Original Article
http://mjiri.iums.ac.ir
Medical Journal of the Islamic Republic of Iran (MJIRI)
Iran University of Medical Sciences

Effect of signal to noise ratio on the speech perception ability of older adults

Elahe Shojaei[1], Hassan Ashayeri*[2], Zahra Jafari[3], Mohammad Reza Zarrin Dast[4]
Koorosh Kamali[5]

Received: 24 January 2015 Accepted: 7 July 2015 Published: 9 March 2016

Abstract

Background: Speech perception ability depends on auditory and extra-auditory elements. The signal-to-noise ratio (SNR) is an extra-auditory element that has an effect on the ability to normally follow speech and maintain a conversation. Speech in noise perception difficulty is a common complaint of the elderly. In this study, the importance of SNR magnitude as an extra-auditory effect on speech perception in noise was examined in the elderly.

Methods: The speech perception in noise test (SPIN) was conducted on 25 elderly participants who had bilateral low–mid frequency normal hearing thresholds at three SNRs in the presence of ipsilateral white noise. These participants were selected by available sampling method. Cognitive screening was done using the Persian Mini Mental State Examination (MMSE) test.

Results: Independent T- test, ANNOVA and Pearson Correlation Index were used for statistical analysis. There was a significant difference in word discrimination scores at silence and at three SNRs in both ears ($p \leq 0.047$). Moreover, there was a significant difference in word discrimination scores for paired SNRs (0 and +5, 0 and +10, and +5 and +10 ($p \leq 0.04$)). No significant correlation was found between age and word recognition scores at silence and at three SNRs in both ears ($p \geq 0.386$).

Conclusion: Our results revealed that decreasing the signal level and increasing the competing noise considerably reduced the speech perception ability in normal hearing at low–mid thresholds in the elderly. These results support the critical role of SNRs for speech perception ability in the elderly. Furthermore, our results revealed that normal hearing elderly participants required compensatory strategies to maintain normal speech perception in challenging acoustic situations.

Keywords: Word Discrimination Score, Signal to Noise Ratio, Elderly.

Cite this article as: Shojaei E, Ashayeri H, Jafari Z, Zarrin Dast MR, Kamali K. Effect of signal to noise ratio on the speech perception ability of older adults. *Med J Islam Repub Iran* 2016 (9 March). Vol. 30:342.

Introduction

Difficulty in speech discrimination, particularly in challenging auditory situations such as noisy places and/or when attempting to trace fast speech, is the most common complaint among the elderly. This difficulty is often attributed to reduced peripheral hearing sensitivity in the elderly (1,2). There is evidence that speech perception in noisy situations is difficult even for normal peripheral hearing sensitivity in the elderly (3). Speech discrimination in noise depends on auditory and extra-auditory factors (4). Spatial hearing, auditory input representation in different regions of the central auditory system, and spectrotemporal cues for speech processing such as F_0 (the number of human vocal cord vibrations that are af-

[1]. PhD Candidate of Audiology, Department of Audiology, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran. elaheshojaei49@gmail .com
[2]. (**Corresponding author**) Professor, Department of Basic Sciences in Rehabilitation, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran. ashayeri.neuroscientist@yahoo.com
[3]. Associate Professor, Department of Basic Sciences in Rehabilitation, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran. jafari.z@iums.ac.ir
[4]. Professor, Department of Pharmacology, Tehran University of Medical Sciences, Tehran, Iran. zarinmr@tums.ac.ir
[5]. Associate Professor, Department of Public Health, Zanjan University of Medical Sciences, Zanjan, Iran. kkamali71@yahoo.com

fected by age and gender) are known as auditory elements for speech perception in noise (5). Cognitive system functions (as an internal element) and physical environmental characteristics (as external elements) are known as extra-auditory participating factors for speech perception in noise. Attention and memory are the most important cognitive elements that result from bottom-up and top-down mechanisms (6). Therefore, auditory–cognitive system interactions are the basis of target signal and background noise segregation in the auditory system (7–12). The physical characteristics of a communicative environment are the other extra-auditory elements that influence target stimulus detection in the presence of competing background noise (13). The signal-to-noise ratio (SNR) is the most effective physical characteristic factor for speech perception in noise, and it is defined as the target stimulus power compared with the background noise power, measured in decibels (dB) (3). Several studies have supported the effect of aging on perceptual abilities. A comparison of these potencies in older and younger people revealed that older people required a 3–4 dB higher SNR than younger people to have the same proper perception under similar noise conditions. It appears that age-related changes in auditory–cognitive system functions are responsible for the requirement of an enhanced SNR in the elderly (14–16).

