Original Article

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Speech perception in noise in elderly hearing aids users with different microphones and noise reduction algorithm

Percepção de fala no ruído em idosos usuários de próteses auditivas com diferentes microfones e algoritmo de redução de ruído

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ABSTRACT

Purpose: To evaluate speech recognition in noise on elderly, new users of hearing aids with directional microphones and noise reduction, and check which feature provides better speech intelligibility. **Methods:** The participants were 36 individuals between 60 and 87 years old with sensorineural hearing loss from mild to moderately severe. The Sentence List test in Brazilian Portuguese was applied, in sound field, obtaining the Sentence Recognition in Noise Percentage Rates (SRNPR) with hearing aids, with four different settings: omnidirectional microphone (OM); noise reduction and omnidirectional microphone (NR + OM); directional microphone (DM); and the noise reduction and directional microphone (NR + DM). **Results:** When speech and noise focused at 0°/0° azimuth, SRNPR median scores were 76.74% with the use of OM; 84.95% with NR + OM; 84.40% with DM and 86.63% with NR + DM. When comparing results, there were differences between OM x DM; OM x NR + DM; NR + OM and DM; NR+ OM and NR+ DM. When noise focused at 0°/180° azimuth, the SRNPR median were 77.4% with the use of OM; 83.79% with NR + OM; 89.46% with DM and 91.9 with NR + DM. When comparing results, there were differences between the performances with OM e DM; OM and NR + DM; NR + OM and DM; and NR + OM and NR + DM. **Conclusion:** Better results were found with the use of NR and DM in both situations of assessment, however, in the situation with noise at 0°/180° azimuth the DM provided a more satisfactory performance.

Keywords: Hearing; Hearing aids; Speech perception; Hearing loss; Aged

RESUMO

Objetivo: Avaliar o reconhecimento de fala no ruído em idosos, novos usuários de próteses auditivas, com microfone direcional e redutor de ruído e verificar qual recurso proporciona melhor inteligibilidade de fala. **Métodos:** Participaram 36 indivíduos, entre 60 e 87 anos de idade, com perda auditiva neurossensorial de grau leve a moderadamente severo. Foi aplicado o teste Listas de Sentenças em Português Brasileiro, em campo sonoro, obtendo os Índices Percentuais de Reconhecimento de Sentenças no Ruído (IPRSR) com próteses auditivas, com quatro diferentes ajustes: microfone omnidirecional (MO); redutor de ruído e microfone omnidirecional (RR+MO); microfone direcional (MD); e redutor de ruído e microfone direcional (RR+MD). **Resultados:** Quando fala e ruído incidiram a 0º/0º azimute, a mediana dos escores de acertos dos IPRSR foi 76,74% com o uso do MO; 84,95% com RR+MO; 84,40% com MD e 86,63% com RR+MD. Ao comparar os resultados, houve diferenças entre MO e MD; MO e RR+MD; RR+MO e MD; RR+MO e RR+MD. Quando o ruído incidiu a 0º/180º azimute, a mediana dos IPRSR foi de 77,4% com o uso do MO; 83,79% com RR+MO; 89,46% com MD e 91,99 com RR+MD. Ao comprar os resultados, houve diferenças entre os desempenhos com o MO e MD; MO e RR+MD; RR+MO e MD; RR+MO e RR+MD. **Conclusão:** Foram observados melhores resultados com o uso do RR e do MD nas duas situações de avaliação, porém, na situação com ruído a 0º/180º azimute o MD proporcionou um desempenho ainda mais satisfatório.

Descritores: Audição; Auxiliares de audição; Percepção da fala; Perda auditiva; Idoso

Study performed in the Speech Therapy Service of the Speech Therapy Course, Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brazil.
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INTRODUCTION

One of the biggest challenges of the elderly population who uses hearing aids, is to understand speech in noisy environments[1]. The use of this technological feature is a way to minimize the negative effects of hearing loss[2]. But even if the hearing aids are adjusted appropriately for the type and degree of hearing loss, changes related to the aging process may contribute to the deterioration and permanence of understanding of complaints in harsh environments[3].

In order to improve speech intelligibility, and hence, the performance of its members, hearing aids noise reduction algorithms and different types of microphones have been developed and incorporated to hearing aids, which have the purpose to reduce the signal/noise in the environment[4,5].

The noise reduction algorithms are meant to attenuate the intensity of noise, when it exceeds a certain proportion in relation to the speech signal[6,7], which may promote speech intelligibility, reduce the discomfort to the sounds and the effort to listen.

