H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 2, 2025
Doi: 10.21020/husbfd.1435195

Original Research

The Effects of Noise on Speech Intelligibility in Normal Hearing Workers Exposed to Noise in Professional Life

Büşra Kaynakoğlu[1], Betül Çiçek Çınar[2], Didem Türkyılmaz[3]

Submission Date: February 21th, 2024 **Acceptance Date:** January 10th, 2025 **Pub. Date:** August 31st, 2025
Online First Date: August 15th, 2025

Abstract

Objectives: In individuals with prolonged background noise exposure and those with peripheral auditory problems, central auditory disorders and cognitive impairments are observed. This study aims to evaluate individuals with and without noise exposure via the Matrix test to reveal concrete indicators of noise effects that are not reflected in pure-tone audiometry results.
Material and Methods: The study included 40 participants between the ages of 22 and 45 with and without a history of noise-exposure divided into control and study groups (n = 20 per group). All participants were administered pure-tone audiometry with high-frequency, speech audiometry, tympanometry, and Matrix tests. The Matrix test performed adaptive measurements in the open-set response format; the participant verbally repeated all the words from a presented sentence.
Results: In the tests performed on the study and control groups, no significant difference was found between the two groups except for the Matrix test.
Conclusions and Significance: Although the audiological results of the individuals exposed to noise were considered normal, their speech discrimination ability in noise deteriorated. Even individuals with normal hearing thresholds in pure-tone audiometry could have trouble with speech discrimination in noisy everyday environments. While evaluating these individuals, testing speech discrimination in noise is critical to show problems in daily life.

Keywords: *speech audiometry, speech recognition in noise, noise exposure, matrix sentence test*

[1]**Büşra Kaynakoğlu (Corresponding Author).** (Selçuk University, Faculty of Health Science, Department of Audiology, Konya-Türkiye, P: +903322416211, e-mail: busra.kaynakoglu@selcuk.edu.tr, ORCID: 0000-0003-0528-1086)
[2]**Betül Çiçek Çınar.** (Hacettepe University, Faculty of Health Science, Department of Audiology, Ankara-Türkiye, P: +903123051667, e-mail: betulcicek01@gmail.com, ORCID: 0000-0002-6570-9876)
[3]**Meral Didem Türkyılmaz.** (Hacettepe University, Faculty of Health Science, Department of Audiology, Ankara-Türkiye, P: +903123051667, e-mail: didemcanatan@yahoo.com, ORCID: 0000-0001-5719-2355)

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 2, 2025
Doi: 10.21020/husbfd.1435195

Introduction

Speech perception is a process that plays a significant role in maintaining communication and combines linguistic and acoustic cues. Speech perception varies depending on many factors; peripheral and central auditory processing involves the acoustic characteristics of the listening environment; the type, level, and amount of reverberation of background noise; the predictability of the speech material; and the speaker's speaking speed accent, and clarity; among other factors (Lucks Mendel & Widner, 2016; Vijayasarathy et al., 2021). Speech perception amid noise is as challenging for individuals with normal hearing as it is for those with hearing problems (Moossavi et al., 2021). When speech is presented against background noise, individuals with normal hearing often benefit from temporary signal-to-noise ratio (SNR) improvements. When the signals fluctuate, sometimes the level of speech is higher than the noise, thus allowing the listener to hear the message. The listener's understanding of language in terms of vocabulary, ability to identify consonants, words, or sentences, understanding of the context, and hearing sensitivity all take an active role in their speech perception (Vijayasarathy et al., 2021).

In individuals with prolonged background noise exposure and those with peripheral auditory problems, central auditory disorders and cognitive impairments are observed. Background noise, whether composed of speech or nonspeech sounds, damages speech signals and affects important bottom-up processing cues necessary for accurate speech perception. Additionally, background noise reduces working memory capacity, making it more difficult to understand speech (Rudner et al., 2012). With industrial noise levels increasing (Bellomo et al., 2021), many individuals have begun to experience increased noise exposure. Many individuals have begun to experience increased noise exposure. With this exposure, auditory problems that may or may not be reflected in the audiogram appear in people. Noise exposure makes it difficult to understand others' speech in noisy settings, creating attention deficits and concentration problems. In a review article, Plack et al. (2014) argued that although there is no direct evidence of noise-induced deficits in humans, there is some evidence that individuals exposed to noise with normal or near-normal hearing thresholds report deficits in complex discrimination tasks (Plack et al., 2014).

