assessment of speech-in-noise perception that the I-NEG required significantly SNR for speech intelligibility compared to both L-NEG and control participants. This impairment in the I-NEG aligns with established neurobiological evidence indicating that noise exposure preferentially damages low spontaneous firing rate (low-SFR) auditory nerve fibers—high-threshold afferents crucial for signal detection in noisy environments. Critically, this cochlear neuropathy occurs without elevating conventional pure-tone thresholds, constituting a hidden hearing loss [11]. This pathophysiological mechanism explains why individuals with normal audiograms exhibit degraded speech-in-noise perception following noise exposure.

This finding is corroborated by multiple lines of research: Eggermont [11] and Wang & Ren [31] established that noise-induced loss of high-threshold, low-SFR auditory nerve fibers (ANFs)—whose firing dynamics resist saturation in background noise—directly compromises speech-in-noise perception in humans.

The observed superiority of L-NEG over I-NEG in speech-in-noise performance warrants mechanistic consideration. While direct comparative studies are limited, fundamental acoustical principles suggest that qualitative differences in sound characteristics (e.g., spectral dynamics, temporal structure, and emotional valence) differentially modulate neural processing. For instance, music training has improved the understanding of speech-in-noise [22] when it is presented at a comfortable level, which does not cause hearing damage. Dynamic spectral-temporal information is used in music as in spoken language; therefore, it has been suggested that music and language may have a common neural biological processing system. Therefore, loud music may have different emotional stress responses than industrial noise.

In this paper, results showed that more SNR-Loss in L-NEG than control group was consistent with Ismail, Nada [32] which reported exposure to leisure noise due to excessive PLDs usage cause elevated high frequency audiometry, decreased transient otoacoustic emissions (TEOAEs) amplitudes and decreased speech-in-noise scores despite normal thresholds. Although, Li et al reported the fast-speed speech recognition in noise decreased significantly in PLD users compared with in non-PLD users [33].

The DPST results indicated a marked decline in temporal processing in the I-NEG group relative to L-NEG and control groups. Temporal processing is essential for speech-in-noise perception and relies on the synchronized firing of auditory nerve fibers. Industrial noise exposure has been shown in animal models to disrupt this synchronization and damage afferent connections, potentially leading to phase-locking deficits [34]. Additionally, short-term auditory memory and attention—both essential for accurate DPST performance—may also be impaired by industrial noise. These results are consistent with studies showing decreased temporal processing performance in noise-exposed individuals despite normal hearing [17].

Contrarily, musical training has been shown to enhance multiple auditory functions, including improved temporal fine structure processing, spectral resolution, and binaural integration [4]. These effects may explain the relatively preserved temporal processing in the L-NEG group, as music is often processed within emotionally and cognitively integrative brain systems.

The analysis of the DDT indicated that the average scores of the I-NEG were lower than the L-NEG and control groups. Noise can alter neural processing in the midbrain, thalamus, and cerebral cortex even without peripheral hearing loss, resulting in decreased DDT scores. Performance in DDT may be influenced by deficits in auditory processing, attention, and other supramodal processes. These results were in line with Bhatt et al. study that reported that dichotic hearing is damaged in people who are exposed to industrial noise, despite normal thresholds [12]. Overall, music training can enhance the bilateral processing of stimuli [4]. So, no significant difference was seen between L-NEG and the control group in DDT results.

Cognitive Processing

memory performance was significantly impaired in the I-NEG group, followed by the L-NEG group. Noise affects memory by modulating auditory pathways connected to the hippocampus, particularly via lemniscal and non-lemniscal projections. Functional MRI studies further confirm these effects, showing reduced hippocampal and increased amygdala activity following chronic noise exposure [13]. In animal studies, showed that moderate-intensity noise (80 dB SPL, 2 h/day) can impair the memory ability, which may result from peroxidative damage, tau hyperphosphorylation, and auditory coding alteration [35]. Also, Liu et al. showed that noise and NIHL independent of oxidative stress impaired spatial memory and spatial learning in mice [36]. Human studies showed that the harmful effects of industrial noise on working memory in people who are exposed to 85 dB(A) noise [17].

