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RESEARCH ARTICLE

Assessment of acceptable noise level in unilateral hearing aid users

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Abstract

Background and Aim: It is well known that hearing aid fitting is an effective approach to improve the communication ability of hearing-impaired people. In the past, most of the hearing aids were fitted unilaterally rather than bilaterally. Whereas the unilateral hearing aid fitting improves verbal communication partially, it causes late-onset auditory deprivation. The main aim of this study is to investigate the ANL for each ear among the users with unilateral hearing aid experience.

Methods: A total of 23 participants were recruited (14 females, 9 males). The mean age was 74.65 years (ranged from 41 to 83). All subjects had bilateral symmetric sensorineural hearing loss. The most comfortable level (MCL), Background Noise Level (BNL), and acceptable noise level (ANL) were measured for ear with amplification experience and ear without experience.

Results: MCL, BNL and ANL in the aided ear was 82.22, 73.48 and 8.74 respectively, in addition in the unaided ear the results for MCL, BNL and ANL was 81.78, 72.13 and 9.65 respectively. Comparing the mean values of MCL, BNL and ANL between two ears showed no significant difference.

Conclusion: There was not any difference for BNL and ANL measures

Keywords: Bilateral hearing loss; acceptable noise level; late onset auditory deprivation; Hearing aid

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Introduction

People with hearing impairments complain from poor function in voice recognition, speech recognition in noisy environments, and communication with others [1], localization [2], and lateralization. They also have problems such as tinnitus [3], hyperacusis [4], over-concentration fatigue [5], memory disorders [6], depression and Alzheimer's [7]. In 1999, over 68% of hearing aids provided in the USA were prescribed binaurally [8]. Except in a few cases, the use of binaural hearing aids is a priority [8]. The percentage of unilateral hearing aid prescriptions in Iran is significant and is due to financial problems, not covered by insurance, cultural problems, cosmetic issue, and binaural interference. The reasons that explain why binaural hearing in noise is better than monaural hearing in noise include head diffraction, which is a completely acoustic phenomenon [9], binaural squelch which means the time difference between messages being sent to the brain by the ears [10], and binaural redundancy, which shows the brain's ability to collect signals sent by the ears [11].

Using unilateral hearing aids in people with bilateral hearing impairment leads to late onset auditory deprivation (LOAD) on ear that does not use a hearing aid [12]. LOAD was first introduced in 1984 by Silman et al. This study showed that using unilateral hearing aids in people with bilateral hearing impairment leads to a decrease in the word recognition score (WRS) in the unaided ear [13]. In another study, the researchers found that the aided ear compared to the unaided ear showed a better recognition in the higher intensity than the unaided ear; it is noteworthy that the change in the perception of sound intensity was only at frequencies amplified by hearing aids [14]. Munro and Trotter studied the severity of uncomfortable loudness level (ULL) in people using unilateral hearing aid. All participants in the study had bilateral and symmetrical hearing impairment. The mean ULL in the two ears before the hearing aid was equal, but after the hearing aids prescription, the sound tolerance in the aided ear increased and showed a significant difference with the unaided ear. It is noteworthy that the difference was higher at higher frequencies in the area where the hearing aid had more amplification [15].

Walker et al. assumed that the acoustic reflex would also change, given the change in ULL in people who used unilateral hearing aids; previous studies have shown the relationship between ULL and acoustic reflexes [16]. This indicates that the use of unilateral hearing aid and the development of hearing loss not only affect recognition and perception of sound but may also affect the physiology of the auditory pathway. The result showed that the threshold of acoustic reflex was 2 to 9 dB higher than the other ear depending on the measured frequency. Given the overlap of the acoustic reflex pathway and the auditory brainstem response (ABR) [17], Munro et al., suggested that the use of unilateral hearing aids in people with bilateral hearing impairment may also affect ABR. All participants in this study had bilateral and symmetrical hearing impairment. Click responses in the ABR test in participants who did not use hearing aid, were similar in the two ears, but in participants with hearing aids, the mean amplitude of the peak to pick of the wave V to SN10 was higher in the amplified ear than in the other ear [18]. In another study, event-related potentials were investigated in a group of patients with sensorinaural hearing loss (SNHL) and symmetric hearing impairment. All participants in the study used unilateral hearing aids. The test continued with two different stimuli; the first stimulus consisted of low frequencies and the second stimulus consisted of higher frequencies; the results showed that at higher frequency and intensity stimulus, amplitude of N1-P2 in the aided ear was higher than that in the unaided ear but at lower intensities amplitude of N1-P2 in the unaided ear was much higher and there was little difference between the two intensities of high or low when the stimulus was presented at low frequency. The results were also examined by functional magnetic resonance imaging (fMRI) to investigate structural changes in the brain following long-term use of unilateral hearing aids, as expected, results were consistent with previous studies [19]. These studies showed that the use of unilateral hearing aids in people with bilateral hearing impairment can change ear function.