Pure tone audiometry is the gold standard in audiology for evaluating hearing. This test, which is highly important in determining hearing sensitivity at specific frequencies, must be revised, especially when identifying speech perception in noise. Routine tests continuously evaluate patients' hearing sensitivity and speech perception in quiet environments. However, these tests do not provide information on speech perception in noise (Lucks Mendel & Widner, 2016). The speech perception in noise ability can be measured in various ways. Speech perception in noise tests is used to assess speech reception threshold and SNR loss in noise (Bellomo et al., 2021).

The hearing health of occupational populations exposed to noise is subject to superficial assessment. If hearing problems occur in humans without noise-induced hearing loss, it is important to consider how noise-exposed workers develop a condition prior to permanent threshold shifts. Indeed, it has been documented that noise-exposed workers with normal hearing have difficulty understanding speech under difficult listening conditions despite having normal hearing thresholds (Soalheiro et al., 2012). Identifying the source of the problem in noise-exposed workers may be key for prevention programs in this population (Pinsonnault-Skvarenina et al., 2022). Also, different studies on animals and humans have determined the auditory impairments caused by noise exposure, which creates the need to evaluate different tests, especially on speech intelligibility in noise (Moshammer et al., 2015; Sliwinska-Kowalska, 2020).

This study aims to reveal noise effects not reflected in pure tone audiometry results by evaluating the speech perception in quiet and noise of normal-hearing factory workers with noise exposure and normal-hearing individuals without noise.

Materials and Method

The ethics committee approved it with the permission of the Hacettepe University Non-Interventional Clinical Research Ethics Committee, accepted number: GO 18/135-26 and dated 10/04/2018. The research was completed in accordance with the Helsinki Declaration. Informed consent was obtained from all individual participants included in the study. The sample size was calculated as 34 participants with a power of 95% and a margin of error of 0.05, taking into account the results of the study conducted by Kumar et al. (Kumar et al., 2012) with the G*Power 3.1.9.4 (Universitat Düsseldorf) package for normal-hearing noise-exposed and non-exposed individuals.

The study included 40 participants between the ages of 22 and 45 with and without a history of noise exposure, divided into control and study groups (n = 20 per group). The primary inclusion criteria were having pure-tone thresholds of 125–8000 Hz in the normal range and no neurological or psychiatric conditions.

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 2, 2025
Doi: 10.21020/husbfd.1435195

The study group (1 Woman, 19 Men) was selected from individuals working in the machine industry. These participants had noise exposure of ≥85 dB (A) for ≥5 hours per day. A noise level of ≥85 dB (A) is between "threatening" and "assumed safe noise," according to the duration and intensity of exposure (Eggermont, 2017). The exposed noise levels of the participants were learned through the self-interview. The study group was selected from high school and university graduates who did not use ear protectors. The inclusion criteria for the study group was a minimum of 5 hours and a maximum of 10 hours/day of noise exposure at an equal distance to each ear. The duration of noise exposure was a mean of 10.1±5.09 years. More specifically, these individuals were regularly exposed to industrial or ambient workplace noise. The control group (5 Women, 15 Men) was determined by a self-interview that determined their exposure to noise among students or academicians. Reaching university graduates in the control group without noise exposure was easier.

Audiometry

Pure-tone audiometry with a high frequency (0.25–16 kHz), traditional speech audiometry, tympanometry, and Matrix tests were administered to all 40 participants in a sound-proof room. Air-conduction hearing thresholds were determined using the supra-aural earphones (125–8000 HZ). Bone-conduction hearing thresholds were assessed with a bone vibrator (500–4000 Hz). The circumaural headphones determined high-frequency hearing within 9–16 kHz. In the traditional speech audiometry test, SRT was ±10 dB of each ear's pure-tone average (PTA) speech level. SDS, a phonetically balanced single-syllable 25-word list, was presented at SRT+40 dB. For each non-repeating word, the score is reduced by 4 points (normal value range: 88–100%). Middle ear pressure was evaluated with a GSI Tympstar Pro device at the 226 Hz probe tone.

Turkish Matrix Test

The Matrix test was performed through circumaural headphones using the software "Oldenburg Measurement Applications." The adaptive test determined 50% speech reception threshold (SRT) SNR in noise. The first sentence was presented to the individual at 0 dB SNR, and the software automatically changed the speech stimulus level according to the client's responses. According to the procedure, if the individual could repeat three out of five words presented, the speech intensity level decreased; if the number of repeated words was less than three, the speech stimulus level increased in the next sentence. These conditions determined the SNR at which 50% of the stimuli could be correctly detected—the non-adaptive test calculated speech intelligibility (SI) at a fixed signal-to-noise ratio of 0 dB. Based on the number of