Among the different types of microphones, directional microphones have, as the main function, capture, with less sensitivity to sounds coming from certain directions and usually are positioned to attenuate sounds coming from behind the individual, usually the ones of less interest[8].

Although some studies[6,7,8] report that these features are important to improve understanding in noisy environments, the evidences found do not clarify whether the elderly can benefit from these settings.

Based on these data, the aim of this study was to evaluate the speech recognition with noise at different angles of incidence in a group of elderly, new users of hearing aids with directional microphones and noise reduction and check which condition provides the best speech intelligibility.

METHODS

This study was conducted at the Speech Therapy Service of the *Universidade Federal de Santa Maria* (UFSM), following the opinion of the Ethics Committee on Research (CEP) number 127.520, being characterized as longitudinal quantitative.

The study included only individuals who agreed with the necessary procedures for carrying out the study and signed the Informed Consent and Informed Term. For this, they were informed about the goals and methodology of the study, as well as data confidentiality and privacy of their identities.

The selection criteria for participation of individuals in the survey were:

- Being 60 years old or older;
- Audiological diagnosis of bilateral hearing loss, mild to moderately severe sensorineural degree, with speech recognition threshold at maximum of 65 decibels (dB) in the better ear;
- Never have used hearing aids;
- Being part of the Hearing Aid Grant Program of the Health Ministry;
- Being in bilateral adaptation process of hearing aid technology type B, with directional microphone and noise reduction, which were the features analyzed in this research.

The assessed patients came to the adaptation stage of hearing aids in the period from October 2012 to September 2013. In the appointments, the hearing aids were given to the patients, who were instructed about use, handling and care.

The individuals who, for some reason, did not accept or quit participating in the research, did not follow the selection criteria, or presented any factor that could interfere in the assessment, such as external and/or medium ear disease, or history of neurological disorder and/or cognitive and articulatory factors were excluded from this study, continuing the usual procedures of the service.

Therefore, 36 seniors were part of this study, aged between 60 and 87 years old, 12 females and 24 males.

Before performing the first assessment, an anamnesis was made, which provided information about personal data, auditory complaints, otologic history, time of hearing loss, daily habits and education level of the participants.

Two models of hearing aids of different brands were selected for this study. However, both have the same type of directional microphone, hyper cardioid, and the same kind of noise reduction, for multiband modulation with nine decibels attenuation when driven at maximum. These hearing aids are part of B Type technological devices, described in instructional hearing rehabilitation of Hearing Health Care Program of the Ministry of Health (GM Ordinance No 793 of April 24, 2012 and Ordinance GM No 835 of April 25, 2012).

Hearing aids of all assessed individuals have been programmed according to the NAL-NL1 prescriptive rule, present in the software programs. The aid was not changed between appointments, only the activation, or not, of the algorithms, has been modified. To provide better understanding of the algorithms during the weeks of use, the selected settings at each appointment were maintained and the user's volume control was deactivated.

The activation, or not, of the adjustments examined in this study was conducted in four appointments, always at the end of each appointment, and was chosen randomly, to diminish the chances of the individual's performance be related to a particular sequence of activations.

Thus, there were four possibilities for programming the adjustments:

- Noise reduction off and omnidirectional microphone;
- Noise reduction on and omnidirectional microphone;
- Noise reduction off and directional microphone;
- Noise reduction on and directional microphone.

When these adjustments were activated, the microphone directionality was adjusted and the noise reduction was set at its maximum.

In order to assess speech understanding, the individuals were submitted to the Sentence Recognition Threshold in Noise (SRTN) without the hearing aid, and the Index Sentences Recognition Percentage in Noise (ISRPN), with and without hearing aids in sound field with incident noise at 0º/180º azimuth.

Obtaining SRTN and ISRPN was performed at different times, consisting of five assessments for each individual. The first assessment was carried out in an appointment for adaptation of hearing aids without their use. On the second, third, fourth and fifth appointments, called monitoring returns, assessments were performed with the use of hearing aids, adjusted at the end of the previous appointment. The period of use of the hearing aids was between 14 and 24 days between the appointments.

The SRTN and ISRPN were obtained using the through Portuguese Sentences Lists test[9] (PSL), consisting of a list of 25 sentences, seven other lists with ten sentences and a noise with speech spectrum. Sentences and noise were recorded in Compact Disc (CD), on independent channels.

The measures of this research were obtained in acoustically treated booth, using a digital two-channel audiometer, Fonix® brand, FA-12 model and an amplification system for audiometry sound field, TA 1010 model. The sentences were presented in a CD Player of Toshiba® make, 4149 model, in lineout option coupled to the audiometer.