Nabelek et al., invented a test that examined the rate of noise acceptance [20]. During this test, connected speech was delivered to the individual. They were required to adjust the intensity to the most comfortable level (MCL). After measuring the MCL; a background noise was broadcast to the individual. It was a multi-speaker recorded noise called multi-talker babble noise. The person was asked to put the noise at a level that was of the highest intensity and at the same time not disturb the person and be able to follow the speech. The background noise was called background noise level (BNL). The difference between MCL and BNL was acceptable noise level (ANL). Studies have investigate the various factors that influence this test. The severity of hearing impairment, age, gender, individual

ULL, and medial olivo-cochlear bundle activity had no effect on the final result of ANL; however, changes in intensity of connected speech presentation, working memory capacity, medication withdrawal in ADHD patients, central cognitive processes, personality, and audiogram configuration affect the outcome [21-31]. This study aimed to investigate the effect of hearing impairment on monaural ANL.

Methods

The study population included 23 individuals, including 14 females and 9 males. Mean age ranged from 41 to 83 years, mean age was 65.74 years and standard deviation was 11.51 years. Inclusion criteria included 6 months or more of unilateral hearing aid experience; age range between 18 and 85 years; average hearing thresholds of 0.5, 1, 2, and 4 kHz in the range of mild to severe hearing loss; maximum 10 dB air-bone gap (ABG) per frequency; symmetrical hearing loss; ≥ 10 dB threshold difference at 4 frequencies 0.5, 1, 2, and 4 kHz between two ears; word recognition score (WRS) of 72% or higher (25 monosyllabic words); no history of neurological diseases; middle ear pressure between +50 to −100 and static compliance also between 0.3 to 1.6 mmho; obtaining +100 score in the Edinburgh questionnaire; and hearing aid experience for at least eight hours per day according to the International Outcome Inventory for Hearing Aid (IOI-HA).

The participants were selected from hospitals and centers affiliated to Shahid Beheshti Medical University such as Loghman Hakim Hospital or private Clinics. All of them met the inclusion criteria and signed the informed consent prior the study. ANL results were obtained and recorded by a software designed by the MATLAB program. The software was installed on a laptop that could play audio files through the headphones monaurally. To increase the sound intensity, an amplifier was fitted to allow ANL detection up to 100 dB HL level under the headphones. Standard headphones were also provided for the sound. The devices were calibrated for 4 to 5 sessions using the sound level meter Type 2250-S analyzer. After selecting the acoustic location to evaluate the ANL, the process of recording results was began. The ANL testing was first instructed to the participant. In this version of ANL, a story was used as connected speech and a 12-talker babble noise. In the program developed by MATLAB, the test file from section 3 (Fig. 1) was selected.

After selecting the desired file, the intensity steps of connected speech were selected in section 5. Then, the connected speech was adjusted to the MCL by the speaker key (section 6 or 7 depending on the testing ear). The desired intensity level was recorded as monaural MCL. To measure BNL, the background noise intensity was chosen in section 9. Then, connected speech was presented to the same ear with the intensity level measured as the monaural MCL, along with the babble noise at 20 dB lower than MCL, to the same ear. It is noteworthy that connected speech and background noise were provided in sections 10 and 11 (depending on the testing ear). At this time, the intensity of the speech remained constant, but the level of noise intensity increased to a level that was no longer tolerable by the subject, while the speech was intelligible and they could follow the sentences. The measured noise intensity level was recorded as monaural BNL. The difference between MCL and BNL in one ear was the monaural ANL. All the steps described were performed separately in the aided and the unaided ears. The monaural parameters (MCL, BNL, and ANL) were measured in each ear.

Results

The age range of participants was 41 to 83 years old, mean age 65.74 years old and standard deviation of 11.51 years old. Mean and standard deviation of the period of use of unilateral hearing aid was 12.03 months and standard deviation of 1.7 months, respectively.