Doi: 10.21020/husbfd.1435195

correctly repeated words, speech intelligibility was determined as a percentage score. The test results were automatically presented on the screen by the software. The matrix test performed adaptive measurements in an open set response format; the participant orally repeated all the words in a presented sentence. Each sentence contained five words, one from each word category (noun, numeral, adjective, object, verb). The test was explained to the participants in detail before they started the test. All participants were administered all four subtests with or without noise. The practice test was performed bilaterally in a quiet environment with 20 randomly selected sentences at a constant level of 40 dB. This test was generally used in this study to establish a baseline for binaural speech discrimination. The second test was performed binaurally with 20 randomly selected sentences at a fixed noise level of 65 dB SPL. Starting at 0 dB SNR and 65 dB SPL constant noise level, the procedure iterated the estimation of the presentation level at which 50% of the presented words were understood. The SNR value was indicated as positive or negative compared to 0 dB. In the third test, both ears were evaluated monaurally at a constant noise level of 65 dB SPL. SNR was determined by increasing or decreasing the stimulus level according to the number of correctly recognized words at a constant noise level of 65 dB SPL. This test was performed with 20 randomly selected sentences for each ear. SNR was obtained at adaptive speech levels. The fourth and final test was performed singly with 30 randomly selected sentences. SRT was determined based on responses at the test baseline stimulus level of 20 dB SPL.

Statistical Analysis

Before data analysis, the related variables were evaluated for compatibility with normal distribution to determine the statistical method to be used. The Kolmogorov–Smirnov and Shapiro–Wilk tests were used with SPSS at this stage. A p-value of 0.05 was considered to be significant. "Unpaired t-test," "the Paired Sample t-test," and "One Way ANOVA" tests were used from parametric methods for variables where the data set complied with normal distribution. "Mann-Whitney U," "Kruskal Wallis," and "Wilcoxon" tests were used from non-parametric methods for variables where the data set did not adapt to normal distribution. The significance level is considered $p<0.05$ for all analyses.

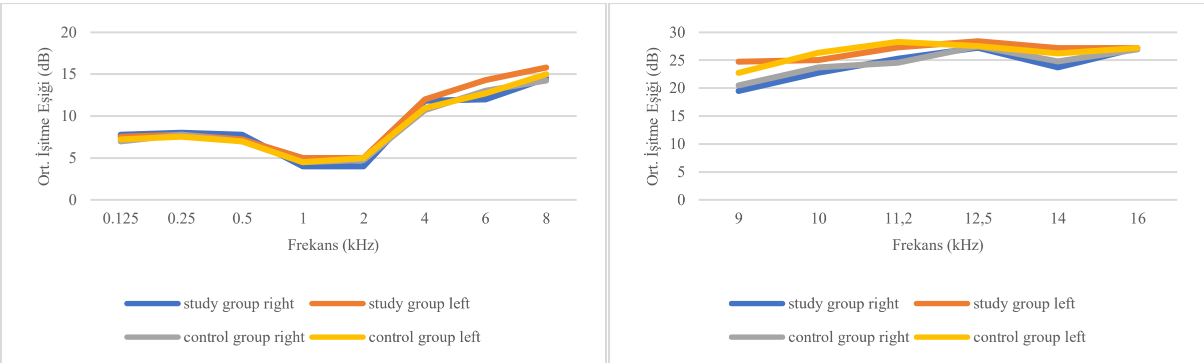
Results

The average age of the study group was 33.95 ± 7.66 years, and the average age of the control group was 33.4 ± 6.58 years. The average ages of the groups were statistically matched ($p = 0.98$; $p > 0.05$).

Doi: 10.21020/husbfd.1435195

In the study and control groups, the air-conduction thresholds (0.125–8 kHz) and bone-conduction thresholds (0.5–4 kHz) were better than 20 dB. There was no significant difference in PTA scores between the groups ($p = 0.76$; $p > 0.05$). There was no significant difference between the control and the study group compared to the hearing thresholds of 0.125-16 kHz ($p=0,98$; $p>0,05$) (Figure 1). For the high-frequency audiometry, the maximum output level for 18 kHz was 30 dB; for 20 kHz, it was 5 dB. At 18 kHz, only eight participants in both groups had hearing thresholds. At 20 kHz, only one participant's hearing threshold was detected in both groups. Due to the low number, the average values for 18 and 20 kHz were not calculated.

Figure 1. 0,125-16 kHz Hearing Threshold Averages of the Participants



All of the participants' SRT results were compatible with the participants' four frequency PTAs (0.5, 1, 2, and 4 kHz). The SDS test was performed at the most comfortable loudness level, and the participants' scores ranged from 88–100% (within the normal range). All participants in both groups had type A tympanogram and normal acoustic reflex thresholds. Binaural speech intelligibility in the quiet condition was 93% in the study group and 99% in the control group. Although these values were within normal levels, the difference was statistically significant ($p = 0.001$; $p < 0.01$).

