Original Article

Ear Canal Role and Psychoacoustic Parameters: Loudness, Sharpness, Roughness, and Fluctuation Strength

Hadi Asady[1], Farhad Forouharmajd[1], Siamak Pourabdian[1], Mehdi Jalali[1,2], Ali Ahmadi[1], Fatemeh Ansari[1], Adrian Fuente[3]

[1]Department of Occupational Health Engineering, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Department of Occupational Health Engineering, School of Health, Neyshabur University of Medical Sciences, Neyshabur, Iran, [3]Research Center of the University Institute of Geriatrics of Montreal, Montreal, Quebec, Canada

Abstract

Aim: The purpose of this study was to investigate whether psychoacoustic parameters could be significantly influenced by the human ear canal and whether gender played a significant role in these effects. **Methods:** In this study, sixty participants were enrolled, with an equal distribution of 30 male and 30 female individuals. White and sinusoidal noises at 75, 85, and 95 dB as stimulus sound pressure levels (SSPLs). Psychoacoustic parameters such as loudness, sharpness, roughness, and fluctuation strength were measured both outside (cavum part of the external ear) and inside the right ear of each participant. These measurements were done using a circular-shaped microphone with a 2-mm diameter and Labview software. The duration for each measurement was 10 s. The independent sample *t*-test and repeated measures ANOVA test were employed for the statistical analysis in this study. The results indicated that the equality of means was rejected at a significance level of $P < 0.05$. All statistical analyses were conducted using SPSS Version 26. **Results:** The mean age and standard deviation of all participants were 22.77 ± 2.60 years old. The comparison of psychoacoustic parameters in the exposure to different types of noises at various levels between genders showed no statistically significant differences (all $P > 0.05$). For both sinusoidal noise and white noise at all three studied SSPLs, the differences in four psychoacoustic parameters between the outer and inner ears of the participants were not statistically significant (all $P > 0.05$). **Conclusion:** Based on our findings, it seems that the human ear canal does not have any effect on psychoacoustic parameters, leading us to conclude that the ear canal does not contribute to noise-induced annoyance.

Keywords: Noise annoyance, participants ear, sinusoidal noise, white noise

Introduction

Noise, as defined, is an undesirable and unpleasant sound that can adversely impact human activities and disrupt their well-being.[1] In recent years, the issue of noise-related health risks has emerged as a significant public health concern. Beyond the detrimental effects on the auditory system, exposure to noise can also lead to a range of other adverse health consequences, such as sleep disruptions, cognitive impairment in children, cardiovascular and pulmonary conditions, type 2 diabetes, unfavorable birth outcomes, and general annoyance.[2-4] The impact of noise on human is a complex phenomenon, influenced by not only the physical characteristics of the noise itself but also the intricate interplay of the body's physical, physiological, and psychological responses. The sound pressure level and frequency composition of the noise are crucial factors, but the human's subjective interpretation and emotional reactions to the auditory stimuli can also significantly shape the overall impact.[5]

The human ear is a remarkable feat of natural engineering, having evolved over countless years to its current sophisticated design. This delicate organ is responsible for the vital functions of hearing and balance, and its intricate structure is a testament to the ingenuity of nature. From the intricate workings of the inner ear to the protective outer shell, the human ear represents a masterful example of the adaptive capabilities of the natural world.[6] The ear comprises three distinct regions that work in

Access this article online	
Quick Response Code:	**Website:** https://journals.lww.com/IJEH
	DOI: 10.4103/ijehe.ijehe_11_24

Address for correspondence: Dr. Farhad Forouharmajd, Department of Occupational Health Engineering, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail: forouhar@hlth.mui.ac.ir

How to cite this article: Asady H, Forouharmajd F, Pourabdian S, Jalali M, Ahmadi A, Ansari F, *et al*. Ear canal role and psychoacoustic parameters: Loudness, sharpness, roughness, and fluctuation strength. Int J Env Health Eng 2025;14:10.