Most of the studies on the speech discrimination abilities of the elderly focused on their hearing impaired abilities, clarifying the causes of decreasing perceptual ability. Pichora-Fuller et al. (17) ascribed elderly speech difficulties in noise to a deficit in central auditory processing. Clark et al. (1) and Fostick et al. (2) attributed elderly speech difficulty in noise to peripheral hearing sensitivity loss, known as presbycusis. Wong et al. (7) found that the speech discrimination ability of the elderly declined more than younger people at a similar SNR. Anderson et al. (11,15) and Sung Hee et al. (18) noted that in the elderly, a decreased speech perception in noise ability was the result of chemical changes in the central nervous system neurotransmitters. Parthasarathy et al. (19), Souza et al. (1), Kamal et al. (20), Anderson et al. (11), Bidelman et al. (21), and Getzmann (22) attributed the elderly decreased speech in noise discrimination ability to temporal synchronization changes in sub-cortical auditory structures. Walton (23) also reported prefrontal and hippocampus atrophy in the brains of the elderly. Gordon-Salant (24) found that a decreased discriminative ability in spectro–temporal processing slows the central nervous system of the elderly. According to Zekveld et al. (25), Shannon et al. (26), Denise and Schwartz (27), and Sohoglu et al. (28), attention and working memory declines are the causes of decreased discriminative skills in the elderly. Wong et al. (29) studied the role of auditory-cognitive system interactions in speech discrimination and noted inadequate results for higher SNR requirements in the elderly compared with younger people under similar noise conditions. As noted above, the majority of related studies evaluated the effects of auditory–cognitive elements on speech perception in noise of the elderly. Because of the important role of the magnitude of SNR on perceptual abilities, it appears that more studies should evaluate auditory and extra-auditory element interactions.

Although it is well known that decreased hearing sensitivity and/or cognitive system dysfunction has a negative effect on the perceptual abilities of the elderly, the importance of physical environmental characteristics such as SNR has received less consideration. In this newly designed study, we investigated the role of the SNR magnitude as an extra-auditory effect element for the speech in noise perception ability of the elderly. This greatly controlled the auditory and cognitive elements legends.

Methods

This study was performed on 25 elderly people (16 women and 9 men) aged 65–74 years with a mean age of 67.9 (±2.45 SD) years. All individuals had normal hearing thresholds at 250–2000 Hz and were selected from three cultural centers in Tehran from October to December 2014. Safety and morality aspects of the research were approved by Iran University of Medical Sciences.

Our study was conducted on right-handed elders with a high school diploma, monolingual with good competency in Persian as their native language, with no history of ear diseases, head trauma or accident, head surgery, depression, epilepsy, or neurological drug intake. To ensure normal hearing thresholds at low-mid frequencies, pure-tone audiometry was accomplished in a double-walled, sound treated audiometric booth, using a two channel calibrated clinical audiometer (Interacoustic AC40) and a supra-aural headphone (Telephonics TDH-49P). Pure tone thresholds were obtained at six octave band frequencies from 250–8000 Hz, using a 10 dB up and 5 dB down regimen according to the Hughson–Westlake method (3). In this phase, the participants had hearing thresholds of≤25 dB HL in both ears at 250–2000Hz. The mean PT average was 13.64 dB and 14.88 dB in the right and left ear, respectively. The mean high frequencies (3–8KH) hearing thresholds were 48 dB and 52 dB in the right and left ear, respectively.

In the speech perception in the noise test (SPIN), each participant was instructed as follows. This simple test was designed to assess the ability to recognize normal words in the presence of noise. Once the stimulus presentation was heard, the heard word was repeated. SPIN was performed using four Persian, monosyllabic, phonetically-balanced, phoneme-balanced lists (n=25) based on 29 Persian language phonemes (6 vowels and 23 consonants) (31). The words were presented at a lively pace at 40 dB SL. Participants responded by repeating the heard words and an adequate response time was given to them. Competing white noise was delivered at three SNRs ipsilaterally: 0, +5, and +10dB (32). Word discrimination scores were calculated based on correct repeated words by each SNR and for each ear.