Regarding speech intelligibility in binaural adaptive stimulus at a fixed noise level, the mean SNR value for the study group was -6.73 dB; it was -8.38 dB for the control group. These scores differed significantly ($p = 0.001$; $p < 0.01$). Similarly, the SNR values for the right and left ear when both stimulus and noise from the ipsilateral ear were present were statistically significant between the study and control groups ($p = 0.001$; $p < 0.01$). The SNR was lower in the control group than in the study group for both the right and left ears. However, within-group comparisons of the right and left ear had no statistically significant differences ($p = 0.106$;

Doi: 10.21020/husbfd.1435195

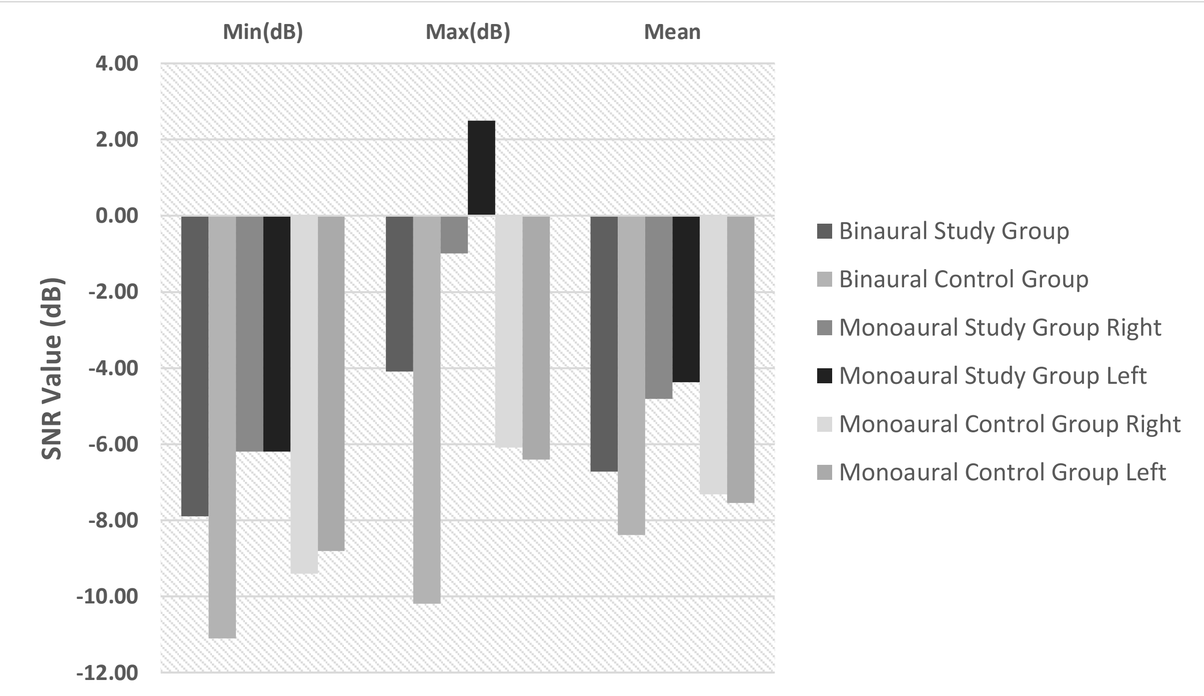
$p > 0.05$) (Figure 2). SNR results of tests performed adaptively in noise environments are shown in Table 1.

Table 1. SNR Results of the Tests Performed Adaptively in Noise Settings

	Group	Ear	N	Min(dB)	Max(dB)	X ± SD
Binaural Adaptive Procedure*	**Study group**	Binaural	20	−7.90	−4.10	−6.73 ± 0.93
	Control group	Binaural	20	−11.10	−10.20	−8.38 ± 4.46
Monaural Adaptive Procedure*	**Study group****	Right	20	−6.20	−1.00	−4.82 ± 1.09
		Left	20	−6.20	+2.50	−4.38 ± 1.83
	Control group**	Right	20	−9.40	−6.10	−7.31 ± 0.83
		Left	20	−8.80	−6.40	−7.54 ± 0.75

*$p = 0.001$; $p < 0.01$, **$p = 0.106$; $p > 0.05$

Figure 2. SNR Results of the Tests Performed Adaptively in Noise Settings



The SRT scores for monoaural adaptivity in the quiet test condition for both the right and left ears were lower in the control group than in the study group (Figure 3 and Table 2). This difference was statistically significant ($p = 0.001$; $p < 0.01$). However, there was no statistically significant difference between the left and right ears in the study or control groups.