The application of the test was performed in an acoustically treated environment, sound field and the individual positioned one meter from the speakers, placed at 0º/0º azimuth and at 0°/180° azimuth, on vertically and horizontally, respectively. The speech remained in the front speaker (0°/0° azimuth), when noise, firstly, was shown on the front speaker (0°/0° azimuth), and subsequently the back speaker (0°/180° azimuth).

The technique for submission of sentences for the SRTN was based on the sequential or adaptive strategy, which determines the speech recognition threshold, which is the necessary level for the individual to correctly identify, approximately 50% of speech stimuli presented. The list choice was based on the order of presentation recorded in the CD.

The procedure of the research of the SRTN was the presentation of a stimulus at a certain level, obtained after training the testing, conducted with the 1A list. If the individual was able to correctly recognize the speech stimulus, the level of sound was decreased. Otherwise, it was increased. This procedure was repeated until the end of the list. 2.5 dB intervals were used after the first change in response pattern of the patient. Two thresholds were researched, one obtained with noise at 0º azimuth and another with noise at 180º azimuth.

In the ISRPN research, the presentation of sentences remained adjusted on the value obtained in SRTN found for each individual[10]. Two indexes, one with noise at 0º/0º azimuth and another with noise at 0º/180º azimuth were obtained. The ISRPN were scored considering, such as error, only the word(s) omitted or repeated incorrectly[11]. Both in research as the thresholds of the indexes, the noise remained constant at 65 dB SPL (A).

After the calculation of ISRPN in different test conditions (noise at 0/180º degrees azimuth) and with the different possibilities of algorithms activation (noise reduction off and omnidirectional microphone; noise reduction off and directional microphone; noise reduction on and omnidirectional microphone; noise reduction off and directional microphone; and noise reduction on and directional microphone) they were analyzed and statistically compared.

In order to verify the normal distribution or not of the variables, the Lilliefors test was used. Since the variables did not show normal distribution, they were compared by using the Wilcoxon test for nonparametric data. The confidence interval was used in 95%, assuming statistical significance $p<0.05$. For descriptive analysis of the data, the median values were considered as a reference.

RESULTS

This study included 36 individuals aged between 60 and 87 years old (average of 73.5 years old), 12 females and 24 males. As for the type and degree of hearing loss of these individuals, in the right ear, 36 had sensorineural hearing loss of moderate degree. In the left ear, 3 showed mild sensorineural hearing loss, 23, sensorineural hearing loss of moderate degree, 9, sensorineural hearing loss moderately severe and 1 had severe sensorineural hearing loss. Regarding education of the participants, two were illiterate, 13 attended 1 to 4 years of regular school, 20 attended 5 to 8 years of regular school and 1 attended 9 to 10 years of regular school.

The minimum, maximum, standard deviation, average and median of SRTN and comparison between different programs, with incident noise in the front position (0° azimuth), are shown in Table 1.

In Table 2, the same variables are presented, but with values related to the incident noise in the posterior position (azimuth 180°).

The average and median performance of individuals in different situations of assessment, with incident noise at 0º azimuth, are described in Figure 1.

In Figure 2, performance with noise at 180° azimuth are presented.

DISCUSSION

It was observed that there were differences between performances obtained with the omnidirectional microphone regarding the three other possibilities of adjustments, when the noise was incident from the front position (Table 1). This result may show that the performance of individuals in this assessment condition, was better with both the noise reduction or directional microphone on, as with these two associated adjustments,

Table 1. Descriptive data of percentage Index of sentence recognition in noise and comparison between different programming (sound 0/0° azimuth)

ISRPN/0°	Minimum	Maximum	SD	Average	Median	p-value
OM	35.20	100.00	13.96	74.31	76.74	0.002055*
NR+OM	42.40	100.00	12.66	82.90	84.95	
OM	35.20	100.00	13.96	74.31	76.74	0.001009*
DM	52.27	100.00	14.20	83.65	84.40	
OM	35.20	100.00	13.96	74.31	76.74	0.005820*
NR+DM	48.46	100.00	10.94	83.18	84.46	
NR+OM	42.40	100.00	12.66	82.90	84.95	0.871132
DM	52.27	100.00	14.20	83.65	84.40	
NR+OM	42.40	100.00	12.66	82.90	84.95	0.626496
NR+DM	48.46	100.00	10.94	83.58	84.63	
DM	52.27	100.00	14.20	83.65	84.40	0.871132
NR+DM	48.46	100.00	10.94	83.58	84.63	