Received: 27-02-2024, **Revised:** 15-08-2024,
Accepted: 20-11-2024, **Published:** 23-05-2025

concert to perceive sound. The outer ear (pinna and the ear canal), consisting of the auricle and ear canal, serves to collect and funnel sound waves toward the tympanic membrane. The middle ear, in turn, transmits these vibrations to the inner ear, where the remarkable cochlea transduces the fluid motion into electrical impulses.[6]

The existing literature has conclusively demonstrated the impact of the ear canal on sound pressure levels. Notably, the study conducted by Asady *et al*. revealed that the ear canal can amplify sound pressure at various frequencies, with the effect observed in both male and female subjects.[5] The study conducted by Jia-Lin *et al*. has revealed intriguing findings regarding the sound pressure level differences between the outlet of the external auditory canal and the eardrum. Their research suggests that these differences are more pronounced at frequencies ≤1500 Hz.[7] Djupesland and Zwislocki's study had the same findings.[8]

In the realm of auditory research, numerous studies have delved into the acoustical roles of the various components within the human ear. While sound pressure level has been a crucial parameter in these investigations, a notable gap remains in the exploration of the psychoacoustical functions of the ear's distinct structures. Psychoacoustics, as a discipline, is primarily concerned with the study of listeners' responses to sonic stimuli, seeking to uncover the statistical and causal connections between the physical attributes of sounds and the corresponding properties of human perception and cognition. This untapped domain presents a compelling opportunity for further inquiry, as elucidating the psychoacoustical roles of the ear's diverse elements could yield valuable insights into the complex mechanisms underlying our auditory experiences.[9] Akin to the tangible attributes of sound, such as sound pressure level,[10] the realm of psychoacoustics encompasses its own unique parameters for calculation and evaluation. Among the most practical of these are the concepts of loudness, sharpness, roughness, fluctuation strength, and tonality. Loudness, a subjective perception of the intensity of a sound, is a crucial factor in understanding how individuals interpret and experience the auditory environment. Sharpness, on the other hand, refers to the perceived high-frequency content of a sound, whereas roughness describes the sensation of irregular or pulsating auditory stimuli. Fluctuation strength, a measure of the temporal variation in a sound, and tonality, the degree to which a sound is perceived as tonal or nontonal, further contribute to the multifaceted nature of psychoacoustic analysis.[11-13] The present investigation sought to elucidate the potential impact of the human ear canal on psychoacoustic parameters, including loudness, sharpness, roughness, and fluctuation strength. In addition, the study explored the role of gender in any observed variations in these acoustic properties. The findings of this research hold significance in enhancing our understanding of the complex interactions between the auditory system and the physical characteristics of the ear canal, which may have important implications for various fields, such as audio engineering, hearing research, and personalized audio technologies.

Materials and Methods

Study sample and inclusion criteria

This cross-sectional study was conducted in the sound and vibration laboratory of the Health Faculty at Isfahan University of Medical Sciences in 2022. In the present study, the researchers have outlined a comprehensive set of inclusion criteria that aimed to identify individuals with healthy hearing systems and a specific age range, as well as a lack of sensitivity to noise. The primary inclusion criterion was the absence of infections or deformities in the hearing structure. This measure ensures that the participants' hearing abilities are not compromised by any underlying physiological conditions, allowing for a more accurate assessment of their overall hearing health. In addition, the researchers evaluated the participants' sensitivity to noise, which is an important factor in understanding the impact of auditory stimuli on individual well-being.

To assess noise sensitivity, the researchers posed a direct question to the volunteers, inquiring about any irritation or discomfort experienced in response to common environmental sounds, such as the jingling of coins, dog barking, car engines, chewing noises, or the operation of a vacuum cleaner. Participants who reported the ability to ignore these sounds were considered eligible for the study, as this indicates a level of tolerance and adaptation to everyday auditory stimuli. The age range of 20–30 years was another important inclusion criterion, as it allows for the examination of hearing health within a specific developmental stage. This age group is often associated with a relatively stable and healthy auditory system, providing a suitable baseline for the investigation of hearing-related phenomena.

The researchers further ensured the informed consent of all participants, informing them of their right to withdraw from the study at any time. This ethical consideration demonstrates the researchers' commitment to upholding the autonomy and well-being of the study participants.

Psychoacoustic parameters measurement

The researchers utilized white and sinusoidal noises (20–20,000 Hz) at three distinct sound pressure levels (SPLs) of 75, 85, and 95 dBA as the stimulus sound pressure levels (SSPLs). To ensure precision, the SPLs were verified before each measurement using a calibrated sound level meter (model TES-1358C) in the SPL (A) mode and near the participants' ears. The speakers, positioned 1.5 m in front of the participants and 87 cm from the laboratory ground, were used to play the stimuli. All participants were instructed to maintain a fixed head position and gaze forward toward the speakers during the measurements.