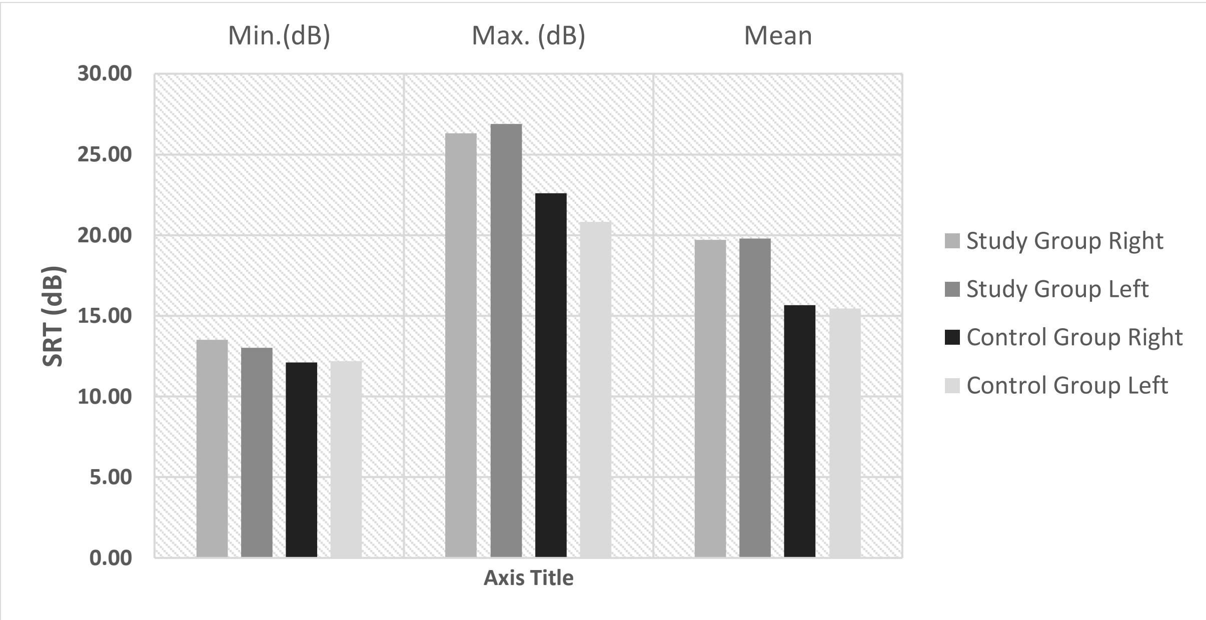
Doi: 10.21020/husbfd.1435195

Table 2. Monoaural Adaptive Procedure–SRT Scores (dB) in Quiet

Group	Ear	N	Min.(dB)	Max. (dB)	X ± SD
Study group	Right	20	13.50	26.30	19.70 ± 3.39
	Left	20	13.00	26.90	19.79 ± 3.39
Control group	Right	20	12.10	22.60	15.66 ± 2.58
	Left	20	12.20	20.80	15.45 ± 2.20

$p = 0.001$; $p < 0.01$

Figure 3. Monoaural Adaptive Procedure–SRT Scores (dB) in Quiet



There was no correlation between the Matrix test procedures and the duration of noise exposure and age ($p > 0.05$) (Table 3). There was only one female participant in the study group and five female participants in the control group; therefore, analyses of possible gender differences were not conducted. That said, Kollmeier et al. (2015) reported that gender did not affect speech intelligibility (Kollmeier et al., 2015).

Doi: 10.21020/husbfd.1435195

Table 3. Correlations Between Turkish Matrix Results and The Duration of Noise Exposure and Age

	Fixed Speech in Quiet (bin)	Adaptive Speech in Noise (bin)	Adaptive Speech in Noise(right)	Adaptive Speech in Noise (left)	Adaptive SRT in Quiet (right)	Adaptive SRT in Quiet (left)
Age (p)	0,395	0,574	0,908	0,118	0,703	0,420
Duration of Noise Exposure (p)	0,842	0,605	0,661	0,322	0,079	0,895

bin: binaural, $p > 0.05$

Discussion and Conclusion

The study tested the hypothesis that noise exposure affects the speech reception skills of adults with normal hearing thresholds. To reveal the effects of noise on auditory tests, especially in factory workers exposed to long-term noise exposure, and to evaluate the effect of noise exposure on speech intelligibility, standard audiological tests, and the Matrix test were administered, and the results of the study and control groups were compared.