Table 1 shows mean, standard deviation, range, minimum, and maximum MCL, BNL, ANL, and the hearing threshold of 0.25, 0.5, 1, 2, 4, and 8 kHz in each ear. Statistical paired t-test showed no significant difference between mean MCL in aided and unaided ears. Paired t-test showed that the mean BNL was not significantly different

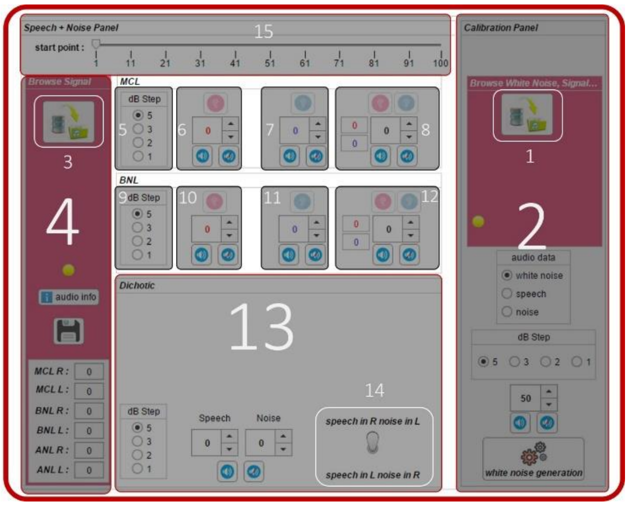

Fig. 1. 1) Calibration of a given file, 2) file type, steps of increasing/decreasing of intensity, intensity dial, and broadcasting on/off buttons 3) selecting the original test file (here the noise acceptance level), 4) The presented sound information, 5) steps of increasing/decreasing MCL, 6) intensity dial for MCL of the right ear, 7) intensity dial for MCL of the left ear, 8) intensity dial for diotic MCL, 9) steps of increasing/decreasing BNL, 10) intensity dial for BNL of the right ear, 11) intensity dial for BNL of the left ear, 12) intensity dial for diotic BNL, 13) dichotic mode; on the left, intensity steps in the speech and noise sections are selected to provide the MCL and background noise level, 14) two dichotic modes; button up for connected speech in the right ear and babble noise in the left ear, button down for connected speech in the left ear and babble noise in right ear, and 15) file playback start time. If the settings in this section are not modified, each file will automatically be played from the beginning.

between two ears. Also there was no significant difference ($p > 0.05$) in ANL mean between aided and unaided ears.

Correlation analysis by Pearson test between ANL and hearing thresholds at different frequencies in aided ear showed a significant and moderate correlation between monaural ANL and hearing threshold at 1 and 4 kHz ($p < 0.032$ and $p < 0.043$, respectively). No significant correlation was found at the rest of the frequencies. Also, there was no significant correlation between the ANL and hearing thresholds at different frequencies in unaided ear based on Pearson test.

Discussion

The current study examined the correlation between ANL and LOAD in users who had bilateral hearing loss but used monaural hearing aid. The study population included 23, including 9 men and 14 women.

Cherry et al. drew the world's scientific attention to binaural phenomena following publishing their article titled "Some experiments on the recognition of speech, with one and with two ears" [31]. Since then, hundreds of studies on the benefits of binaural hearing and binaural speech perception have been done. Noise tolerance and speech perception in noise have been the focus of attention in recent years. One way to test the noise tolerance was to use the ANL test developed by Nabelek in 1991 [20]. The monaural ANL consists of two components; that the delivered speech which according to researchers occurs in mid- and high frequency regions and has the greatest effect on the MCL intensity [32], and the other part is babble noise, which has the highest frequency spectrum distribution in the middle and low frequencies, and has the highest impact on BNL intensity [31,33]. Therefore, if the hearing thresholds are symmetrical at different frequencies in both ears, the monaural ANL in the two ears will not be much different; in the present study, in addition to hearing loss, the effect of LOAD on ANL due to monaural use of hearing aids was investigated, and it was found that LOAD leads to lower MCL. BNL decreased as well. Because of concurrent MCL and BNL changes, ANL showed no significant difference between two ears. The reason can be attributed to the relationship between audiogram configuration and the ANL. In most of studies, there was no significant relationship between audiogram shape and ANL, but according to Olsen et al., contrary to previous findings, the relationship between hearing thresholds and ANL was significant and the ANL would be higher if the slope of the audiogram is such that the average threshold before the 1 kHz frequency is significantly