*Significant values (p<0.05) – Wilcoxon Test

Subtitle: SD = standard deviation; ISRPN = Index Sentences Recognition Percentage in Noise; 0° = Sound on the front position; OM = omnidirectional microphone; DM = directional microphone; NR+OM = noise reduction and omnidirectional microphone; NR+DM = noise reduction and directional microphone

Table 2. Descriptive data of the percentage rate of sentence recognition in noise and comparison between different programming (sound 0°/180° azimuth)

ISRPN/180°	Minimum	Maximum	SD	Average	Median	p-value
OM	43.29	100.00	17.06	75.54	77.40	0.122713
NR+OM	43.03	100.00	15.00	81.56	83.76	
OM	43.29	100.00	17.06	75.54	77.40	0.000200*
DM	63.37	100.00	9.97	89.39	89.46	
OM	43.29	100.00	17.06	75.54	77.40	0.000019*
NR+DM	57.08	100.00	10.45	89.54	91.99	
NR+OM	43.03	100.00	15.00	81.56	83.76	0.017960*
DM	63.37	100.00	9.97	89.39	89.46	
NR+OM	43.03	100.00	15.00	81.56	83.76	0.001542*
NR+DM	57.08	100.00	10.45	89.54	91.99	
DM	63.37	100.00	9.97	89.39	89.46	0.859684
NR+DM	57.08	100.00	10.45	89.54	91.99	

* Significant values (p<0.05) – Wilcoxon Test

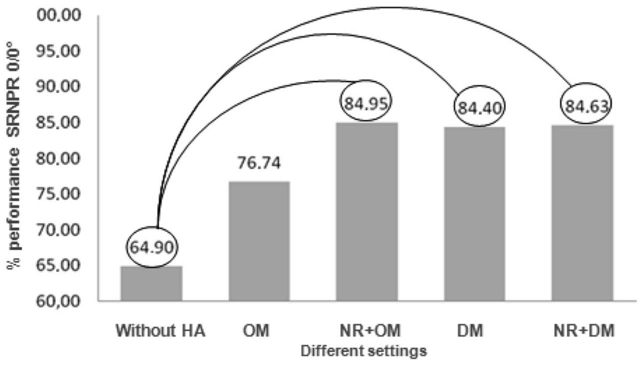
Subtitle: SD = standard deviation; ISRPN = Index Sentences Recognition Percentage in Noise; OM = omnidirectional microphone; DM = directional microphone; NR+OM = noise reduction and omnidirectional microphone; NR+DM = noise reduction and directional microphone; 180°= sound on the front position

regarding performance with the omnidirectional microphone. It was also observed that the lowest score was found when only the omnidirectional microphone was on.

When comparing the performances of individuals with noise at 0°/180° azimuth, statistical significance was found among higher scores, in the conditions in which the directional microphone or this associated with noise reduction, was compared to the other two activation possibilities of adjustments (Table 2). Thus, based on these findings, it can be inferred that, when the noise was behind the individual, the directional microphone, or this associated with noise reduction, provided better communicative performance. Moreover, it was possible to verify that the lowest scores were found when the noise reduction and omnidirectional microphone were on.

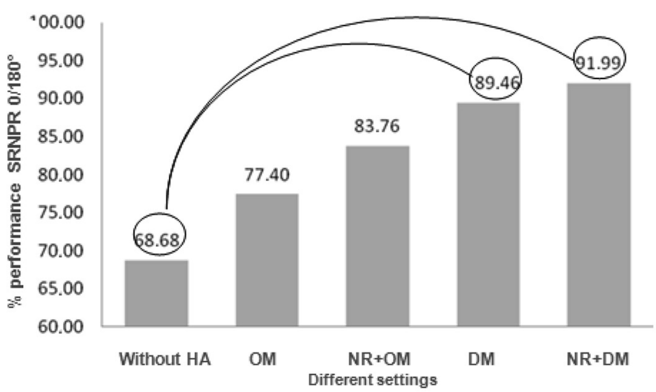
Based on these results, it may be suggested that when speech and noise come from the same sound source, and it is located in front of the subject, both the noise reduction, as directional microphone, or both on, promote better speech recognition, compared to using only the omnidirectional microphone. But when the noise comes from behind, the directional microphone is essential to provide better communication.

Although studies[12,13,14] have reported that the noise reduction algorithm does not provide improved speech intelligibility and that it may bring, as a result, distortion in the speech signals[3], these are findings that differ from the ones mentioned in this research.



