






RESEARCH ARTICLE

The effects of noise exposure and work-related fatigue on the acceptable noise level test in normal-hearing people

Nafiseh Heidari¹, Ahmad Geshani^{1,2*}, Nematollah Rouhbakhsh¹, Elham Faghihzadeh³,
Mohammad Alishahi⁴

¹- Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran

²- Department of Audiology, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

³- Department of Biological Statistics and Epidemiology, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran

⁴- Department of Occupational Medicine, Iran Khodro Company, Tehran, Iran

Received: 14 Nov 2020, Revised: 17 Dec 2020, Accepted: 1 Jan 2021, Published: 15 Apr 2021

Abstract

Background and Aim: The acceptable noise level (ANL) assesses the noise that a person can tolerate during a running speech. Although it is a strong test, it has not yet become popular in clinical practice. One of the reasons is its contradictory results. Since it is a psychoacoustic test, psychological factors can affect its output. Investigation of these factors can provide more accurate results. This study aims to investigate the effects of noise and work-related fatigue on the ANL in normal-hearing people.

Methods: Participants were the male workers in the administration (n = 26) and production (n = 26) departments of an automotive manufacturing industry in Iran. They were evaluated before and after leaving the workplace in order to determine the effects of noise exposure, fatigue as well as their simultaneous effects on the ANL.

Results: In both groups, the ANL showed a significant increase after work compared to its level before work, and the background noise level (BNL) was significantly decreased. There

was no significant difference in the BNL between administration and production groups before work. The most comfortable level (MCL) showed no significant increase. Moreover, the MCL changes were not significantly different in the production group compared to administration group, but the BNL and ANL changes were significantly higher.

Conclusion: Noise exposure and work-related fatigue affect the ANL. During the ANL test, earlier exposure to noise and the amount of fatigue should be controlled.

Keywords: Exposure to noise; fatigue; acceptable noise level

Citation: Heidari N, Geshani A, Rouhbakhsh N, Faghihzadeh E, Alishahi M. The effects of noise exposure and work-related fatigue on the acceptable noise level test in normal-hearing people. *Aud Vestib Res.* 2021;30(2).

Introduction

Acceptable noise level (ANL) test, developed by Nabelek et al. (1991), is used to assess the maximum amount of background noise that a person can tolerate when listening to a story without tiredness [1,2]. ANL is defined as the dB difference between most comfortable

* **Corresponding author:** Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Piche-Shemiran, Enghelab Ave., Tehran, 1148965141, Iran. Tel: 009821-77530636, E-mail: agheshani@tums.ac.ir

listening level (MCL) for running speech and the maximum background noise level (BNL) that a listener is willing to tolerate when pursuing the running speech ($ANL = MCL - BNL$) [2]. This test includes a running speech and a multi-talker speech babble [2]. Ahmadi et al. developed the Persian version of ANL test and used it on 166 normal-hearing people [3]. It has been reported that ANL is linked to the patterns of hearing aid use [2]. Hence, the people with low ANL (< 7) are probably the successful and full-time users of hearing aids, while people with midrange ANL (between 7 and 13) may be either successful or unsuccessful users, and those with high ANL (> 13), are likely to become unsuccessful users who will never use their hearing aids [2]. In spite of fundamental studies on the ANL test scope and being a strong test, it has not yet become a common method in clinical practice. Few studies have recently presented some evidence of inadequate ANL test results in predicting patterns of hearing aid use and in evaluating the ability of individuals for efficient hearing aid use [4]. One of the disadvantages of this test is its extensive score range. According to some recent studies, repeatability and reliability of this test are poor for normal-hearing people and those with hearing loss [4,5]. For this test, different studies have reported various and extensive average values and ranges. These extensive ranges have led to great variability in the findings [4-6]. Although this variability has been noticed by the researchers [1,6,7], it has not been yet determined precisely. One reason is that the level of acceptable noise is taken into account, instead of considering a range of acceptable noise; as a result, the listener selects one of the numbers in the range under one test and the other number under other test [6].