The Labview software (V 2012, by National Instruments National Instruments Corp, USA) and a data acquisition card (DAQ) from the National Instrument Co (model MC-3642) were utilized to play the stimulus sounds at the specified pressure levels and to measure and calculate the relevant psychoacoustic parameters.

The stimulus sounds were played using the Va-lab4 module within the Labview software, whereas the measurement of the psychoacoustic parameters, including loudness (phone), sharpness (acum), roughness (asper), and fluctuation strength (vacil), was conducted using the Va-lab2 module. A calibrated circular-shaped microphone with a 2-mm diameter was used for all the measurements, and a calibrator (1000 Hz and 94 dB) was employed to ensure the accuracy of the microphone before each measurement session.

The noise exposure duration for each participant was 20 s, with the total exposure time for each type of stimulus sound being 1 min. The 20 s exposure was divided into two 10 s intervals, with the first 10 s used to measure the parameters in the outside (cavum part of the external ear) and the second 10 s used to measure the parameters on the inside (at a 2.0 cm depth from the entrance to the ear canal) of the right ear of each participant. The psychoacoustic parameters were measured after each exposure using the Moore method, which is a well-established approach in the field of psychoacoustics. To minimize the potential effects of confounding factors, all participants were exposed to the same environmental conditions during the measurements.

Statistical analysis

The data were analyzed using SPSS (V26, IBM SPSS Statistics, USA) software. The mean and standard deviation (SD) also 95% confidence interval for mean (95% CI for mean) were reported for the quantitative variables. For qualitative variables, the number and its related percent were reported. The independent sample *t*-test and repeated measures ANOVA test were used for the statistical analysis, and the equality of means was rejected at $P < 0.05$.

Results

The participant pool comprised 60 individuals, of which 30 were men, representing 50% of the total group. A deeper examination of the educational backgrounds of these participants reveals that the majority, 41 individuals (68.3%), were Bachelor of Science (BSc) degree holders. In addition, there were 18 participants (30%) pursuing Master of Science (MSc) degrees, whereas a single participant (1.7%) was at the PhD level. Concerning the age of the participants, the mean age was calculated at 22.77 years, with a SD of 2.60 years. Further analysis of the participants' physical characteristics reveals the mean height, weight, and BMI. The mean and SD for height, weight, and body mass index (BMI) of all participants were 171.55 ± 9.65 cm, 64.30 ± 11.39 kg, and 21.3 ± 2.95, respectively.

The largest mean value (132.83 ± 2.70) for loudness in the exposure to the sinusoidal noise was seen inside the ear of the participants and SSPL was equal to the 95 dB. The largest mean value for loudness, recorded at 132.93 ± 2.79, was observed during exposure to white noise external to the participants' ears, with a sound pressure level (SSPL) of 85 dB. For further details, please refer to Tables 1 and 2.

Examining psychoacoustic parameters in response to sinusoidal noise at a SSPL of 75 dB, researchers sought to elucidate potential differences between genders. The studied parameters included loudness, sharpness, roughness, and fluctuation strength, measured both externally and internally. Notably, the findings indicated a lack of statistically significant differences in these parameters across genders. When assessing the psychoacoustic responses measured externally to the ear, the parameters of loudness, sharpness, roughness, and fluctuation strength yielded *P* values of 0.816, 0.350, 0.214, and 0.084, respectively. Similarly, the psychoacoustic parameters measured internally presented comparable outcomes. The parameters recorded loudness (P = 0.786), sharpness (P = 0.212), roughness (P = 0.773), and fluctuation strength (P = 0.791) also did not show statistically significant differences. It is critical to highlight that this consistency in response was further validated by analogous findings observed with alternative stimuli and varying sound pressure levels, as detailed in Tables 3-8 of the original study.

The present study aimed to investigate the psychoacoustic effects elicited by sinusoidal noise and white noise across various sound pressure levels (SSPLs) in participants. Specifically, it focused on the comparative analysis of four key psychoacoustic parameters between the exterior and interior of the participants' ears. The methodology employed a repeated measures ANOVA test to discern any statistically significant differences across the selected conditions.

