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Frequency compression and speech recognition in elderly people

Compressão de frequências e reconhecimento de fala em idosos

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ABSTRACT

Purpose: To evaluate and compare the performance of elderly people in speech recognition tests, in silence and in noise, using hearing aids with and without the activation of the nonlinear compression algorithm (NLFC). **Methods:** Forty-eight subjects were evaluated, 33 male and 15 female, ranging in age from 61 to 84 years, with mild to moderate hearing loss of descending configuration. The Lists of Sentences in Portuguese (LSP) test was applied, seeking the Sentence Recognition Threshold in Silence (SRTS), the Sentence Recognition Threshold in Noise (SRTN), expressed by the signal-to-noise ratio (S/N) and the Sentence Recognition Percentage Index in Silence (SRPIS) and in noise (SRPIN). All measurements were obtained twice: with the use of hearing aids without the activation of NLFC (SC) and with the activation of the NLFC (CC). **Results:** It was found a statistically significant difference between the SRTS and PSRS obtained using hearing aids without and with CNLF, the latter being those that provided better results. In the S/N ratio and ISRN the analysis pointed no significant difference between the use of hearing aids SC and CC. **Conclusion:** In the measurements obtained in silence, the hearing aids with NLFC CC presented statistically better results than with NLFC SC. In the measurements with competitive noise, it was not found a statistically significant difference between the results obtained with the use of hearing aids SC and CC. This suggests that elderly people with hearing loss of descending configuration could benefit from using hearing aids with NLFC, especially in silence.

Keywords: Hearing aids; Hearing loss, High-frequency; Aged; Speech discrimination tests; Speech perception

RESUMO

Objetivo: Avaliar e comparar o desempenho de idosos em testes de reconhecimento de fala, no silêncio e no ruído, usando próteses auditivas sem e com a ativação do algoritmo de compressão não linear de frequências (CNLF). **Métodos:** Foram avaliados 48 sujeitos, 33 do gênero masculino e 15 do feminino, com idades entre 61 e 84 anos, com perda auditiva de grau leve a moderado e configuração descendente. Aplicou-se o teste Listas de Sentenças em Português (LSP), tendo sido pesquisados os Limiares de Reconhecimento de Sentenças no Silêncio (LRSS) e no Ruído (LRSR), estes últimos expressos pelas Relações Sinal/Ruído (S/R) e Índices Percentuais de Reconhecimento de Sentenças no Silêncio (IPRSS) e no Ruído (IPRSR). Todas as medidas foram obtidas duas vezes, com o uso de próteses auditivas, sem a ativação da CNLF (SC) e com a ativação da CNLF (CC). **Resultados:** Observou-se diferença entre os LRSS e IPRSS, obtidos quando usadas próteses auditivas SC e CC, sendo as próteses CC as que proporcionaram melhores resultados. Na relação S/R e IPRSR, não foi observada diferença significativa entre o uso de próteses auditivas SC e CC. **Conclusão:** Nas medidas obtidas no silêncio, as próteses auditivas CC apresentaram resultados melhores do que as SC. Nas medidas com ruído competitivo, não foi verificada diferença entre os resultados obtidos com o uso de próteses auditivas SC e CC. Sugere-se que idosos com perda auditiva de configuração descendente podem beneficiar-se do uso de próteses auditivas com CNLF, especialmente no silêncio.

Descritores: Auxiliares de audição; Perda auditiva de alta frequência; Idoso; Testes de discriminação da fala; Percepção da fala

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INTRODUCTION

Over a lifetime, numerous factors can lead to damage in the cochlea, causing hearing loss. Cumulative effects of such factors may cause presbycusis, an age-related hearing loss which, due to the cochlea characteristics, at first is larger in high-frequency than low-frequency sounds, resulting in a descending curve in the audiometric configuration[1].

The effects of presbycusis have impact on speech recognition, considering that perception of more than 25% of the speech bands are provided by frequencies starting at 3000 Hz[2]. Such difficulty can be worse in noisy environments, where the bands number decreases significantly[3].