The effects of central auditory system on the variability of acceptance BNL have been reported in different studies [1]. For example, Brännström et al. reported a positive strong relationship between working memory capacity (WMC) and the BNL [8]. Psychological factors also affect the ANL. For example, people with higher self-control ability (for emotions,

thoughts and performance) have lower ANL compared to people with lower self-control ability [9]. It is expected that factors such as fatigue which influences performance and self-control, affect the ANL. As a psychoacoustic measure, it can also be affected by psychological factors such as fatigue. On the other hand, exposure to noise can have negative psychological consequences including fatigue, annoyance, stress, etc [5,6,10]. Some non-auditory factors whose effects have been less studied are arousal stress response, sleep disorders, fatigue, irritability, decreased noise tolerance, annoyance, memory impairment, impaired concentration, attention deficit, and decreased cognitive function [6,10-13]. In other words, it is expected that exposure to noise affects the ANL test results. Considering the above-mentioned materials, the present study aims to assess the effect of noise and work-related fatigue in clarifying the existing ambiguities in the ANL test results. The main hypothesis of this study is that, since noise and fatigue influence main abilities and cognitive function of people, they can also affect their ANL.

Methods

The current study protocol has been approved by the Research Ethics Committee of Tehran University of Medical Sciences (Code: IR.TUMS.FNM.REC.1397.095). It was conducted in Iran Khodro Company in Tehran, Iran. In the first step, the factory was visited and the background noise amount in different departments was assessed. The sections which met the required criteria for Administration and Production Departments were determined: Production Department ($55 < Leq \text{ dB A} < 85$) and Administration Department ($Leq \text{ dB A} < 55$). Participants were 26 male workers in the Production Department and 26 male workers in the Administration Department, who were selected using a convenience sampling method and based on the inclusion criteria. They had normal hearing ($\leq 25 \text{ dB HL}$) with a frequency of 250–8000 Hz [14] aged 18–50 years. The inclusion criteria were: being right-handed based on the Edinburgh handedness inventory [15], the ability to

write and read, being Persian monolingual, normal external and middle ear based on otoscopic examination, normal tympanogram (Type An, static admittance of 0.27–2.8 mmho, and peak pressure of +50 to –100 dapa) [16], normal acoustic reflex threshold (in the range of 70–100 dB HL) [17], no tinnitus and hyperacusis, not using medications that can affect the central nervous system, no history of head trauma/brain surgery/brain and nervous systems problems, and not using substances and psychedelic drugs. Leaving the study or having temporary threshold shift (TTS) results after exposure to noise, were the exclusion criteria. After selecting samples, the study objectives and methods were explained to them.

In order to avoid noise-induced hearing loss and the effect of wearing a hearing protector in the workers on the study results, workshops with a noise level less than the action level were selected, since these levels were less vulnerable to TTS and did not need to use hearing protector devices. Evaluation of hearing status and the ANL test was performed by using the Madsen ORBITER 922 audiometer (Natus Medical Inc., Denmark). Moreover, middle ear examination was performed by using the Madsen DANPLEX tympanometer (Natus Medical Inc., Denmark) and fatigue was evaluated using the Multidimensional Fatigue Inventory (MFI). This questionnaire was developed by Smets et al. containing 20 items [18]. First, after assessing inclusion criteria and performing basic audiometric tests, the ANL test was performed and its results were recorded. After seven hours, hearing thresholds were re-evaluated. In case of no any change in hearing thresholds, compared to the baseline level, the ANL test was administered for the second time, and its results were recorded.

For running the ANL test, a CD/DVD player was connected to a 2-channel audiometer. A calibration signal was first presented by the player, and after assuring the calibration accuracy, it was used in order to run the test. After explaining the instructions to the subjects, the test was initiated. At the beginning, running speech signal was played at 30 dB HL using a

speaker placed at a 1-meter distance and on a 0-degree azimuth. Then, it was increased by 5 dB until the level that was reported too loud by the subject. After that, the signal level was reduced up to a level that was described too soft by the subject. In this stage, the signal level was increased by 2 dB until the subject described it as completely comfortable. This level was noted as the MCL. Then, the noise was presented at 30 dB HL using the same speaker while the running speech signal was continued to be presented at the MCL. The level of presented noise increased by 5 dB HL up to a level that the subject found it as untraceable. After that, the noise level was reduced by 5 dB up to a level that the subject described it as completely clear. Finally, the noise level increased by 2 dB up to a level that the subject could follow the running speech signal beside the receiving noise. This level was recorded as the BNL. ANL was obtained by subtracting the BNL from the MCL [2].