The results of the analysis revealed that, for both sinusoidal noise and white noise, the differences in the psychoacoustic parameters measured at all three SSPLs were not statistically significant. The statistical outcomes indicated *P* values exceeding the threshold of 0.05, suggesting that any observed variations could likely be attributed to random chance rather than systematic effects associated with the auditory conditions applied. This finding is documented further in Tables 9 and 10 of the study.

Discussion

Recent research into the psychoacoustic parameters associated with the human ear canal has yielded results that challenge previous assumptions about auditory perception based on anatomical differences and gender. Our findings indicate that the human ear canal does not influence psychoacoustic parameters significantly, nor does gender appear to play a decisive role in this context. This conclusion is particularly surprising given our initial hypothesis that the ear canal's structure might affect sound pressure levels and, consequently, psychoacoustic experiences.

Psychoacoustics is the study of how humans perceive sound, involving parameters such as loudness, sharpness, roughness, and fluctuation strength. Researchers have speculated that the human ear canal could alter these parameters due to its unique shape and resonance properties. We anticipated that

Table 1: Descriptive statistic of the psychoacoustic parameters in the different stimulus sound pressure level for sinusoidal noise

Sinusoidal noise	SSPL[10]					
	75		85		95	
	Outside	Inside	Outside	Inside	Outside	Inside
Loudness (phone)						
Mean±SD	132.41±3.00	132.39±3.03	132.72±2.52	132.81±2.66	132.72±2.52	132.83±2.70
95% LB*	131.63	131.61	132.07	132.12	132.07	132.13
95% UB**	133.19	133.18	133.37	133.50	133.37	133.53
Sharpness (acum)						
Mean±SD	2.35±0.24	2.35±0.23	2.34±0.25	2.35±0.24	2.33±0.28	2.34±0.27
95% LB	2.29	2.29	2.28	2.28	2.26	2.27
95% UB	2.41	2.41	2.41	2.41	2.41	2.41
Roughness (asper)						
Mean±SD	32.76±1.28	32.64±1.25	32.96±1.39	32.46±1.68	32.58±1.61	32.44±1.40
95% LB	32.43	32.32	32.60	32.03	32.17	32.08
95% UB	33.09	32.96	33.32	32.90	32.99	32.80
Fluctuation strength (vacil)						
Mean±SD	0.11±0.01	0.11±0.01	0.15±0.16	0.15±0.13	0.17±0.20	0.15±0.13
95% LB	0.10	0.10	0.11	0.11	0.12	0.12
95% UB	0.11	0.11	0.19	0.18	0.22	0.18

*95% CI for mean (LB), **95% CI for mean (UB). CI: Confidence interval, SD: Standard deviation, LB: Lower bound, UB: Upper bound, SSPL: Stimulus sound pressure level

Table 2: Descriptive statistic of the psychoacoustic parameters in the different stimulus sound pressure levels for white noise

White noise	SSPL[10]					
	75		85		95	
	Outside	Inside	Outside	Inside	Outside	Inside
Loudness (phone)						
Mean±SD	132.92±2.73	132.89±2.72	132.93±2.79	132.86±2.70	132.87±2.76	132.87±2.79
95% LB*	132.21	132.19	132.21	132.16	132.15	132.15
95% UB**	133.62	133.59	133.65	133.56	133.58	133.59
Sharpness (acum)						
Mean±SD	2.37±0.18	2.35±0.23	2.35±0.23	2.36±0.22	2.36±0.22	2.36±0.22
95% LB	2.32	2.30	2.30	2.30	2.30	2.30
95% UB	2.42	2.41	2.41	2.41	2.41	2.41
Roughness (asper)						
Mean±SD	32.35±1.73	32.59±1.62	32.40±1.34	32.53±1.53	32.88±1.64	32.79±1.85
95% LB	31.91	32.17	32.05	32.13	32.46	32.32
95% UB	32.80	32.99	32.75	32.92	33.31	33.27
Fluctuation strength (vacil)						
Mean±SD	0.13±0.07	0.18±0.28	0.14±0.12	0.13±0.07	0.14±0.15	0.15±0.19
95% LB	0.12	0.11	0.11	0.11	0.1	0.1
95% UB	0.15	0.25	0.17	0.15	0.18	0.19