Table 1. Descriptive measures of hearing threshold, most comfortable loudness level, background noise level, and acceptable noise level in aided and unaided ears (n = 23)

	Aided ear				Unaided ear			
Hearing threshold (dB HL)	**Mean (SD)**	**Min**	**Max**	**Range**	**Mean (SD)**	**Min**	**Max**	**Range**
0.25 kHz	35 (8.6)	15	50	35	32.39 (9.75)	20	55	35
0.5 kHz	40.43 (10.96)	15	65	50	37.17 (12.32)	15	70	55
1 kHz	46.96 (10.84)	20	65	45	42.83 (13.72)	15	70	55
2 kHz	51.74 (11.83)	30	75	45	47.17 (12.59)	30	75	45
4 kHz	63.70 (14.78)	45	100	55	60.65 (17.66)	40	105	65
8 kHz	13.47 (72.14)	50	100	50	67.38 (17.50)	30	110	80
Most comfortable level (dB HL)	82.22 (8.2)	65	96	31	81.78 (11.6)	60	106	46
Background noise level (dB HL)	73.48 (9.29)	58	92	34	72.13 (12.5)	48	95	47
Acceptable noise level (dB HL)	8.74 (3.29)	3	15	12	9.65 (4.43)	0	19	19

different from the average thresholds of higher frequencies [31].

According to numerous studies on the speech frequency spectrum, it can be concluded that the highest frequency distribution of the speech frequency spectrum is in the middle frequencies and to a lesser extent at the higher frequencies. Studies have also shown that the highest frequency spectrum of babble noise is at low frequencies [33].

Due to the high mean age in this study; it was impossible to convince some elderly to participate in this study. It is suggested that the same study be conducted with a lower mean age and higher hearing threshold or in participants with asymmetric hearing loss.

Conclusion

The results of this study show that LOAD has no significant effect on noise tolerance and there is no significant difference between ANL, BNL and MCL in subjects with bilateral and symmetrical hearing loss but use the unilateral hearing aid. It is worth noting that in people with higher hearing loss or longer their deprivation time; different results are likely to be expected.

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Conflict of interest

The authors declared no conflicts of interest.

References

1. Arlinger S. Negative consequences of uncorrected hearing loss-a review. Int J Audiol. 2003;42 Suppl 2:2S17-20. doi: 10.3109/14992020309074639
2. Byrne D, Noble W. Optimizing sound localization with hearing aids. Trends Amplif. 1998;3(2):51-73. doi: 10.1177/108471389800300202
3. Shargorodsky J, Curhan GC, Farwell WR. Prevalence and characteristics of tinnitus among US adults. Am J Med. 2010;123(8):711-8. doi: 10.1016/j.amjmed.2010.02.015
4. Nelson JJ, Chen K. The relationship of tinnitus, hyperacusis, and hearing loss. Ear Nose Throat J. 2004;83(7):472-6. doi: 10.1177/014556130408300713
5. Bernarding C, Strauss DJ, Hannemann R, Latzel M, Seidler H, Jobst U, et al., editors. The effects of age and hearing impairment on the extraction of listening effort correlates. Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE; 2011: IEEE.
6. Na W, Kim G, Kim G, Han W, Kim J. Effects of