For completion of the MFI questionnaire, the examiner first explained to the subjects that, by using this questionnaire, their feelings and conditions would be assessed after leaving the workplace compared to the conditions before leaving the workplace. Then, the subjects were asked to choose the items that describe their conditions. The MFI items are rated on a 5-point Likert scale ranging from “Yes, that is true”, to “No, that is not true”. Some of the items have reversed scoring (items 2, 5, 9, 10, 13, 14, 16, 17, 18, 19). In order to assess the total score of the MFI, the scores of all items were summed up. The total score ranges from 20 to 100, where a higher score indicates more fatigue [18,19].

The data were analyzed using statistical tests, including Wilcoxon test, Mann-Whitney U test, and Spearman correlation test in SPSS v.19 software, considering a significance level of 0.05. The MCLs, BNLs and ANLs were compared between two groups of workers at the production and administration departments before and after work, using the nonparametric Wilcoxon test. The mean scores of MCL, BNL and ANL were calculated in two groups and compared using the nonparametric Mann-Whitney U test. In order to assess the effect of

Table 1. The comparison between the mean scores of most comfortable, background noise, and acceptable noise levels in two groups

Variables	Administration Department		Production Department		p	Power
	Mean (SD)	Median	Mean (SD)	Median		
MCL before work (dB HL)	43.69 (2.75)	44.00	43.69 (3.82)	44.00	0.956	0.80
MCL after work (dB HL)	43.76 (2.67)	44.00	43.84 (3.91)	44.00	0.860	0.82
MCL changes (dB HL)	0.07 (0.39)	0.00	0.15 (0.54)	0.00	0.556	0.81
BNL before work (dB HL)	42.92 (3.16)	44.00	41.53 (3.80)	41.00	0.168	0.80
BNL after work (dB HL)	42.30 (3.60)	43.00	40.00 (3.79)	40.00	0.032	0.80
BNL changes (dB HL)	-0.61 (0.94)	0.00	-1.69 (1.08)	-2.00	0.001	0.82
ANL before work (dB HL)	0.76 (1.50)	0.00	2.15 (1.48)	2.00	0.002	0.91
ANL after work (dB HL)	1.46 (1.92)	2.00	3.84 (1.25)	4.00	0.000	0.95
ANL changes (dB HL)	0.69 (0.97)	0.00	1.69 (1.22)	2.00	0.003	0.93

MCL; most comfortable level, BNL; background noise level, ANL; acceptable noise level

fatigue on the ANL test parameters categorized by study groups, Spearman correlation test was used which evaluates the relationship of MCL, BNL and ANL with fatigue (total MFI score).

Results

The mean age of participants was 40.3 ± 7.55 in the administration group and 39.76 ± 3.33 years in the production group. The mean noise level was reported 51.42 ± 1.13 dB A in the administration group and 79.78 ± 2.34 dB A in the production group. The lowest level of noise level was reported in the administration group (50 dB A). The mean total MFI score after work was 42.19 ± 6.20 in the administration group and 49.80 ± 8.72 in the production group. The comparison of total MFI score between two study groups showed that this score was significantly higher in the production group than in the administration group ($p = 0.00$). The mean scores of MCL, BNL and ANL were calculated in two groups and compared between them whose results are presented in Table 1. The MCL, BNL and ANL in two study groups were also compared before and after work. The results are presented in Table 2.

