http://dx.doi.org/10.1590/S2317-64312014000200005

Speech perception: performance of individuals with hearing aids and a directional microphone

Percepção de fala: desempenho de indivíduos usuários de aparelho de amplificação sonora individual com microfone direcional

Maria Fernanda Capoani Garcia Mondelli[1], *Caio César Calderon de Almeida*[2]

ABSTRACT

Purpose: To investigate speech recognition functioning in noise for hearing-impaired adults who use a hearing aid (HA) with a directional microphone, compared to those patients with no HA and HA with an omnidirectional microphone. **Methods:** A cross-sectional study of 45 subjects bilaterally fitted with digital hearing aids was performed. The subjects were evaluated by the Hearing In Noise Test (HINT-Brazil) under three conditions: without HA, with HA and omnidirectional microphone activated, and with HA and directional microphone activated. **Results:** Through analysis of descriptive measures and statistical tests, we were able to verify that the directional microphone was significantly better. **Conclusion:** Based on the results, we can conclude that the directional microphone contributes most significantly to speech recognition in noise.

Keywords: Noise; Hearing aids; Auditory perception; Hearing loss; Technology

RESUMO

Objetivo: Avaliar o desempenho da percepção de fala no ruído, de indivíduos com perda auditiva, usuários de Aparelho de Amplificação Sonora Individual (AASI) com microfone direcional, nas seguintes situações: sem AASI, com AASI e microfone omnidirecional e com AASI e microfone direcional. **Métodos:** Estudo de coorte histórica, com corte transversal, e participação de 45 sujeitos bilateralmente adaptados com AASI de tecnologia digital. Os sujeitos foram avaliados por meio do teste HINT - Brasil, em três momentos: sem AASI, com AASI e microfone omnidirecional ativado e com AASI e microfone direcional ativado. **Resultados:** Por meio de análise de medidas descritivas e testes estatísticos foi possível verificar diferença entre as três condições de avaliação: sem AASI, com AASI e microfone direcional e com AASI e microfone omnidirecional, sendo o menor valor de p para o microfone direcional ativado. **Conclusão:** A ativação do microfone direcional contribui para o melhor desempenho da percepção de fala em situação de ruído controlado.

Descritores: Ruído; Auxiliares de audição; Percepção auditiva; Perda auditiva; Tecnologia

Research conducted at the Faculty of Dentistry of Bauru, Universidade de São Paulo – USP – Bauru (SP), Brazil.
(1) Department of Speech-Language Pathology, Faculty of Dentistry of Bauru, Universidade de São Paulo – USP – Bauru (SP), Brazil.
(2) Speech Therapy Course, Faculty of Dentistry of Bauru, Universidade de São Paulo – USP – Bauru (SP), Brazil.
Conflict of interest: No
Author's contribution: *MFCGM* planning, guidance and corrections; *CCCA* data collection, data analysis and drafting of the article.
Correspondence address: Maria Fernanda Capoani Garcia Mondelli. Al. Octávio Pinheiro Brizola, 9/75 Vila Universitária, Bauru (SP), Brazil, CEP: 17012-901. E-mail: mfernandamondelli@hotmail.com
Received on: 6/18/2013; **Accepted on:** 4/7/2014

INTRODUCTION

Speech perception and understanding are complex processes that require anatomical integrity and functioning of the auditory system and involve phonological, phonetic, lexical, syntactic, semantic, pragmatic, and cognitive abilities. Lesions of the auditory system affect many of these abilities, disrupting the processing of acoustic or speech signals[1,2].

The development of speech recognition ability for an individual with hearing loss is a challenge for professionals in the field of audiology, since speech is a part of daily life, and the most frequent complaint has been the inability to recognize and understand speech signals in noise situations, which occur competitively in most communication scenarios.

The problems arising from sensory deprivation can be minimized with the use of a hearing aid (HA), which provides audibility of the speech signal as well as other sounds, thereby enhancing communication abilities[3]. The restoration of speech perception depends on the characteristics of the hearing loss of the individual. However, HA users also report various difficulties in noisy environments. Among these problems are speech understanding, discomfort with the noise intensity, and background noise[4].