Cognitive screening was performed using Persian Mini-Mental State Examination (MMSE) test. A score>27 was defined as successful cognitive function (30).

Statistical Analysis

Statistical analysis was performed using SPSS.18 software (Chicago, IL, USA). Significance was defined as $p<0.05$. The Kolmogorov–Smirnov test was utilized to verify the normal distribution of the numerical data. Analysis of variance (ANOVA) was conducted to compare word recognition scores at silence and three SNRs. Pearson correlations was used for the age-relationship study with word recognition scores in silence and at 0, +5, and +10dBs.

Results

The Kolmogorov–Smirnov test indicated that data were normally distributed among all SPIN test scores ($p>0.086$). There was a significant difference among word discrimination scores in silence and all SNRs for both ears (Tables 1 and 2). The 0, +5, and +10dB SNRs were 0.030, 0.024, and 0.023 in the right ear and 0.034, 0.019, and 0.017 in the left ear, respectively ($p<0.034$). The mean of word discrimination scores in silence and at 0, +5, and +10dB SNRs were 85.07% (2.94), 64.76% (2.19), 71.82% (1.17), and 78.24% (1.78) in the right ear and 84.08% (2.84), 64.74% (2.22), 70.56% (1.60), and 78.31% (1.57) in the left ear, respectively. Moreover, we observed a significant difference between word discrimination scores for each pair of three SNRs (0 and +5, 0 and +10, and +5 and +10dB) ($p<0.095$) (Table 3). There was no significant correlation between age and word discrimination scores for total in silence and three SNRs in both ears ($p>0.30$) (Table 4).

Table 1. Difference between word discrimination score (WDS) in silent and WDS in three signal to noise ratios (SNRs) in the right ear

Group (n=25)		Mean (%)	SD	p
SNR=0dB	Female	66.9	2.00	0.029
	Male	62.6	2.38	0.032
SNR=+5 dB	Female	73.5	1.09	0.046
	Male	70.2	1.08	0.047
SNR =+10dB	Female	80.2	1.08	0.017
	Male	76.3	1.78	0.028

WDS: Word discrimination scores (WDS), SNR: signal to noise ratio

Table 2. Difference between word discrimination score (WDS) in silent and WDS in three signal to noise ratios (SNRs) in the left ear

Group (n=25)		Mean (%)	SD	p
SNR=0dB	Female	65.9	2.15	0.067
	Male	63.6	2.29	0.018
SNR=+5dB	Female	71.2	1.40	0.041
	Male	69.9	1.80	0.044
SNR =+10dB	Female	79.4	2.00	0.026
	Male	77.3	1.14	0.031

WDS: Word discrimination scores (SDS), SNR: signal to noise ratio

Table 3. Difference between word discrimination scores (WDSs) for each pair of three signal to noise ratios (SNRs) (n=50)

Pair SNR (dB)	Mean*(%)*	SD	P Value
0 and +5	64.7	4.66	0.040
0 and +10	70.8	6.76	0.025
+5 and +10	78.3	6.85	0.095

WDS: Word discrimination score (WDS), SNR: signal to noise ratio

Table 4. Correlation between age and word discrimination score (WDS) in silence and three signal to noise ratios (SNRs) in both ears

		SDS in silence	SNR=0dB	SNR=+5 d	SNR=+10dB
Age	Pearson Correlation (r)	0.400	0.300	0.300	0.300
(N=50)	Sig. (2-tailed)	0.598	0.386	0.389	0.483

** Pearson Correlation is significant at the <0.05 level (2-tailed)
WDS: Word discrimination score (WDS)
SNR: Signal to noise ratios

Discussion

The main finding of this study was the significant difference between word discrimination scores in silence and at 0, +5, and +10dB SNRs in both ears. We found that the word discrimination ability in the elderly was significantly reduced in noisy conditions, and this is in agreement with Martin and Jerger (33), Pichora-Fuller et al (17), Gordon-Salant (23), Walton (24), and Doberva et al. (34) who all believed that speech perception disability by the elderly is related to non-peripheral auditory factors. With regards to the participants' normal auditory sensitivity at 250–2000 Hz and remarkable decreased word discrimination at higher noise levels, it appears that the ability of the elderly to discriminate word in noise is considerably dependent on the SNR magnitude as an extra-auditory element. Moreover, comparison of word discrimination scores in silence and at 0 dB SNR revealed that the perceptual ability of the elderly was considerably reduced at equal signal and noise levels.