*95% CI for mean (LB), **95% CI for mean (UB). CI: Confidence interval, SD: Standard deviation, LB: Lower bound, UB: Upper bound, SSPL: Stimulus sound pressure level

differences might be observed when comparing psychoacoustic measures taken outside the ear canal versus those recorded within it. Our hypothesis was informed by previous studies, including the work of Park *et al*., which indicated that hearing thresholds vary significantly between genders at certain frequencies, specifically noting greater differences at 4 kHz in individuals.[14] However, our results did not support this hypothesis. Upon statistical analysis, the mean comparison of psychoacoustic parameters – both inside and outside the ear canal, across both genders revealed no significant differences. This lack of statistical significance implies that the ear canal's acoustic properties may not be influential on psychoacoustics parameters. Our findings suggest that while other studies have identified variances in hearing thresholds related to gender,

Table 3: Comparison of psychoacoustic parameters with using of independent sample *t*-test between two genders in the exposure to the sinusoidal noise with the level of 75 dB (*n*=60)

Sinusoidal noise	SSPL[10] 75									
	Outside					Inside				
	Mean±SD	*t*	95% CI Lower	95% CI Upper	*P*	Mean±SD	*t*	95% CI Lower	95% CI Upper	*P*
Loudness										
Male	132.50±3.71	−0.234	−1.76	1.40	0.816	132.50±3.71	−0.273	−1.80	1.37	0.786
Female	132.32±2.17					132.30±2.22				
Sharpness										
Male	2.32±0.22	0.941	−0.07	0.19	0.350	2.31±0.28	1.264	−0.05	0.20	0.212
Female	2.38±0.27					2.39±0.17				
Roughness										
Male	32.55±1.17	1.256	−0.25	1.08	0.214	32.68±1.21	0.290	−0.56	0.75	0.773
Female	32.97±1.38					32.59±1.30				
FS										
Male	0.11±0.006	1.756	−0.001	0.004	0.084	0.11±0.005	0.266	−0.003	0.003	0.791
Female	0.11±0.006					0.11±0.006				

SD: Standard deviation, 95% CI: 95% Confidence interval of the difference, *P*: *P* value, FS: Fluctuation strength, SSPL: Stimulus sound pressure level

Table 4: Comparison of psychoacoustic parameters with using of independent sample *t*-test between two genders in the exposure to the sinusoidal noise with level of 85 dB (*n*=60)

Sinusoidal noise	SSPL[10] 85									
	Outside					Inside				
	Mean±SD	*t*	95% CI Lower	95% CI Upper	*P*	Mean±SD	*t*	95% CI Lower	95% CI Upper	*P*
Loudness										
Male	132.96±1.97	−0.735	−1.80	0.84	0.466	133.01±2.95	−0.571	−1.78	0.99	0.570
Female	132.48±2.99					132.61±2.38				
Sharpness										
Male	2.30±0.31	1.363	−0.05	0.21	0.180	2.31±0.30	1.345	−0.05	0.21	0.185
Female	2.39±0.16					2.39±0.16				
Roughness										
Male	32.88±1.54	0.474	−0.56	0.90	0.638	32.18±1.89	1.296	−0.31	1.43	0.200
Female	33.05±1.25					32.74±1.43				
FS										
Male	0.18±0.21	−1.282	−0.14	0.03	0.208	0.18±0.16	−1.657	−0.12	0.02	0.106
Female	0.13±0.08					0.12±0.06				

SD: Standard deviation, 95% CI: 95% Confidence interval of the difference, *P*: *P* value, FS: Fluctuation strength, SSPL: Stimulus sound pressure level

these differences do not extend to psychoacoustic parameters in the way we anticipated.

Furthermore, gender differences in the association between hearing loss and cognitive function were seen in Huang *et al*.'s study.[15] This kind of difference was seen in Wasano *et al*.'s study too.[16] We realized that both gender ear canal functions in the field of psychoacoustic are the same and we can say that gender differences in sound perception are free from ear canal differences. In other words, the external hearing system of humans (ear canal part) does not have any effects on the perceived sound quality and these parameters are more related to the frequency content, pure-tone components, and impulsiveness.[17]

Our recent findings indicate that the psychoacoustical characteristics exhibited by the human ear canal against the sound pressure levels[5,18] remain consistent, even when faced with diverse auditory stimuli. Psychoacoustics, the study of the perception of sound, encompasses a wide range of phenomena related to how humans interpret auditory stimuli. Conventionally, it has been assumed that variations

Table 5: Comparison of psychoacoustic parameters with using of independent sample *t*-test between two genders in the exposure to the sinusoidal noise with level of 95 dB (*n*=60)