In contrast, music is known to facilitate memory encoding and retrieval. The emotional and contextual components of music can enhance recall and serve as mnemonic devices. However, excessive exposure to loud music may impair specific cognitive abilities such as visuospatial memory, as shown in high-exposure listeners [37].

The Semantic Stroop Test was used to evaluate selective attention and reaction time. Results indicated lower accuracy in the I-NEG group compared to L-NEG and control groups, though the difference in reaction time was not statistically significant. Jafari et al. reported that low-frequency industrial noise impairs both visual and auditory attention, especially at intensities reaching 95 dBA [10]. Therefore, it seems that the frequency and content of noise can have a different effect on attention.

Based on different nature of music and industrial noise, it was shown that there is a significant difference in the scores of the Semantic Stroop Test between the two groups. Although, to the best of our knowledge, no study has examined the effect of listening to loud music on selective attention, a study has shown that even the type level of sound stimulation (stimulating or relaxing) can have different or destructive effects on cognitive processes [4]. There is a research gap in this field that should be further investigated. In this research, there is a significant relationship between exposure and speech-in-noise perception, especially in the I-NEG. Although, a multivariate regression model in a study showed that 23.3% of the variance in speech-in-noise test was explained by group category (L-NEG vs. L-NEG) and hearing thresholds.

Conclusion

Our findings indicate that exposure to industrial noise can adversely effect on temporal processing, speech-in-noise perception, binaural hearing, short-term memory and selective attention in adults with normal thresholds. Furthermore, individuals who frequently use PLDs exhibited negative outcomes in temporal processing, speech-in-noise perception, selective attention, and memory relative to the control group. These results underscore the necessity of educating workers in noisy environments and regular PLDs users. It is also essential to integrate these factors into hearing screening programs and protocols within occupational medicine, particularly for health professionals in industrial settings, despite existing permissible noise exposure limits aimed at reducing the risk of CAPD. Additionally, addressing the potential adverse effects associated with improper PLD usage should be prioritized within public health initiatives. Given the existing knowledge gaps, further research is essential to comprehensively understand the harmful impacts of noise on central auditory processing and cognitive functions.

Limitation and recommendation for future studies

Due to limitations in measuring PLDs output directly, equivalent noise exposure for the leisure group was calculated; future apps for direct measurement are recommended. Although subjects had normal conventional audiometry, the lack of high-frequency testing is a limitation, suggesting future studies assess this and possibility of hidden hearing loss. Furthermore, the male-only cohort limits generalizability; including both genders in future research is essential.

Ethical considerations This study has been registered with the code of ethics IR.TUMS.FNM.REC.1401.168 in the Ethics Committee of Tehran University of Medical Sciences.

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Access upon request

Statements and Declarations

Conflict of interest:

The authors declare that they have no competing interests

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Table 1: Demographic and noise exposure characteristics of the study groups

I-NEG (n=46)	Mean±SD:88.80±3.36 Range= 85-95	Mean±SD : 6.47± 1.24 Range=4-9	Leq (8h) dB mean±SD: 87.79±2.68 Range=84.42 – 92.95	Mean: 30.80 ± 5.45 years Range= 21–40	13.15±3.85 Range=5-20	29.93±0.24 Range=29-30
L-NEG (n=45)	Decibel Equivalents Mean±SD: 92.62±4.39 Range= 88.53-100.82	Mean: 1.77±0.33 Range=1-2	Leq (8h) dB mean±SD: 85.19± 3.67 Range 81.73- 92.73 Leq (24h): mean±SD: ٨٠,۴٩±٣,٨٩ Range=٧٧,١٩-٨٩,٢٠	Mean: 29.07± 3.31 Range=23–40	١١.56± .۴5 Range=5-20	29.86±0.40 Range=28-30
Control (n=45)	-	-	-	29.36 ± 5.45 years Range= 19-40	11.89± 4.03 Range=5-20	29.91±0.28 Range=29-30

L-NEG; leisure noise exposure group, I-NEG; industrial noise exposure group, CONTROL=Control Group

Table 2: Self-reported volume settings and estimated output levels in personal listening devices users

80%	88.539	21(46%)
85%	91.6105	7 (20%)
90%	94.682	12 (33%)
100%	100.82	5 (11%)
Total		45 (100%)