The remarkable difference between word discrimination scores for each pair of SNRs (0 and +5, 0 and +10, and +5 and +10dB) showed that decreasing the signal level and increasing the competing noise amount extremely reduced the perceptual ability of the elderly. This finding is in agreement with Larsby et al. (35) and Tomchic and Zhongmin (36). It appears that when increasing the background noise, elderly people need compensatory strategies for adequate speech sound perception.

No significant correlation was found between age and word discrimination scores in silence and at 0, +5, and +10dB SNRs.

This finding is in agreement with Wong et al. (29) who found that the ability of speech discrimination in noise was not only related to the auditory system function, but also to the compensatory interaction of the auditory–cognitive systems. Therefore, one can say there is an assistive factor in the central nervous system of the elderly that prevents further speech in noise discrimination deterioration at higher ages. It appears that increased activity in general cortical cognitive regions such as the prefrontal area acts as an assistive factor to compensate for the sensory representation deficit in other cortical areas. This enhanced prefrontal activity following attention has been supported by behavioral-neurophysiologic studies (15-21). The ability of speech perception in the elderly affects peripheral/central auditory, cognitive, and environmental elements. Peripheral age-related hearing loss effects on elderly perceptual abilities is caused by a reduced auditory input transition from the cochlea to the higher auditory centers. Central auditory system dysfunction resulted from processing declines at the brainstem and in higher auditory regions (15,21). Conversely, cognitive system dysfunction reduces the working memory and attention capacity of the elderly. Physical environmental characteristic deterioration reduces the speech sound transportation from the speaker to the listener (37). These factors interact and facilitate the speech message perception of the listener. Although we greatly controlled auditory–cognitive element effects by screening the elders' normal hearing at low–mid frequencies, the participants' speech perception dropped considerably even at equal signal and noise levels. It appears that reparative strategies such as prosodic rhythm tracing at the phoneme level can help reduce speech sounds transition and processing compensation. Increasing the background noise and decreasing the signal level is helpful for maintaining conversation (38,39). Moreover, the effect of auditory training to improve perceptual ability through neural plasticity in the central nervous system of the elderly is supported in various studies. It appears that acetylcholine levels increase following auditory training and is responsible for exhibitory-inhibitory mechanism interactions resulting in speech representation improvements at sub-cortical and cortical levels (40). Therefore, simple stimuli based auditory training and/or memory auditory based cognitive training (IMPACT: Improvement in Memory with Plasticity-based Adaptive Cognitive Training) (45) is the best strategy to improve brain plasticity in the elderly and improve their speech in noise perception (41–44).

Recent findings are only reliable in the frame of this research because of our small sample size. Our general findings are dependent on similar studies with adequate sample sizes. We could not eliminate the effect of peripheral high frequency loss of speech in noise perception in the elderly. Another study at 250–8000 Hz with normal hearing elders may control this effect. More audiology perceptual tests are recommended to confirm our findings. A study of the SNR effect on hearing impaired elders perceptual abilities and the effect of negative SNRs on speech perception in noise is recommended to evaluate auditory/extra-auditory element interactions.

Conclusion

This study revealed considerably reduced speech perception ability in the presence of background noise in normal, low–mid frequencies peripheral hearing, and cognitive system function. Moreover, decreasing the signal level and increasing the competing noise significantly reduced the perceptual abilities of the elderly. It appears that the SNR has an important critical role for proper speech perception in noise for the elderly, even those who have normal peripheral auditory–cognitive function systems. According to recent findings, elderly people may need adaptive strategies such as auditory training to facilitate speech perception in the presence of background noise.