Subtitle: ISRPN = Index Sentences Recognition Percentage in Noise; without HA = Without Hearing Aids; OM = omnidirectional microphone; NR+OM = noise reduction and omnidirectional microphone; DM = directional microphone; NR+DM = noise reduction and directional microphone

Figure 1. Performance of individuals in different assessment situations, with incident noise 0°/0° azimuth



Subtitle: ISRPN= Index Sentences Recognition Percentage in Noise; without HA = Without Hearing Aids; OM = omnidirectional microphone; NR+OM = noise reduction and omnidirectional microphone; DM = directional microphone; NR+DM = noise reduction and directional microphone

Figure 2. Performance of individuals in different assessment situations, with incident noise 0°/180° azimuth

Even if, by reducing interference from dominant noise to the total signal, noise reduction decreases the gain in frequencies on which is not dominant, occurring good chance of losing information that contributes to the intelligibility(3), it was observed that, in this research, it has positively contributed to the increase of high scores, providing better performance, especially when the noise was facing the individual.

These findings can be explained by the fact that the noise reduction algorithms attenuate the effort to listen, making aversive sounds less uncomfortable, improving the comfort of sounds, in general(15,16,17,18) and providing better sound quality(19,20). Thus, the cognitive ability of the individuals is released(21) to perform auditory closure and, consequently, increase the chances of improving speech understanding, based on the context(22).

Another point to be considered is the type of noise used in the evaluation of the individuals, because when the speech and noise spectra were similar, there was no evident improvements in speech perception. Thus, since speech and noise overlap, the speech signal is probably also attenuated by spectral subtraction(23).

As for the directional microphone, it was observed that it promoted better performance, both with noise coming from the front, and behind, being essential in this last condition. This result is justified, since directional microphones promote better understanding of speech in situations where the sound of interest and noise are spatially separated. So this may be the best strategy to provide increase in signal/noise ratio, which may be, on average 3 to 4 dB higher in low reverberation environments(24,25).

In general, higher scores in speech recognition with directional microphone were observed in experimental conditions where the stimulus was presented in front of the listener and the noise source set behind(19,26,27). But when the signal of interest came from behind the listener, speech recognition could be considered poor or limited(19). As for the presence of reverberation, diffuse noise sources, or other more realistic acoustic conditions may result in little improvement regarding intelligibility, a study reported that, even in a diffuse noise situations with different types of noise and S/R when the sound of interest comes from the front of the listener, better performances are found using the directional microphone(19).

It was observed that the noise situation at 0º/0º, the median of higher scores was found when hearing aids were set with noise reducer, omnidirectional microphone and the two activated settings, being approximately 20% higher compared to the performance without hearing aids and 8% higher compared to using only the omnidirectional microphone (Figure 1). But when the noise was presented at 0°/180° azimuth, the medians of scores were higher with the directional microphone and when it was associated with noise reducer, providing an approximately 22% higher score compared to the same situation without hearing aids and approximately 13% better compared to omnidirectional microphone (Figure 2).

Based on these findings, it appears that when the noise is spatially separated from the sound source of interest, speech intelligibility is less deteriorated, compared to the situation in which both have as a source the same direction. When noise comes from the subject's side and the sound of interest comes from the front, the head shadow effect attenuates the noise(28). When the noise comes from behind, the directional microphone operates so that it is picked up with lower sensitivity and, with the noise reduction helps to promotes a better performance in this situation. However, only the noise reducer, acting in this condition, is not efficient to improve speech understanding.

Based on the results found in this study, it may be suggested that in noisy environments, where speech and noise come from the same direction, the use of the noise reduction only or directional microphone, when both settings were associated, it promoted a higher score. But when the noise was coming from behind, the directional microphone is essential for better speech recognition.

Thus, it is suggested that, in elderly individuals with complaints of difficulty in understanding speech in noise, noise reduction is used as the default setting of programming. However, regarding the directional microphone, in order to find more than satisfactory results and, in this research, it has been shown as essential when the source of the noise came from behind the individual, their adjusted activation is not recommended as it may interfere in speech understanding in quiet environments and lower awareness of environmental sounds[29]. Thus, it is advised to combine directional and omnidirectional microphones. A possible combination would be to adjust one ear with directional microphone and the other with omnidirectional microphone, which has proven performance in speech understanding, close to or comparable to performance with the use of directional microphones in both hearing aids[21,29]. Other options would be the directional microphone added to another program, or even the use of adaptive directional microphone, which switches automatically between omnidirectional or directional microphone, if the noise is detected.

Even if the evidence found show positive results in communication, it is worth emphasizing, however, that the use of these resources must be carefully selected. Since changes occur in signal processing, these settings may degrade the information in the elderly with cognitive decline[30].

CONCLUSION

The noise reduction and directional microphone promoted better performance in the speech test in noise, and the directional microphone showed an even more evident effect when the noise came from the back of the individual.

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