Sinusoidal noise	SSPL[10] 95									
	Outside					Inside				
	Mean±SD	*t*	95% CI		*P*	Mean±SD	*t*	95% CI		*P*
			Lower	Upper				Lower	Upper	
Loudness										
Male	133.01±2.99	−0.909	−1.90	0.72	0.368	133.03±2.98	−0.579	−1.81	0.99	0.565
Female	132.42±1.96					132.63±2.43				
Sharpness										
Male	2.28±0.36	1.509	−0.04	0.26	0.139	2.30±0.32	1.227	−0.06	0.22	0.226
Female	2.39±0.16					2.38±0.20				
Roughness										
Male	32.21±1.48	1.855	−0.06	1.58	0.069	32.34±1.59	0.573	−0.52	0.94	0.569
Female	32.96±1.68					32.55±1.20				
FS										
Male	0.21±0.19	−1.574	−0.18	0.03	0.125	0.17±0.14	−0.868	−0.09	0.04	0.389
Female	0.13±0.08					0.14±0.12				

SD: Standard deviation, 95% CI: 95% Confidence interval of the difference, *P*: *P* value, FS: Fluctuation strength, SSPL: Stimulus sound pressure level

Table 6: Comparison of psychoacoustic parameters with using of independent sample *t*-test between two genders in the exposure to the white noise with level of 75 dB (*n*=60)

White noise	SSPL[10] 75									
	Outside					Inside				
	Mean±SD	*t*	95% CI		*P*	Mean±SD	*t*	95% CI		*P*
			Lower	Upper				Lower	Upper	
Loudness										
Male	133.08±3.05	−0.462	−1.75	1.09	0.646	133.05±3.04	−0.457	−1.74	1.10	0.649
Female	132.75±2.40					132.73±2.41				
Sharpness										
Male	2.34±0.21	1.150	−0.04	0.15	0.256	2.31±0.30	1.461	−0.04	0.21	0.152
Female	2.40±0.15					2.40±0.14				
Roughness										
Male	32.23±1.89	0.552	−0.66	1.15	0.583	32.60±1.77	−0.080	−0.88	0.81	0.936
Female	32.48±1.57					32.57±1.47				
FS										
Male	0.14±0.08	−0.931	−0.06	0.02	0.355	0.18±0.21	−0.092	−0.16	0.14	0.927
Female	0.13±0.07					0.18±0.33				

SD: Standard deviation, 95% CI: 95% Confidence interval of the difference, *P*: *P* value, FS: Fluctuation strength, SSPL: Stimulus sound pressure level

in both the type of sound and the pressure levels at which they are presented would yield significant changes in psychoacoustic responses. However, our research suggests that the inherent psychoacoustic parameters associated with the human ear canal are robustly impermeable to these auditory alterations. This finding implies that the ear canal functions not merely as a passive conduit for sound waves but as a critical element of the auditory system, whose internal mechanics operate with a remarkable degree of stability despite external fluctuations.

Our investigations focused on examining the relationship between sound type variations and sound pressure levels, and their corresponding effects on the psychoacoustic parameters of the ear canal. Notably, the results demonstrated minimal to no effect of sound pressure levels and types on the psychoacoustic characteristics measured. Rather, it appears that the ear canal's responsiveness is governed by a set of underlying principles that prioritize a stable auditory experience for the listener, irrespective of external auditory manipulations.

Table 7: Comparison of psychoacoustic parameters with using of independent sample *t*-test between two genders in the exposure to the white noise with level of 85 dB (*n*=60)

White noise	SSPL[10] 85									
	Outside					Inside				
	Mean±SD	*t*	95% CI		*P*	Mean±SD	*t*	95% CI		*P*
			Lower	Upper				Lower	Upper	
Loudness										
Male	132.95±3.06	−0.045	−1.49	1.42	0.964	132.99±2.99	−0.376	−1.67	1.15	0.708
Female	132.91±2.55					132.73±2.42				
Sharpness										
Male	2.31±0.29	1.435	−0.04	0.21	0.159	2.32±0.27	1.409	−0.04	0.20	0.166
Female	2.40±0.15					2.40±0.15				
Roughness										
Male	32.37±1.63	0.182	−0.64	0.77	0.857	32.39±1.68	0.694	−0.52	1.07	0.491
Female	32.43±1.00					32.66±1.37				
FS										
Male	0.16±0.15	−1.567	−0.11	0.02	0.128	0.15±0.09	−1.816	−0.07	0.004	0.079
Female	0.12±0.02					0.12±0.02				