Acknowledgement

We would like to sincerely thank the Eshragh, Andishe, Bahman cultural centers for their extensive cooperation. This study was supported by a grant (contract number 4723/260/90/d/ on 2009/1/12) from the Rehabilitation Research Center of Iran University of Medical Sciences, whose financial support is much appreciated. The authors of this paper are thankful to Ms. Kobra Esfandiyari for sample selection and we also thank all the participants in this research.

Conflict of Interest

The authors declare that they have no competing interest.

References

1. Clark PA, Strait DL, Anderson S, Hittner N, Kraus N. Musical experience and the aging auditory system: Implication for cognitive abilities and hearing speech in noise. PloS ONE 2011;6(5).
2. Fostick L ,Ben-Artzi E, Babkoff H. Aging and speech perception: Beyond hearing threshold and cognitive ability.J Basic Clin Physiol Pharmacol 2013;24(3):175-183.
3. Katz J. Handbook of clinical audiology. 6th d. Williams & Willkin. 2009.
4. Song JH, Skoe E, Banaei K, Kraus N. Perception of speech in noise: Neural correlates. J Cogn Neurosci 2011;23(9):2268-79.
5. Souza P, Arehart K, Miller CW, Muralimanohar RK. Effects of aging on Fo discrimination and intonation in simulated electric and electroacoustic hearing. Ear Hear 2011;32(1):75 -83.
6. Besser J, Zekueld A, Kramer S, Rönnberg J, Festen JM. New measures of masked Text recognition in relation to speech in noise perception and their associations with age and cognitive abilities. J Speech Lang Hear Res 2012;55(1):194-209.
7. Wong CM, Ettlinger M, Sheppard JP, Gunasekera GM, Dhar S. Neuroanatomical characteristics and speech perception in noise in order adults. Ear Hear 2010;31(4):471-79.
8. Zekveld A, Kramer SE, Fasten JM. Cognitive load during speech perception in noise: The influence of age, hearing loss and cognition on pupil response. Ear Hear 2011;23(4):498-510.
9. Anderson P, White-Schwoch T, Parbery-Clark A, Kraus N. A dynamic auditory- cognitive system supports speech in noise perception in older adults. Hear Res 2013;300:18-32.
10. Meister H, Schreitmuller S, Grugel L, Beutner D, Walger M, Meister I. Examining speech perception in noise and cognitive functions in elderly. Am J Audiol 2013;22:310-12.
11. Anderson P, Pirre Gang JE. Older adults expend more listening efforts than young adults recognizing speech in noise. J Speech Lan Hear Res 2011;54:944-58.
12. Alain C, Zendel BR, Hutka S, Bidelman GM. Tuning down the noise: the benefit of musical training on the aging auditory brain. Hear Res 2014; 308:162-73.
13. Tun PA, Williams VA, Small BJ, Hafter ER. The effects of aging on auditory processing and cognition. Am J Audiol 2012;21(2):344-50.
14. Schneider BA. How age affects auditory-cognitive interactions in speech comprehension. Audiol Res 2011
15. Anderson S, Parbery–Clark A, Han-Gyol Y, Kraus N. A neural basis of speech in noise perception in order adults. Ear Hear 2011 Nov;32(6):750-7.
16. Souza P, Arehart K, Miller CW, Muralimanohar RK. Effects of aging on F0 discrimination and intonation in simulated electric and electroacoustic hearing. Ear Hear 2011;32(1):75 -83.
17. Pichora-Fuller MK, Schneider BA, Mc Donald EP, Brown S. Temporal jitter disrupts speech intelligibility: A simulation of auditory aging. Hear Res 2007;223(1-2):114-121.
18. SungHee K, Frisinaa RD, Frisinaa DR. Effects of age on speech understanding in normal hearing listeners: Relationship between the auditory efferent system and speech intelligibility in noise. Speech Communic 2006;48(7):855-862.
19. Parthasarathy A, Bartlett EL. Age-related auditory deficits in temporal processing in F-344 rats. Neurosci 2011.
20. Kamal B, Holman C, Villers-Sidani D. Shapping the aging brain: role of the auditory input patterns in the emergence of auditory cortical impairments. Front Syst Neurosci 2013;7:52.
21. Bidelman GM, Villafuerte JW, Moreno S, Alain C. Age related changes in the subcortical – Cortical encoding and Categorical perception of speech. Neurobiol Aging 2014;35(11):2526-40.
22. Getzmann S. Handicapped due to age? Behavioral and electrophysiological correlates of speech perception of dichotically presented narratives in young and middle-aged listeners. J Psychoph 2012;26(3):132-144.
23. Walton JP. Timing is everything: temporal processing deficits in the aged auditory brainstem. Hear Res 2010;264(1-2):63-9.
24. Gordon-Salant S. Hearing loss and aging: new research findings and clinical implications. J Rehabil Res Dev 2005;42(4 Suppl 2):9-24.
25. Zekveld AA, Kramer SE, Kessens JM, Vlaming MS, Houtgast T. The influence of age, hearing, and working memory on the speech comprehension benefit derived from an automatic speech recognition system. Ear Hear 2009;30(2):