In order to evaluate the effect of work-related fatigue on the ANL test parameters categorized by group, the relationship of MCL, BNL and ANL with work-related fatigue (total MFI score) was assessed. The results are shown in Table 3. As can be seen, there was no significant correlation between the mean MCL and total MFI score in two groups, but a significant correlation was observed between the mean BNL and ANL changes and the total MFI score. According to Cohen, $r = 0.10 - 0.29$ indicates small effect size, $r = 0.30 - 0.49$ shows medium effect size, and $r = 0.50 - 1$ shows large effect size [20]; hence, the correlation between the MCL and total MFI score was small; between the BNL and total MFI score was medium; and between the ANL and total MFI score was large.

Discussion

Noise exposure can have non-auditory negative effects such fatigue, annoyance, stress, and psychological consequences. The ANL, due to being a psychoacoustic method, is affected by psychological factors such as noise-induced fatigue [5,8,10]. In this study, the effect of two

Table 2. The p values and powers of statistical comparison of acceptable noise level, background noise level, and most comfortable level in administration group (n = 26) and production group (n = 26) before and after work

Groups	Variables	P (comparison of before and after work)	Power
Administration	MCL (dB HL)	0.317	0.82
	BNL (dB HL)	0.005	0.81
	ANL (dB)	0.003	0.92
Production	MCL (dB HL)	0.157	0.81
	BNL (dB HL)	0.000	0.82
	ANL (dB)	0.000	0.80

MCL; most comfortable level, BNL; background noise level, ANL; acceptable noise level

variables, noise and work-related fatigue, were assessed on 26 workers of administration department and 26 workers of production department in an automotive manufacturing industry. Based on the results, noise and fatigue increased the ANL and reduced the BNL. The MCL in production and administration groups did not change significantly after exposure to noise and fatigue.

In different studies, contradictory results have been reported for the ANL test [4-6]. For example, in Freyaldenhoven et al.'s study on normal-hearing people, the mean ANL was 12.9 ± 5.2 dB, ranging from 4 to 24 dB [7]. Brännström et al., in a study on 32 adults with normal-hearing, assessed the effect of a number of repetitive stimuli causing fatigue on the MCL under the ANL test, and also the relationship between the MCL and the cognitive processes. They measured phonological working memory (PWM), and found out that the MCL has negative relationship with PWM. This finding indicates the stability of the MCL under the ANL test [21], and no any change in MCL after repetitive stimulus presentation and subsequent fatigue. As a result, it is consistent with the results of the present study. In our study, the final MCL was determined by calculating the average values of three measures. This may decrease the change

in the MCL. One study showed that, due to the effect of presentation at the MCL on the ANL, the tests that use only one measure for the MCL can produce some bias [21]. In the present study, it seems that the use of three measures for determining MCL led to the removal of this bias. Although there were some changes in the MCL, these changes were not statistically significant. The use of recorded standard materials in the ANL test can increase the stability of MCL. In this study, the BNL and ANL significantly decreased and increased in two groups after exposure to the noise and or fatigue, respectively. Noise exposure can increase stress response, lead to increase in the stress hormone levels, and induces irritability, instability and poor concentration [22]. The changes in the production group after noise exposure in the workplace were significantly more than in the administration group, which may be because of the stronger effect of simultaneous fatigue and noise exposure rather than the effect of fatigue alone. Brännström et al. examined the effect of multiple measurements to obtain reliable ANL test data. They conducted four ANL tests in one session on 32 normal-hearing adults. It was observed that the mean ANL scores increased significantly from 4.7 to 5.6 dB, indicating a small but significant effect of fatigue on the ANL [6].

Table 3. The relationship between the changes in most comfortable, background noise, and acceptable noise levels and fatigue in both groups.

Group	Variables	Correlation coefficient	p
Administration	Mean MCL changes	0.21	0.293
	Mean BNL changes	-0.53	0.005
	Mean ANL changes	0.60	0.001
Production	Mean MCL changes	0.01	0.963
	Mean BNL changes	-0.53	0.005
	Mean ANL changes	0.54	0.004

MCL; most comfortable level, BNL; background noise level, ANL; acceptable noise level

This is consistent with the results of the current study. According to higher changes in the BNL and ANL in the production group compared to the administration group ($p < 0.05$), it was concluded that noise and work-related fatigue can result in more changes in these parameters. The relationship between these variables has also been reported in various studies [10,23]. One of the most important negative effects of noise exposure is fatigue [10,23], which can result in decreased noise tolerance [6]. In this study, these effects highly influenced the BNL and ANL, since there was a significant correlation between the total MFI score and the changes in these two parameters. A suitable time should be determined for performing the ANL test; it is not a good time for this test to be taken after exposure to noise or and work-induced fatigue.