hearing loss on speech recognition under distracting conditions and working memory in the elderly. Clin Interv Aging. 2017;12:1175-81. doi: 10.2147/CIA.S142962
7. Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L. Hearing loss and incident dementia. Arch Neurol. 2011;68(2):214-20. doi: 10.1001/archneurol.2010.362
8. Mencher GT, Davis A. Bilateral or unilateral amplification: is there a difference? A brief tutorial. Int J Audiol. 2006;45 Suppl 1:S3-11. doi: 10.1080/14992020600782568
9. Eddins DA. Hearing aids. Second edition, Harvey Dillon. Ear Hear. 2013;34(6):813. doi: 10.1097/01.aud.0000436254.15629.5b
10. Carhart R. Monaural and binaural discrimination against competing sentences. J Acoust Soc Am. 1965; 37(6):120-5. doi: 10.1121/1.1939552
11. Harris JD. Monaural and binaural speech intelligibility and the stereophonic effect based upon temporal cues. Laryngoscope. 1965;75:428-46. doi: 10.1288/00005537-196503000-00003
12. Silman S, Gelfand SA, Silverman CA. Late-onset auditory deprivation: effects of monaural versus binaural hearing aids. J Acoust Soc Am. 1984;76(5):1357-62. doi: 10.1121/1.391451
13. Robinson K, Gatehouse S. Changes in intensity discrimination following monaural long-term use of a hearing aid. J Acoust Soc Am. 1995;97(2):1183-90. doi: 10.1121/1.412230
14. Robinson K, Gatehouse S. The time course of effects on intensity discrimination following monaural fitting of hearing aids. J Acoust Soc Am. 1996;99(2):1255-8. doi: 10.1121/1.414637
15. Munro KJ, Trotter JH. Preliminary evidence of asymmetry in uncomfortable loudness levels after unilateral hearing aid experience: evidence of functional plasticity in the adult auditory system. Int J Audiol. 2006;45(12):684-8. doi: 10.1080/14992020600640444
16. Olsen SØ. The relationship between the uncomfortable loudness level and the acoustic reflex threshold for pure tones in normally-hearing and impaired listeners--a meta-analysis. Audiology. 1999;38(2):61-8. doi: 10.3109/00206099909073004
17. Borg E. On the neuronal organization of the acoustic middle ear reflex. A physiological and anatomical study. Brain Res. 1973;49(1):101-23. doi: 10.1016/0006-8993(73)90404-6
18. Munro KJ, Pisareva NY, Parker DJ, Purdy SC. Asymmetry in the auditory brainstem response following experience of monaural amplification. Neuroreport. 2007;18(17):1871-4. doi: 10.1097/WNR.0b013e3282f1b003
19. Hwang J, Wu C, Chen J, Liu T. Changes in activation of the auditory cortex following long-term amplification: an fMRI study. Acta Otolaryngol. 2006; 126(12):1275-80. doi: 10.1080/00016480600794503
20. Nabelek AK, Tucker FM, Letowski TR. Toleration of background noises: relationship with patterns of hearing aid use by elderly persons. J Speech Hear Res. 1991;34(3):679-85. doi: 10.1044/jshr.3403.679
21. Rogers DS, Harkrider AW, Burchfield SB, Nabelek AK. The influence of listener's gender on the acceptance of background noise. J Am Acad Audiol. 2003;14(7):372-82.
22. Franklin CA, White LJ, Franklin TC. Relationship between loudness tolerance and the acceptance of background noise for young adults with normal hearing. Percept Mot Skills. 2012;114(3):717-22. doi:10.2466/24.22.PMS.114.3.717-722
23. Harkrider AW, Smith SB. Acceptable noise level, phoneme recognition in noise, and measures of auditory efferent activity. J Am Acad Audiol. 2005;16(8):530-45. doi: 10.3766/jaaa.16.8.2
24. Franklin CA, Thelin JW, Nabelek AK, Burchfield SB. The effect of speech presentation level on acceptance of background noise in listeners with normal hearing. J Am Acad Audiol. 2006;17(2):141-6. doi: 10.3766/jaaa.17.2.6
25. 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
26. Freyaldenhoven MC, Thelin JW, Plyler PN, Nabelek AK, Burchfield SB. Effect of stimulant medication on the acceptance of background noise in individuals with attention deficit/hyperactivity disorder. J Am Acad Audiol. 2005;16(9):677-86. doi: 10.3766/jaaa.16.9.5
27. Tampas JW, Harkrider AW. Auditory evoked potentials in females with high and low acceptance of background noise when listening to speech. J Acoust Soc Am. 2006;119(3):1548-61. doi: 10.1121/1.2167147
28. Harkrider AW, Tampas JW. Differences in responses from the cochleae and central nervous systems of females with low versus high acceptable noise levels. J Am Acad Audiol. 2006;17(9):667-76. doi: 10.3766/jaaa.17.9.6
29. 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
30. Brännström KJ, Olsen SØ. The acceptable noise level and the pure-tone audiogram. Am J Audiol. 2017; 26(1):80-7. doi: 10.1044/2016_AJA-16-0033
31. Cherry EC. Some experiments on the recognition of speech, with one and with two ears. J Acoust Soc Am. 1953;25(5):975-9. doi: 10.1121/1.1907229
32. Byrne D, Dillon H, Tran K, Arlinger S, Wilbraham K, Cox R, et al. An international comparison of long-term average speech spectra. J Acoust Soc Am. 1994; 96(4):2108-20. doi: 10.1121/1.410152
33. American National Standards Institute. Acoustical performance criteria, design requirements, and guidelines for schools, part 1: Permanent schools (ANSI S12. 60-2010). New York, NY: Author; 2010.