262-72.
26. Heald SLM, Nusbaum HC. Speech perception as an active cognitive process Front Syst Neurosci 2014;8:35.
27. Denise PC, Schwartz N. Cognitive aging: A Primer. Psychophisiology press 2012.
28. Sohoglu E, Peelle JE, Carlyon RP, Davis MH. Predictive Top-Down Integration of Prior Knowledge during Speech Perception. J Nerorosci 2012;32(25).
29. Wong PCM, Ettlinger M, Sheppard JP, Gunasekera GM, Dhar S. Neuroanatomical Characteristics and Speech Perception in Noise in Older Adults. Ear Hear 2010;31(4):471-479.
30. Foroughan M. Validation of mini-mental state examination in Iranian elderly. European Regional Meeting of IPA. Istanbul, Turkey 2007.
31. Mosleh M. Development and evaluation of a speech recognition test for Persian speaking adults. Audiol 2001;9(1,2):72-6.
32. Kumar S. Descending control of response in the auditory midbrain. The University of Western Australia 2007.
33. Martin JS, Jerger JF. Some effects of aging on central auditory processing. J Rehabil Res Dev 2005;42(4 Suppl 2):25-44.
34. Dobreva MS, O'Neill WE, Paige GD. Influence of aging on human sound localization. J Neurophysiol 2011 May;105(5):2471-86.
35. Larsby B, Hällgren M, Lyxell B. The interference of different background noises on speech processing in elderly hearing impaired subjects. Int J Audiol 2008;47(12):83-90.
36. Tomchic SM, Zhongmin LU. Modulation of auditory signal- to - noise ratios by efferent stimulation. J Neurophysiol 2006;95(6):3562-70.
37. Harris KC, Mills JH, Jihe N. Age related differences in sensitivity to small changes in frequency assessed with cortical evoked potential. Hear Res 2008;2431(1):74-56.
38. Anderson P, Pirre Gang JE. Older adults expend more listening efforts than young adults recognizing speech in noise. J Speech Lang Hear Res 2011;54:944-58.
39. Clinard CG, Tremblay KL, Krishnan AR. Aging alter the perception physiological representation of frequency: Evidence from human frequency following Response encoding. Hear Res 2010;264(1): 48-55.
40. Katz E, Elgoyhen AB. Short-term plasticity and modulation of synaptic transmission at mammalian inhibitory cholinergic olivocochlear synapses. Front Syst Neurosci 2014;8:224.
41. Anderson S, Whither–Schwoch T, Barberry Clark A, Kraus N. Reversal of age related neural timing delays with training Not. Acad Scrmam 2013;110:4357-62.
42. Anderson S, White-Schwoch T, Choi HJ, Kraus N. Training changes processing of speech cues in older adults with hearing loss. Front Syst Neurosci 2013;28(7):97.
43. White-Schwoch T, Carr KW, Anderson S, Strait DL, Kraus N. Older adults benefit from music training early life: Biologic evidence for long-term training- Driven Plasticity. J Neurosci 2013; 33(45):17667-674.
44. Parbery-Clark A, Striat DL, Anderson S, Hittner E, Kraus N. Musical experience and the aging auditory system : implications for cognitive abilities and hearing speech in noise. Plos ONE 2011 May.
45. Smith GE, Housen P, Ruff KR, Kennison RF, Mahncke HW, Zelinski EM. A Cognitive Training Program Based on Principles of Brain Plasticity: Results from the Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) Study. J Am Geriat Soc 2009;57(4):594-603.