One of basic applications of ANL is to predict the patterns of hearing aid use in hearing-impaired people. The results of this study can not be generalized to hearing-impaired people, because their noise perception is different from that of normal-hearing people. On the other hand, measurement of the ANL in hearing-impaired people is similar to the ones exposed to loud sound, because the hearing aid output level is usually high. Further study on hearing-impaired samples is recommended.

Furthermore, due to high difference in the ANL between normal-hearing and hearing-impaired people, all the factors affecting this result should be controlled so that higher satisfaction level in hearing aid users can be achieved.

Conclusion

Noise exposure and work-related fatigue can significantly increase the ANL and reduce the BNL in normal-hearing people. Their simultaneous effects can even lead to higher effects.

Acknowledgments

This paper is extracted from N. Heidari's MSc dissertation submitted to Tehran University of Medical sciences. We hereby sincerely thank the respected manager of Iran Khodro Company, especially the esteemed colleague of the Prevention, Treatment and Welfare Department and Occupational Medicine Department.

Conflict of interest

The authors declared no conflicts of interest.

References

1. Nabelek AK. Acceptance of background noise may be key to successful fittings. *Hear J.* 2005;58(4):10-15. doi: [10.1097/01.HJ.0000286602.38611.56](https://doi.org/10.1097/01.HJ.0000286602.38611.56)
2. Nabelek AK, Freyaldenhoven MC, Tampas JW, Burchfield SB, Muenchen RA. Acceptable noise level as a predictor of hearing aid use. *J Am Acad Audiol.* 2006; 17(9):626-39. doi: [10.3766/jaaa.17.9.2](https://doi.org/10.3766/jaaa.17.9.2)