In noisy environments or adverse conditions, such as when speech is distorted, the individual may face several difficulties in speech intelligibility. This is because the number of cues (acoustic, linguistic, semantic, and circumstantial) decrease significantly, leading to only available cues being used in such situations[5].

Technological advances have enabled the improvement of signal processing in digital HAs, providing hearing comfort in the noisiest of situations. Currently, digital noise reduction and directional microphone algorithms are used to improve the performance of HA users in speech perception under noisy conditions.

With relation to directionality, the HA can be equipped with omnidirectional and directional microphones. Omnidirectional microphones amplify sounds coming from any direction in a circular polar pattern[6].

HA were introduced in the U.S. market in 1971[7] and are currently optional in most HAs favoring the S/N. Directional microphones are more sensitive to sounds coming from a certain direction, generally from the front of the head, reducing sounds that come from other directions[8,9]. The improvement in the signal/noise ratio (S/N) in directional microphones varies by 3–5 dB, contributing to the intelligibility of the speech signal[10].

Directional microphones can be subdivided into fixed, automatic fixed, adaptive, and automatic adaptive[11].

Fixed directional microphones provide a standard static response, which focuses on sound directionality to the front of the individual. This strategy is based on the assumption that the speaker is facing the listener and the sound will come from the side or back. However, some studies indicate that the speech signal is not from the front of the listener in more than 20% of situations[12].

The automatic adaptive directional mode is the main feature of directionality drive, according to information provided by the environment[3]. Thus, the polar pattern varies with detection of speech sounds and noise, general level of the input sound, and direction of speech signals[11].

Researchers have evaluated the performance of adults with sensorineural hearing loss with respect to speech perception using digital HAs with the noise reduction algorithm activated and deactivated in the presence of noise. The results demonstrated a significant difference between the two situations, suggesting that the algorithm could provide a benefit to most individuals. These findings indicate the importance of technological advancement[1].

In a study of 16 HA users, speech recognition in noise was evaluated by separate activation of two components: noise reduction and a directional microphone. The results revealed that activation of the directional microphone was clearly beneficial for speech reception. There was no additional benefit from the combined effect of both components[13].

Researchers compared the performance of speech perception in noise, the benefit and satisfaction obtained by adults with hearing loss using HAs with digital noise reduction, and types of omnidirectional behind-the-ear (BTE), directional BTE, omnidirectional in-the-canal (ITC), and omnidirectional completely-in-canal (CIC) HAs. No significant difference was found in the perception of speech in noise between groups of digital HA users with omnidirectional and directional reduction noise algorithms. However, it was observed that the directivity obtained by acoustic or electronic means favored speech recognition[14].

Since one of the main objectives of HA fitting is to improve speech perception, and thus, facilitating the communication process, it is necessary to verify, by means of standardized tests, the performance of HA in individuals. In general, speech perception tests simulate conditions specific to listening and quantify the changes in speech perception ability with the use of HAs; thus, specifying the hearing condition[8].

The speech tests in noise were developed with the aim of hampering the identification and recognition of speech signals and to simulate more realistic situations experienced by patients[15].

Different tests have been developed with the aim of evaluating the performance obtained with and without the use of HAs. In 1994, the Hearing in Noise Test (HINT) was developed, with the purpose of being a reliable and efficient method for assessment and recognition of an individual's speech reception threshold, both in silence and in noise[16]. The speech reception threshold is defined as the presentation level necessary for the individual to recognize correctly 50% of the speech material. The HINT was translated into Brazilian Portuguese and published in 2008[17] and can be used to

compare the performance of patients with different HAs or the performance of different groups of individuals.

Researchers investigated the benefit of the directional microphone in two models of open-fit HAs using the HINT test. The 16 individuals who participated were between 50 and 85 years of age, with high frequency hearing loss and no prior experience with the use of HAs. The evaluation of benefit with an omnidirectional and directional microphone was performed separately, with the directional microphone in speech perception[18].