The Matrix test mimics real-life environments to evaluate participants' speech discrimination. Sentences in the Matrix are composed of frequently used words in the correct grammatical order; this feature objectively reveals any difficulties that individuals with noise exposure may have with speech intelligibility (Kollmeier et al., 2015). Additionally, the test can produce a limitless number of sentences in the correct grammatical order, ensuring that the participant cannot learn the sentences rather than repeating what they hear (Yeend et al., 2017). There has been a partial difference in education between groups, even if it was not affected by the educational status and socio-economic level due to these features of the Matrix test results.

This study compared speech perception test results between two groups in quiet and noisy conditions. There was no significant difference between the groups regarding single-syllable word recognition scores in quiet settings. However, the two groups' speech discrimination scores differed significantly when the test material was changed to a sentence in one of the Matrix procedures. Phonemes, words, and sentences can be used as test material for speech discrimination tests. There is an increase in linguistic information when moving from phoneme to word and sentence as stimuli. Specifically, linguistic and contextual cues increase from phonemes to words and sentences; therefore, when phonemes are used in speech discrimination tests, linguistic and contextual information are removed, and real-life listening situations are not produced. Using sentences in speech discrimination tests includes more

Doi: 10.21020/husbfd.1435195

linguistic information and requires cognitive processing. Standard speech audiometry in a quiet condition mainly uses phonemes or words; however, real-life difficulties that individuals experience might be overlooked due to the test material and setting (Krueger et al., 2017).

In our study, high-frequency hearing thresholds were matched in the control and study groups, and although there was no difference between the two groups in hearing thresholds, 9-16 kHz hearing thresholds were lower than 0.125-8 kHz. This result is consistent with the findings that noise-induced hearing loss occurs in the basal part of the cochlea (Fernandez et al., 2015; Liberman et al., 2016). It should also be shown that the effects of noise are revealed by applying high-frequency audiometry as well as conventional audiometry to factory workers exposed to noise. In addition, Liberman et al. show that high-frequency hearing thresholds are not associated with speech perception performance in any listening situation in this study on young adults divided into two groups, low-risk and high-risk, according to noise exposure (Liberman et al., 2016).

Similarly, the results from the current study revealed that even though average pure-tone threshold and normal speech discrimination scores with single-syllable words, in participants with a history of noise exposure, the speech discrimination scores decreased in the speech discrimination test featuring sentences. This situation can be attributed to noise exposure, education level, and age (Carcagno & Plack, 2020; Plack et al., 2014). The education levels and ages of the participants were selected closely together. However, due to the control group of students and academicians, their cognitive functions may work more actively. This may be the main reason for the difference between the groups. Also, due to the Matrix test's structural characteristics, results are thought to be minimally affected by these differences. One study stated that factors other than sensory processing may be effective on speech perception in noise. These factors may include education and cognitive factors such as working memory, attention, and language capacities (DiNino et al., 2022; Pienkowski, 2017). Future studies should control for cognitive abilities when interpreting speech perception in noise performance in individuals with occupational noise exposure (Pinsonnault-Skvarenina et al., 2022).

In the literature, there has been no association between lifetime noise exposure and speech perception in noise performance in audiometrically normal young adults (Fulbright et al., 2017; Grose et al., 2017; Shehabi et al., 2022; Smith et al., 2019). However, it has been argued that exposure negatively affects speech perception in noise when there is more noise exposure. This poor performance may be due to undiagnosed noise-induced hearing loss (Shehabi et al., 2023). Consistent with our study's results, the study reported that young and middle-aged train drivers with normal hearing exhibited poorer speech recognition scores (using specialized sentences embedded in multi-talker babble noise) compared to an age-matched control group (Kumar et al., 2012). Vijayasarathy et al. (2021) reported that similarly, construction workers with normal hearing had significantly worse speech perception in noise scores (using bisyllabic words embedded in conversational background noise) than an age-matched control group exposed to minimal noise (Vijayasarathy et al., 2021).

In our study, there was no significant difference in the results between the right and left ear in speech comprehension tests that we performed adaptively in noisy and quiet environments. In the literature, it is reported that many people exhibit better recognition and discrimination skills for acoustic stimuli coming from the right ear (Roup, 2011; Sendesen et al., 2023; Tai & Husain, 2018). In Roup's (2011) study, right-handed and normal-hearing individuals were administered a dichotic word recognition test with monosyllabic words in noise and quiet. When word stimuli were presented to the right ear in noise and quiet, better results were obtained than when presented to the left ear (Roup, 2011). Another study reported that speech perception performance in noise was better in the right ear in individuals with normal hearing and tinnitus (Tai & Husain, 2018).