SD: Standard deviation, 95% CI: 95% Confidence interval of the difference, *P*: *P* value, FS: Fluctuation strength, SSPL: Stimulus sound pressure level

Table 8: Comparison of psychoacoustic parameters with using of independent sample *t*-test between two genders in the exposure to the white noise with level of 95 dB (*n*=60)

White noise	SSPL[10] 95									
	Outside					Inside				
	Mean±SD	*t*	95% CI		*P*	Mean±SD	*t*	95% CI		*P*
			Lower	Upper				Lower	Upper	
Loudness										
Male	132.99±3.03	−0.373	−1.71	1.17	0.710	133.02±3.07	−0.416	−1.75	1.15	0.679
Female	132.73±2.52					132.72±2.52				
Sharpness										
Male	2.32±0.26	1.270	−0.05	0.19	0.210	2.32±0.16	1.319	−0.04	0.19	0.193
Female	2.39±0.17					2.39±0.26				
Roughness										
Male	32.64±1.88	1.167	−0.36	1.34	0.248	33.02±2.29	−0.943	−1.41	0.51	0.349
Female	33.13±1.35					32.57±1.28				
FS										
Male	0.16±0.14	−1.175	−0.12	0.04	0.249	0.13±0.06	0.536	−0.08	0.13	0.594
Female	0.12±0.03					0.16±0.19				

SD: Standard deviation, 95% CI: 95% Confidence interval of the difference, *P*: *P* value, FS: Fluctuation strength, SSPL: Stimulus sound pressure level

Table 9: Comparison of psychoacoustic parameters between outside and inside of the participant's ear with using of repeated measures ANOVA test (*n*=60)

SSPL[10]	Psychoacoustic parameters															
	Loudness (phone)				Sharpness (acum)				Roughness (asper)				Fluctuation strength (vacil)			
	Outside**	Inside***	*F*	*P*	Outside	Inside	*F*	*P*	Outside	Inside	*F*	*P*	Outside	Inside	*F*	*P*
75	132.41	132.39	0.421	0.519	2.37	2.35	0.025	0.876	32.76	32.64	0.331	0.567	0.11	0.11	0.164	0.687
85	132.72	132.81	0.652	0.432	2.34	2.35	0.038	0.846	32.96	32.46	3.314	0.076	0.15	0.15	0.187	0.667
95	132.72	132.83	1.343	0.251	2.33	2.34	0.210	0.649	32.58	32.44	0.407	0.526	0.17	0.15	1.660	0.286

**Mean of outside, ***Mean of inside. SSPL: Stimulus sound pressure level, *P*: *P* value

Table 10: Comparison of psychoacoustic parameters between outside and inside of the participant's ear with using of repeated measures ANOVA test (n=60)

SSPL[10]	Psychoacoustic parameters															
	Loudness (phone)				Sharpness (acum)				Roughness (asper)				Fluctuation Strength (vacil)			
	Outside**	Inside***	*F*	*P*	Outside	Inside	*F*	*P*	Outside	Inside	*F*	*P*	Outside	Inside	*F*	*P*
75	132.92	132.89	0.936	0.337	2.37	2.36	2.137	0.149	32.35	32.59	0.735	0.395	0.13	0.18	2.624	0.111
85	132.86	132.93	0.408	0.526	2.35	2.36	0.358	0.552	32.53	32.40	0.350	0.556	0.14	0.13	0.680	0.413
95	132.87	132.87	0.068	0.795	2.36	2.36	0.204	0.653	32.88	32.79	0.092	0.763	0.14	0.15	0.058	0.810

**Mean of outside, ***Mean of inside. SSPL: Stimulus sound pressure level, *P*: *P* value

Moreover, our study's findings revealed a scarcity of comparative literature concerning the independence of psychoacoustic behaviors of the ear in relation to types of stimulus sounds and pressure levels across both genders. This gap highlights a compelling avenue for future research.

Conclusion

The human ear canal exhibits no discernible effects on psychoacoustic parameters; consequently, while noise annoyance correlates with these parameters, it does not alter the function of the ear canal. Moreover, this study indicated that the behavior of ear canals in both genders is the same with respect to psychoacoustic responses. Investigation into other stimuli sound pressure levels also types, and psychoacoustic parameters has been suggested by authors for future research.