Currently, there is a need to verify the performance of HAs fitted with directional microphones in noise situations. Thus, this study aimed to evaluate the performance of HAs with a directional microphone in individuals with hearing loss using a test of speech perception with and without noise situations.

METHODS

Prior to its implementation, this project was submitted to the Ethics Committee for Research in Humans of the Faculty of Dentistry of Bauru, Universidade de São Paulo (USP), and was approved under case number 48522 and CAAE 04461312.0.0000.5417.

A historical, cross-sectional cohort study was conducted with 45 subjects. The sample was selected randomly, according to the following inclusion criteria:

- greater than or equal to 18 years of age;
- diagnosed with post-lingual or moderate to severe bilateral sensorineural hearing loss;
- flat or descending configuration of hearing loss, symmetric or not;
- speech recognition index (SRI) equal to or above 70%;
- no prior experience with HAs;
- minimum of three months and a maximum of six months hearing aid usage, for a minimum period of eight hours/day, uninterrupted;
- fitted with a bilateral hearing aid with digital technology and a microphone with fixed directionality.

Research participants read and signed the consent form. Participants were excluded if they did not have an adequate understanding of proposals and questions, showed changes in cognitive processes, or showed fluctuations in audiometric thresholds.

All subjects were using eXtra 311 AZ HAs (Phonak®) without the program directionality triggered at the time of evaluation. To conduct the speech perception test, we chose to keep the noise suppressor switched off, keeping only the directional microphone activated. The directional microphone, when enabled, displays the fixed cardioid polarity.

Clinical audiology sessions were scheduled through the Regional Health Division, and the participants were transported to the relevant prefecture. These logistics favored the participation of individuals without faults during the requested returns.

Assessment of speech perception with the Brazil-HINT[17] was performed in three stages: without HA (V1), with HA and the omnidirectional microphone activated (V2), and with HA and the directional microphone activated (V3).

The HINT consists of 12 lists with 20 recorded sentences. It can be applied through headphones or in the open field and uses the adaptive procedure for evaluating speech recognition in quiet situations and in noise. The HINT sentences should have similar difficulties being heard in noise, so that the S/N is the primary factor of influence on speech intelligibility.

To review the free field with competing noise, the noise level was kept fixed at 65 dB (A), and the level of speech increased and decreased during the test, according to the accuracy of the individual responses, until it reached 50% speech recognition[19]. This value is set by the HINT protocol and presents two phases: (1) the first, which estimates the threshold of the individual, involves the four initial sentences, with intensities ranging from 4 by 4 dB, (2) the second, which starts from the fifth sentence, with intensities ranging from 2 by 2 dB, enabling accurate determination of the threshold.

The results of HINT in noise were presented in dB (S/N), representing the required level of signal presentation and presentation level of the noise difference for the individual to recognize 50% of the stimuli. When a correct answer was obtained, the S/N was reduced by an equivalent amount. When the answer was incorrect, the S/N was increased by the same equivalent value. For example, an S/N of −5 dB ratio indicates that the sentences were presented at 60 dB (5 dB or below the noise of 65 dB), with 50% of the sentences repeated correctly.

Responses were considered correct when the individual repeated the presented sentence without errors or omissions.

With a lower S/N, difficulty in speech recognition in noise was lesser, since the individual was capable of performing this acivity with little difference between the speech signal and background noise.

This research was conducted in a free field, with speech presented at 0° azimuth and noise at 180° azimuth. For test application, the hardware HINT PRO[20], connected to a computer, was used.

The test was conducted in an acoustically-treated room, allowing proper positioning of the participant, the evaluator, and equipment. In all conditions reviewed, two speakers were positioned at a distance of one meter from the participant box, with issuing sentences at 0° azimuth and noise emission box with a 180° azimuth, both at the time the hearing aid microphone was used.

To review the free field, the participant was instructed to remain in the same position throughout the test, to ensure that the intensity that was reaching the microphone of the hearing aid was the same. All procedures were conducted after calibration and marking of the box positions. The equipment used was done so exclusively for this research during the period of data collection.