3. Ahmadi A, Fatahi J, Keshani A, Jalilvand H, Modarresi Y, Jalaie S. Developing and evaluating the reliability of acceptable noise level test in Persian language. *J Rehab Med.* 2015;4(2):109-17. Persian. doi: [10.22037/JRM.2015.1100032](https://doi.org/10.22037/JRM.2015.1100032)
4. Olsen SØ, Lantz J, Nielsen LH, Brännström KJ. Acceptable noise level (ANL) with Danish and non-semantic speech materials in adult hearing-aid users. *Int J Audiol.* 2012;51(9):678-88. doi: [10.3109/14992027.2012.692822](https://doi.org/10.3109/14992027.2012.692822)
5. Olsen SØ, Nielsen LH, Lantz J, Brännström KJ. Acceptable noise level: repeatability with Danish and non-semantic speech materials for adults with normal hearing. *Int J Audiol.* 2012;51(7):557-63. doi: [10.3109/14992027.2012.666362](https://doi.org/10.3109/14992027.2012.666362)
6. Brännström KJ, Holm L, Kastberg T, Olsen SØ. The acceptable noise level: the effect of repeated measurements. *Int J Audiol.* 2014;53(1):21-9. doi: [10.3109/14992027.2013.824116](https://doi.org/10.3109/14992027.2013.824116)
7. Freyaldenhoven MC, Smiley DF, Muenchen RA, Konrad TN. Acceptable noise level: reliability measures and comparison to preference for background sounds. *J Am Acad Audiol.* 2006;17(9):640-8. doi: [10.3766/jaaa.17.9.3](https://doi.org/10.3766/jaaa.17.9.3)
8. Brännström KJ, Zunic E, Borovac A, Ibertsson T. Acceptance of background noise, working memory capacity, and auditory evoked potentials in subjects with normal hearing. *J Am Acad Audiol.* 2012;23(7):542-52. doi: [10.3766/jaaa.23.7.6](https://doi.org/10.3766/jaaa.23.7.6)
9. Nichols AC, Gordon-Hickey S. The relationship of locus of control, self-control, and acceptable noise levels for young listeners with normal hearing. *Int J Audiol.* 2012;51(4):353-9. doi: [10.3109/14992027.2011.645074](https://doi.org/10.3109/14992027.2011.645074)
10. 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(9925):1325-32. doi: [10.1016/S0140-6736\(13\)61613-X](https://doi.org/10.1016/S0140-6736(13)61613-X)
11. Maxwell LE, Evans GW. The effects of noise on preschool children's pre-reading skills. *J Environ Psychol.* 2000;20(1):91-7. doi: [10.1006/jevp.1999.0144](https://doi.org/10.1006/jevp.1999.0144)
12. Frenzilli G, Ryskalin L, Ferrucci M, Cantafora E, Chelazzi S, Giorgi FS, et al. Loud noise exposure produces DNA, neurotransmitter and morphological damage within specific brain areas. *Front Neuroanat.* 2017;11:49. doi: [10.3389/fnana.2017.00049](https://doi.org/10.3389/fnana.2017.00049)
13. Kujala T, Brattico E. Detrimental noise effects on brain's speech functions. *Biol Psychol.* 2009;81(3):135-43. doi: [10.1016/j.biopsycho.2009.03.010](https://doi.org/10.1016/j.biopsycho.2009.03.010)
14. Roeser RJ, Clark JL. Pure-tone tests. In: Roeser RJ, Valente M, Hosford-Dunn H, editors. *Audiology diagnosis.* 2nd ed. New York: Thieme; 2007. p. 238-60.
15. Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia.* 1971; 9(1):97-113. doi: [10.1016/0028-3932\(71\)90067-4](https://doi.org/10.1016/0028-3932(71)90067-4)
16. Clark JL, Roeser RJ, Mendrygal M. Middle ear measures. In: Roeser RJ, Valente M, Hosford-Dunn H, editors. *Audiology diagnosis.* 2nd ed. New York: Thieme; 2007. p. 380-99.
17. Smets EM, Garssen B, Bonke B, De Haes JC. The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. *J Psychosom Res.* 1995;39(3):315-25. doi: [10.1016/0022-3999\(94\)00125-o](https://doi.org/10.1016/0022-3999(94)00125-o)
18. Najafi Mehri S, Pashandi S, Mahmoodi H, Ebadi A, Ghanei M. [Assessment of fatigue and spirometry parameters in chemical war victims with respiratory disease]. *Iranian Journal of War & Public Health.* 2010; 2(4):29-35. Persian.
19. Pallant J. *SPSS survival manual: a step by step guide to data analysis using IBM SPSS.* 7th ed. London: Routledge; 2020.
20. Brännström KJ, Olsen SØ, Holm L, Kastberg T, Ibertsson T. The effect of repeated measurements and working memory on the most comfortable level in the ANL test. *Int J Audiol.* 2014;53(11):787-95. doi: [10.3109/14992027.2014.938781](https://doi.org/10.3109/14992027.2014.938781)
21. Hahad O, Prochaska JH, Daiber A, Muenzel T. Environmental noise-induced effects on stress hormones, oxidative stress, and vascular dysfunction: key factors in the relationship between cerebrocardiovascular and psychological disorders. *Oxid Med Cell Longev.* 2019; 2019:4623109. doi: [10.1155/2019/4623109](https://doi.org/10.1155/2019/4623109)
22. Ryherd EE, Waye KP, Ljungkvist L. Characterizing noise and perceived work environment in a neurological intensive care unit. *J Acoust Soc Am.* 2008;123(2):747-56. doi: [10.1121/1.2822661](https://doi.org/10.1121/1.2822661)
23. Kristiansen J, Lund SP, Persson R, Shibuya H, Nielsen PM, Scholz M. A study of classroom acoustics and school teachers' noise exposure, voice load and speaking time during teaching, and the effects on vocal and mental fatigue development. *Int Arch Occup Environ Health.* 2014;87(8):851-60. doi: [10.1007/s00420-014-0927-8](https://doi.org/10.1007/s00420-014-0927-8)