Acknowledgments

The authors would like to thank all students who participated in this study.

Financial support and sponsorship

This research has been supported by Isfahan University of Medical Sciences grant (ID number: 299149). This fund was used for data analysis.

Ethics code

IR.MUI.MED.REC.1399.771.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Hadi Asady: Conception and design of the work, Data management and cleaning, Data analysis, Drafting the work, Critically revising the manuscript; Siamak Pourabdian: Data management and cleaning, Critically revising the manuscript; Adrian Fuente: Drafting the work, Critically revising the manuscript; Mehdi Jalali: Data management and cleaning, Critically revising the manuscript; Ali Ahmadi: Data management and cleaning, Data analysis, Critically revising the manuscript; Fatemeh Ansari: Data management and cleaning, Data analysis, Critically revising the manuscript; Farhad Forouharmajd: Conception and design of the work, Critically revising the manuscript.

References

1. Nassiri P, Monazam M, Fouladi Dehaghi B, Ibrahimi Ghavam Abadi L, Zakerian SA, Azam K. The effect of noise on human performance: A clinical trial. Int J Occup Environ Med 2013;4:87-95.
2. Li X, Dong Q, Wang B, Song H, Wang S, Zhu B. The influence of occupational noise exposure on cardiovascular and hearing conditions among industrial workers. Sci Rep 2019;9:11524.
3. Bagheri Hosseinabadi M, Khanjani N, Ebrahimi MH, Mirbadie SR, Biganeh J. The effects of industrial noise exposure on lipid peroxidation and antioxidant enzymes among workers. Int Arch Occup Environ Health 2019;92:1041-6.
4. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, *et al.* Auditory and non-auditory effects of noise on health. Lancet 2014;383:1325-32.
5. Asady H, Fuente A, Pourabdian S, Forouharmajd F, Shokrolahi I. Acoustical role of ear canal in exposure to the typical occupational noise levels. Med J Islam Repub Iran 2021;35:58.
6. Sundar PS, Chowdhury C, Kamarthi S. Evaluation of human ear anatomy and functionality by axiomatic design. Biomimetics (Basel) 2021;6:31.
7. Liu JL, Qin XL, Wang LH, Liang CY, Jiang T. Measurement of sound pressure level at outlet of external auditory canal and eardrum. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 2003;21:353-5.
8. Djupesland G, Zwislocki JJ. Sound pressure distribution in the outer ear. Acta Otolaryngol 1973;75:350-2.
9. Guski R, Blauert J. Psychoacoustics without psychology? Rev Gen Psychol 2009;8:265-72.
10. Lie A, Skogstad M, Johannessen HA, Tynes T, Mehlum IS, Nordby KC, *et al.* Occupational noise exposure and hearing: A systematic review. Int Arch Occup Environ Health 2016;89:351-72.
11. Poveda-Martínez P, Ramis-Soriano J. A comparison between psychoacoustic parameters and condition indicators for machinery fault diagnosis using vibration signals. Appl Acoust 2020;166:107364.
12. Engel MS, Fiebig A, Pfaffenbach C, Fels J. A review of the use of psychoacoustic indicators on soundscape studies. Curr Pollut Rep 2021;7:359-78.
13. Yost WA. Psychoacoustics: A brief historical overview. Acoust Today 2015;11:46-53.
14. Park YH, Shin SH, Byun SW, Kim JY. Age- and gender-related mean hearing threshold in a highly-screened population: The Korean national health and nutrition examination survey 2010-2012. PLoS One 2016;11:e0150783.
15. Huang B, Cao G, Duan Y, Yan S, Yan M, Yin P, *et al.* Gender differences in the association between hearing loss and cognitive function. Am J Alzheimers Dis Other Demen 2020;35.
16. Wasano K, Kaga K, Ogawa K. Patterns of hearing changes in women and men from denarians to nonagenarians. Lancet Reg Health West Pac 2021;9:100131.
17. Crocker MJ. Handbook of Noise and Vibration Control. Hoboken, New Jersey: John Wiley & Sons; 2007.
18. Yu JF, Cheng WD. Effect of canal depth on sound pressure level distribution in human bilateral ears. Appl Mech Mater 2012;145:63-7.