Table 3. Between-Group comparisons on measure of Central Aditory Processing

DPST result in right ear (%)	L-NEG	95.77(4.04)	96(96-96)	81.20	<0.001*	L-NEG* CONTROL	0.03*
	I-NEG	83.69(9.6)	83(80-90)			I-NEG* CONTROL	<0.001*
	CONTROL	98.29(6.67)	100(96-100)			L-NEG*I-NEG	<0.001*
DPST result in left ear (%)	L-NEG	96.21(4.58)	96(96-100)	82.37	<0.001*	L-NEG* CONTROL	0.1
	I-NEG	84.20(8.78)	86(76-90)			I-NEG* CONTROL	<0.001*
	CONTROL	98.44(6.67)	100(96-100)			L-NEG*I-NEG	<0.001*
SNR Loss (dB)	L-NEG	0.9(1.38)	0.5(-0.5-0.5)	34.56	<0.001*	L-NEG* CONTROL	<0.01*
	I-NEG	3.04(3.20)	2(0.5-5.75)			I-NEG* CONTROL	<0.001*
	CONTROL	-0.1(1.22)	-0.5(-1-1)			L-NEG*I-NEG	0.018*
DDT result in right ear (%)	L-NEG	83.27(13.21)	88.5(77-92)	15.66	<0.001*	L-NEG* CONTROL	0.87
	I-NEG	71.90 (15.77)	75 (60-85)			I-NEG* CONTROL	0.018*
	CONTROL	80.73 (9.47)	80(73-88)			L-NEG*I-NEG	<0.001*
DDT result in left ear (%)	L-NEG	84.61(14.79)	77.5 (62-85)	39.62	<0.001*	L-NEG* CONTROL	0.48
	I-NEG	61.19(14.11)	60(51-70)			I-NEG* CONTROL	<0.001*
	CONTROL	77.11(9.98)	77.5 (68-87)			L-NEG*I-NEG	<0.001*

L-NEG; leisure noise exposure group, I-NEG; industrial noise exposure group, CONTROL=Control Group, DDT; dichotic digit test, DPST; Duration pattern sequence test, SD; Standard Deviation

Table 4 . Between-Group comparisons on measure of cognitive function

RAVLT result (%)	L-NEG	7.9 (1.98)	8(6-9)	87.20	<0.001*	L-NEG* CONTROL	<0.001*
	I-NEG	5.08(1.77)	5(4-6)			I-NEG* CONTROL	<0.001*
	CONTROL	10.06(1.61)	10(9-11)			L-NEG*I-NEG	<0.001*
The correct answer of the neutral words (%)	L-NEG	97.56(2.57)	98(96-100)	41.14	< 0.001*	L-NEG* CONTROL	≤0.001*
	I-NEG	93.54(15)	96(95-98)			I-NEG* CONTROL	< 0.001*
	CONTROL	99.56(0.89)	100 (99-100)			L-NEG*I-NEG	0.018*
The correct answer of the target words (%)	L-NEG	95.18(2.88)	96(95-97)	84.74	< 0.001*	L-NEG* CONTROL	< 0.001*
	I-NEG	90.70(13)	95(91-95)			I-NEG* CONTROL	<0.001*
	CONTROL	98.93(1.13)	99(98-100)			L-NEG*I-NEG	0.019*
Reaction time to neutral words (ms)	L-NEG	491(63.43)	498(450-528	4.46	0.10	L-NEG* CONTROL	-
	I-NEG	533(101)	523(457-586)			I-NEG* CONTROL	-
	CONTROL	505(46.74)	505(475-547)			L-NEG*I-NEG	-
Reaction time to target words (ms)	L-NEG	493(59.97)	492(459-539)	5.8	0.055	L-NEG* CONTROL	-
	I-NEG	540(105)	538 (456-592)			I-NEG* CONTROL	-
	CONTROL	510(45.32)	510(479-542)			L-NEG*I-NEG	-

L-NEG; leisure noise exposure group, I-NEG; industrial noise exposure group, CONTROL=Control Group, RAVLT' Ray Auditory Verbal Learning Test, SD; Standard Deviation