For each of the evaluated conditions (silence/noise), a list of 20 sentences was presented, chosen randomly by the HINT PRO software. The score for the test conducted in silence was expressed in dB (A), as the threshold for recognition of 50% of the sentences. For evaluation in noise, a fixed level of 65 dB (A) was maintained throughout the test. The level of initial presentation of the sentences was equal to 60 dB (A), varying according to the responses of the participant. Thus, a lower S/N indicated a better performance for the participant in the evaluated condition.

Statistical analysis

After conducting evaluations, the data were stored in the database and subsequently analyzed descriptively, using the STATISTICA software, version 7.0 for Windows. Friedman analysis of variance (ANOVA) was used for the three variables along with the Wilcoxon signed-rank test, in order to provide a more detailed comparison between the variables

Among all statistical procedures, we considered the significance level of 5% ($p<0.05$).

RESULTS

This study comprised of 45 adults, and the characterization of sex and age of the patients is described in Table 1.

Table 1. Characteristics of the sample according to age and gender of participants

Age						
n	F	M	Min	Max	x	SD
45	24	21	26	81	60.93333	15.61349

Note: F = female; M = male; min = minimum; max = maximum; x = mean; SD = Standard Deviation

The results of Brazil-HINT demonstrate the average S/N values for variables without a HA, with a HA and omnidirectional microphone connected, and with a HA and directional microphone connected (Table 2).

Negative S/N values indicate a better performance of the participant in noise conditions. Positive values and the Friedman ANOVA statistical test show a statistical difference among the three groups (p=0.00002).

Table 2. Descriptive measures obtained for speech recognition in noise in the tested variables

Descriptive measures					
Variable	n	Min	Max	x	DP
V1	45	-1.0	14.8	7.34	5.41701
V2	45	-3.5	10.6	4.18	4.02194
V3	45	-7.1	5.1	-1.07	3.31801

Note: V1 = no hearing aid; V2 = with hearing aid and omnidirectional microphone connected; V3 = with hearing aid and directional microphone connected; Min. = minimum; Max. = maximum; X = mean; SD = standard deviation

Given that the statistical Wilcoxon signed-rank test was used for the lack of independence between the variables measured in the same participant, the three variables were compared as follows: V1 to V2; V1 to V3; and V2 to V3 (Table 3).

Table 3. Results after using the paired Wilcoxon statistical test

Wilcoxon paired test		
Variable	n	p-value
V1 x V2	45	0.040889
V1 x V3	45	0.000655
V2 x V3	45	0.000805

Wilcoxon paired test (p = 0.00002)

Note: V1 = no hearing aid; V2 = with hearing aid and omnidirectional microphone connected; V3 = with hearing aid and directional microphone connected

DISCUSSION

The ability to understand speech is the most important aspect to be measured while selecting and fitting a HA, since it allows for the evaluation of the receptive communicative function, providing information about the individual's performance in daily listening under very diverse circumstances, including room acoustics and noise.

Subjects with hearing loss often complain of difficulty in recognizing speech, especially in the presence of background noise. Due to the prevailing clinical requirement, this research was conducted and comprised of adult patients (Table 1) bilaterally fit with HA.

It is important that the evaluation of speech recognition is similar to conditions prevailing in real life situations, and the audiological tests using sentences as stimuli should also be performed in the presence of noise.

The mean values of Speech Recognition Thresholds (SRT/HINT) in noise were different without HA, with HA and omnidirectional microphone connected, and with HA and directional microphone connected (Table 2). In a search conducted to evaluate speech understanding in noise with HAs and a directional microphones (bilateral omnidirectional microphone, omnidirectional microphone in one ear and directional in the opposite, and bilateral directional), improvement in speech understanding was observed with asymmetrical use of the directional microphone (i.e. a directional microphone in one ear and an omnidirectional in the other ear). The authors also found that individuals accepted background noise better when using directional microphones in both ears[21].