Speech perception problems in noise, which occur as a result of long-term occupational noise exposure, were reflected in the Matrix test results in our study. It has also been conveyed that noise exposure affects speech perception in quiet and noise, possibly due to difficult listening tasks. These results suggest that standard audiologic tests are insufficient to assess the consequences of noise exposure, and additional procedures are needed. Furthermore, it is emphasized that cognitive characteristics may affect speech perception in noise, but this should be further investigated in future studies. To objectively demonstrate the effect of noise exposure on speech perception, it is thought that age, gender, and educational status should be matched exactly, and the number of participants should be increased.

Declaration Of Interest Statement

The authors report that there are no competing interests to declare.

Financial Support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Doi: 10.21020/husbfd.1435195

References

Bellomo, T. R., Prasad, S., Abou-Hanna, J., Talluru, S., Xie, Y., Wang, L., . . . Neitzel, R. L. (2021). Characterization of noise exposure in places of worship. _Applied Acoustics_, _180_, 108114. https://doi.org/https://doi.org/10.1016/j.apacoust.2021.108114

Carcagno, S., & Plack, C. J. (2020). Effects of age on electrophysiological measures of cochlear synaptopathy in humans. _Hearing Research_, _396_, 108068. https://doi.org/https://doi.org/10.1016/j.heares.2020.108068

DiNino, M., Holt, L. L., & Shinn-Cunningham, B. G. (2022). Cutting through the noise: noise-induced cochlear synaptopathy and individual differences in speech understanding among listeners with normal audiograms. _Ear and Hearing_, _43_(1), 9-22. https://doi.org/10.1097/AUD.0000000000001147

Eggermont, J. J. (2017). Effects of long-term non-traumatic noise exposure on the adult central auditory system. Hearing problems without hearing loss. _Hearing Research_, _352_, 12-22. https://doi.org/https://doi.org/10.1016/j.heares.2016.10.015

Fernandez, K. A., Jeffers, P. W., Lall, K., Liberman, M. C., & Kujawa, S. G. (2015). Aging after noise exposure: acceleration of cochlear synaptopathy in "recovered" ears. _Journal of Neuroscience_, _35_(19), 7509-7520. https://doi.org/https://doi.org/10.1523/JNEUROSCI.5138-14.2015

Fulbright, A. N., Le Prell, C. G., Griffiths, S. K., & Lobarinas, E. (2017). Effects of recreational noise on threshold and suprathreshold measures of auditory function. _Seminars in Hearing_, _38_(4), 298–318. https://doi.org/10.1055/s-0037-1606325

Grose, J. H., Buss, E., & Hall Iii, J. W. (2017). Loud music exposure and cochlear synaptopathy in young adults: Isolated auditory brainstem response effects but no perceptual consequences. _Trends in Hearing_, _21_, 2331216517737417. https://doi.org/https://doi.org/10.1177/2331216517737417

Kollmeier, B., Warzybok, A., Hochmuth, S., Zokoll, M. A., Uslar, V., Brand, T., & Wagener, K. C. (2015). The multilingual matrix test: Principles, applications, and comparison across languages: A review. _International Journal of Audiology_, _54_(sup2), 3-16. https://doi.org/https://doi.org/10.3109/14992027.2015.1020971

Krueger, M., Schulte, M., Zokoll, M. A., Wagener, K. C., Meis, M., Brand, T., & Holube, I. (2017). Relation between listening effort and speech intelligibility in noise. _American Journal of Audiology_, _26_(3S), 378-392. https://doi.org/https://doi.org/10.1044/2017_AJA-16-0136

Kumar, U. A., Ameenudin, S., & Sangamanatha, A. (2012). Temporal and speech processing skills in normal hearing individuals exposed to occupational noise. _Noise and Health_, _14_(58), 100. https://doi.org/https://doi.org/10.4103/1463-1741.97252

Liberman, M. C., Epstein, M. J., Cleveland, S. S., Wang, H., & Maison, S. F. (2016). Toward a differential diagnosis of hidden hearing loss in humans. _PLoS One_, _11_(9), e0162726. https://doi.org/https://doi.org/10.1371/journal.pone.0162726

Lucks Mendel, L., & Widner, H. (2016). Speech perception in noise for bilingual listeners with normal hearing. _International Journal of Audiology_, _55_(2), 126-134. https://doi.org/https://doi.org/10.3109/14992027.2015.1061710

Moossavi, A., Mehrkian, S., Gohari, N., Nazari, M. A., Bakhshi, E., & Alain, C. (2021). The effect of harmonic training on speech perception in noise in hearing-impaired children. _International Journal of Pediatric Otorhinolaryngology_, _149_, 110845. https://doi.org/https://doi.org/10.1016/j.ijporl.2021.110845