Noise is unwanted sound, present in various environments. The interference of noise on speech can be expressed through S/N, defined as the difference between the level of the speech signal and noise level. Although the methodology of the cited study differs from that used in the present study, it suggests that the use of a directional microphone favors comfort and speech intelligibility in noise situations.

The possibility to understand speech better in daily life, such as in traffic, at the supermarket or bank, and during television programs, was raised by all subjects in the study who opted to make use of the directional microphone on such occasions. The programing change (omnidirectional microphone to directional microphone and vice versa) was done manually, and according to all participants, the directional microphone provided greater effectiveness.

In a study[22] of four individuals, performance of speech recognition was compared between omnidirectional microphones and fixed directional or automatically-activated adaptive directional microphone. It was found that, qualitatively, individuals generally opted for the omnidirectional microphone.

In this research, the preference for the directional microphone in everyday life may have been a result of the assessment conducted with HINT. At the time of testing, when the evaluator modified the omnidirectional microphone to the directional microphone, individual perception of improvement in comprehension of sentences was referred to. It is noteworthy that this study was not designed to evaluate the satisfaction of the individual, but their performance with HAs.

The intention of using HINT is to assess in greater detail the difficulties encountered in speech perception of HA users by improving the adaptation parameters in the audiological routine[23].

Negative S/N values indicated that individuals recognized speech in noise more effectively, thereby demonstrating better performance. The analysis of the mean values of the descriptive measures showed that the HAs with directional microphones produced better results. Similar results were found in a study that evaluated the use of directionality in HINT[24].

Statistical analysis has shown a significant difference between the three groups. The results showed statistical significance among all comparisons (Table 3). The first condition, V1 *vs*. V2 compared the performance of the group without HA and the group with HA and an omnidirectional microphone, which confirmed the benefit provided by HA use. The results of the second comparison condition, V1 *vs*. V3, were also significant. However, the p value was not consistent and showed an enhanced sentence recognition using the directional microphone in noise situations.

Many studies have revealed that[1,13,14,18], since the year 2000, there has been considerable research on this topic. The data of the past researched conducted are in agreement with the results obtained from the current research, thereby confirming that directionality favors speech recognition in noise situations[14,23,24], and for moderate to severe hearing loss, the bilateral directional microphone offers greater benefit compared to the bilateral omnidirectional microphone.

Selection of the microphone type is one of the important aspects to be considered when aiming to improve speech recognition in noise in HA users. The continuity of auditory rehabilitation in the post-adjustment period may contribute to the improvement of this ability.

Clinical studies proving the effectiveness of the algorithms available in the market have become critical in aiding the decision of the professional when selecting a HA.

CONCLUSION

The activation of a directional microphone contributes to better speech recognition performance under controlled conditions compared to the use of an omnidirectional microphone or non-use of HA.

REFERENCES

1. Oliveira JRM, Lopes ES, Alves AF. Percepção de fala dos deficientes auditivos usando aparelho de amplificação com algoritmo de redução de ruído. Braz J Otorhinolaryngol. 2010;76(1):14-7. http://dx.doi.org/10.1590/S1808-86942010000100003

2. Mendes BCA, Barzaghi L. Percepção e produção da fala e deficiência auditiva. In: Bevilacqua MC, Balen SA, Martinez MAN, organizadores. Tratado de audiologia. São Paulo: Santos; 2011. p. 653-69.

3. Magni C, Freiberger F, Tonn K. Avaliação do grau de satisfação entre os usuários de amplificação de tecnologia analógica e digital. Rev Bras Otorrinolaringol. 2005;71(5):650-7. http://dx.doi.org/10.1590/S0034-72992005000500017

4. Palmer CV, Bentler R, Mueller HG. Amplification with digital noise reduction and the perception of annoying and aversive sounds. Trends Amplif. 2006;10(2):95-104.