Moshammer, H., Kundi, M., Wallner, P., Herbst, A., Feuerstein, A., & Hutter, H.-P. (2015). Early prognosis of noise-induced hearing loss. _Occupational and Environmental Medicine_, _72_(2), 85-89. https://doi.org/https://doi.org/10.1136/oemed-2014-102200

Pienkowski, M. (2017). On the etiology of listening difficulties in noise despite clinically normal audiograms. _Ear and Hearing_, _38_(2), 135. https://doi.org/https://doi.org/10.1097/aud.0000000000000388

Pinsonnault-Skvarenina, A., Moïn-Darbari, K., Zhao, W., Zhang, M., & Qiu, W. (2022). No effect of occupational noise exposure on auditory brainstem response and speech perception in noise. _Frontiers in Neuroscience_, _16_, 915211. https://doi.org/https://doi.org/10.3389/fnins.2022.915211

Plack, C. J., Barker, D., & Prendergast, G. (2014). Perceptual consequences of "hidden" hearing loss. _Trends in Hearing_, _18_, 2331216514550621. https://doi.org/https://doi.org/10.1177/2331216514550621

Roup, C. M. (2011). Dichotic word recognition in noise and the right-ear advantage. https://doi.org/https://doi.org/10.1044/1092-4388(2010/09-0230)

Rudner, M., Lunner, T., Behrens, T., Thorén, E. S., & Rönnberg, J. (2012). Working memory capacity may influence perceived effort during aided speech recognition in noise. _Journal of the American Academy of Audiology_, _23_(08), 577-589. https://doi.org/https://doi.org/10.3766/jaaa.23.7.7

Sendesen, E., Colak, H., Korkut, Y., Yalcınkaya, E., & Sennaroglu, G. (2023). The right ear advantage–a perspective from speech perception in noise test. _Hearing, Balance and Communication_, 1-6. https://doi.org/https://doi.org/10.1080/21695717.2023.2181562

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 2, 2025
Doi: 10.21020/husbfd.1435195

Shehabi, A. M., Prendergast, G., Guest, H., & Plack, C. J. (2022). The effect of lifetime noise exposure and aging on speech-perception-in-noise ability and self-reported hearing symptoms: An online study. *Frontiers in Aging Neuroscience*, *14*, 890010. https://doi.org/https://doi.org/10.3389/fnagi.2022.890010

Shehabi, A. M., Prendergast, G., Guest, H., & Plack, C. J. (2023). Noise Exposure in Palestinian Workers Without a Diagnosis of Hearing Impairment: Relations to Speech-Perception-in-Noise Difficulties, Tinnitus, and Hyperacusis. *Journal of Speech, Language, and Hearing Research*, *66*(3), 1085-1109. https://doi.org/https://doi.org/10.1044/2022_JSLHR-22-00461

Sliwinska-Kowalska, M. (2020). New trends in the prevention of occupational noise-induced hearing loss. *International Journal of Occupational Medicine and Environmental Health*, *33*(6), 841-848. https://doi.org/http://dx.doi.org/10.13075/ijomeh.1896.01600

Smith, S., Krizman, J., Liu, C., White-Schwoch, T., Nicol, T., & Kraus, N. (2019). Investigating peripheral sources of speech-in-noise variability in listeners with normal audiograms. *Hearing Research*, *371*, 66-74. https://doi.org/https://doi.org/10.1016/j.heares.2018.11.008

Soalheiro, M., Rocha, L., do Vale, D. F., Fontes, V., Valente, D., & Teixeira, L. R. (2012). Speech recognition index of workers with tinnitus exposed to environmental or occupational noise: a comparative study. *Journal of Occupational Medicine and Toxicology*, *7*(1), 1-8. https://doi.org/https://doi.org/10.1186/1745-6673-7-26

Tai, Y., & Husain, F. T. (2018). Right-ear advantage for speech-in-noise recognition in patients with nonlateralized tinnitus and normal hearing sensitivity. *Journal of the Association for Research in Otolaryngology*, *19*, 211-221. https://doi.org/https://doi.org/10.1007/s10162-017-0647-3

Vijayasarathy, S., Mohan, M., Nagalakshmi, P., & Barman, A. (2021). Speech perception in noise, gap detection and amplitude modulation detection in suspected hidden hearing loss. *Hearing, Balance and Communication*, *19*(3), 203-211. https://doi.org/https://doi.org/10.1080/21695717.2021.1876494

Yeend, I., Beach, E. F., Sharma, M., & Dillon, H. (2017). The effects of noise exposure and musical training on suprathreshold auditory processing and speech perception in noise. *Hearing Research*, *353*, 224-236. https://doi.org/https://doi.org/10.1016/j.heares.2017.07.006