5. Caporali SA, Silva JA. Reconhecimento de fala no ruído em jovens e idosos com perda auditiva. Rev Bras Otorrinolaringol. 2004;70(4):525-32. http://dx.doi.org/10.1590/S0034-72992004000400014

6. Teixeira AR, Garcez VRC. Aparelho de amplificação sonora individual: componentes e características eletroacústicas. In: Bevilacqua MC, Balen SA, Martinez MAN, organizadores. Tratado de audiologia. São Paulo: Santos; 2011. p. 349-59

7. Ricketts TA, Hornsby BWY. Sound quality measures for speech in noise through a commercial hearing aid implementing digital noise reduction. J Am Acad Audiol. 2005;16(5):270-7.

8. Dillon H. Hearing aids. Austrália: Boomerang; 2001. Capítulo 2, Hearing aids components; p.18-47.

9. Blamey PJ, Ficket HJ, Steele BR. Improving speech intelligibility in background noise with an adaptative directional microphone. J Am Acad Audiol. 2006;17(7):519-30.

10. Valente M, Mispagel KM, Tchorz J, Fabry D. Effect of type of noise and loudspeaker array on the performance of omnidirectional and directional microphones. J Am Acad Audiol. 2010;17(6):398-412.

11. Fabry DA. Adaptive directional microphone technology and hearing aids: theoretical and clinical implications. Hear Rev. 2005 [acesso em 1 mar 2013]. Disponível em: http://www.hearingreview.com/issues/articles/2005-04_02.asp

12. Ricketts T, Henry P, Gnewikow D. Full time directional versus user selectable microphone modes in hearing aids. Ear Hear. 2003;24(5):424-39.

13. Boymans M, Dreschler WA. Field trials a digital hearing aid with active noise reduction and dual-microphone directionality. Audiology. 2000;39(5):260-8.

14. Quintino CA, Mondelli MFCG, Ferrari DV. Direcionalidade e redução de ruído em AASI: percepção de fala e benefício. Braz J Otorhinolaryngol. 2010;76(5):630-8. http://dx.doi.org/10.1590/S1808-86942010000500016

15. Matas CG, Iório MCM. Verificação e validação do processo de seleção e adaptação de próteses auditivas. In: Almeida K, Iório MCM. Próteses auditivas: fundamentos teóricos e aplicações clínicas. 2a ed. São Paulo: Lovise; 2003. p. 305-23.

16. Nilson M, Soli SD, Sullivan JA. Development of the hearing in noise test for the measurement of speech reception thresholds in quiet in noise. J Acoust Soc Am. 1994;95(2):1085-99.

17. Bevilacqua MC, Banhara MR, Costa EA, Vignoly AB,Alvarenga KF. The Brazilian Portuguese hearing in noise test (HINT). Int J Audiol. 2008;47(6):364-5. http://dx.doi.org/10.1080/14992020701870205

18. Klemp EJ, Dhar S. Speech perception in noise using directional microphones in open-canal hearing aids. J Am Acad Audiol. 2008;19(7):571-8.

19. Weiss D, Dempsey JJ. Performance of bilingual speakers on the English and Spanish versions of the Hearing In Noise Test (HINT). J Am Acad Audiol, 2009;19(1):5-17.

20. Bio-logics Systems Corporarion. HINT Pro 7.2: hearing in noise test users and service manual. Mundelein: BioLogic Systems Corporation; 2007

21. Kim JS, Bryan MF. The effects of asymmetric directional microphone fittings on acceptance of background noise. Int J Audiol. 2011;50(4):290-6. http://dx.doi.org/ 10.3109/14992027.2010.551786

22. Mazzochi MT, Aita ADC. Direcionalidade e reconhecimento de fala no ruído: estudo de quatro casos. Rev CEFAC. 2013;15(3):689-96. http://dx.doi.org/10.1590/S1516-18462012005000097

23. Arieta AM. Teste de percepção de fala HINT Brasil, em normo-ouvintes e usuários de aparelhos auditivos: atenção à saúde auditiva [dissertação]. Campinas: Universidade Estadual de Campinas; 2009.

24. Mueller MH, Weber J, Bellanova M. Clinical evaluation of a new hearing aid anti-cardioid directivity pattern. Int J Audiol. 2011;50(4):249-54. http://dx.doi.org/10.3109/14992027.2010.547992