The amplification of high frequencies with the purpose of enhancing the acoustic information transmitted to an individual and, consequently, improving his/her communication, has been provided to persons with descending hearing loss through adaptation of the hearing aids. However, in this case adaptation tends to be more complex when compared to individuals with other audiometric configurations.

This difficulty may be related to various factors, such as the limitations of gain and maximum output, mainly at high frequencies, limitations of the amplification system of the hearing aids and the risk of occurring acoustic feedback or discomfort due to the high levels of the prescribed sound pressure, especially at frequencies over 3000 Hz[4,5].

The technical limitations of conventional hearing aids eventually lead to restricted benefits and satisfaction of individuals with descending hearing loss, users of hearing aids, which led researchers to develop a number of new technologies, based on the same core idea: moving high-frequency hearing information to be perceived at low frequencies.

One of the resources of the hearing aids marketed today is nonlinear frequency compression (NLFC). It is an algorithm based on two parameters set by the professional: cut-off frequency (COF) and frequency compression ratio (CR)[6].

COF consists of the frequency at which NLFC begins to occur. Thus, the algorithm acts only on the high frequencies, preserving all those below COF, preventing the overlap of the compressed wave and low-frequency sounds. The amount of compression is progressive, i.e., frequencies above COF will be more compressed than those closer to it[6].

Although researches have been carried out using frequency compression in populations, such as in children and adults already using conventional hearing aids[4,5,7-9], benefits from this algorithm have not been yet clarified, especially for elderly persons having no prior experience in the use of hearing devices.

Aiming to contribute with the literature and the selection of the best procedures for the elderly hearing-impaired persons and to enhance their quality of life and communication, this study aimed to evaluate and compare the performance of elderly persons in speech recognition tests, either in silence or noise, using hearing aids with and without activation of the nonlinear frequency compression algorithm.

METHODS

This research was approved by the Committee for Ethics and Human Research of the Universidade Federal de Santa Maria (UFSM), process nº 05765712.3.0000.5346, and is part of a project registered at the Projects Office under no. 032630. All subjects who agreed to participate signed the Free and Informed Consent Form.

It is a cross-sectional, quantitative, observational and descriptive study. To select the samples, the personal data and audiologic assessments, as described in the medical records of all subjects who came to the *Núcleo de Seleção e Adaptação de Próteses Auditivas* (NUSEAPA) (Center for Selection and Adaptation of Hearing Aids) to initiate the selection process for adaptation of hearing aids in the period of August 2012 to January 2013, were analyzed.

A total of 275 medical records were examined, and the criteria for inclusion in the sample were: age over 60 years (elderly); having mild to moderate sensorineural hearing loss[10] and post-lingual-acquired descending configuration[11], having Speech Recognition Rate (SRR) of 60% at least without hearing aids; and having never used hearing devices.

Based on these criteria, 49 subjects were contacted by phone to participate in the research and schedule an appointment for the evaluation.

The criteria for exclusion were: history of neurological alteration, cognitive and/or articulatory factors that could interfere in the evaluation or excessive cerumen, or other alterations observed during the visual inspection of the ear canal.

Of the 49 individuals evaluated, one was excluded from the sample for having score below the cut-off on the Mini Mental State Examination (MMSE)[12], indicating a possible alteration in the cognitive area.

So, the sample was comprised of 48 individuals, 33 male and 15 female and aged between 61 and 84 years, with sloping hearing loss (Figure 1).

Data was collected between October 2012 and March 2013 at the Laboratory of Hearing Aids (*Laboratório de Próteses Auditivas* - LPA), at Universidade Federal de Santa Maria in a single assessment session. The subjects were submitted to anamnesis, application of MMSE and visual inspection of the external auditory meatus before the procedures with the use of hearing aids started.

Everyone was assessed using hearing aids binaurally, of the same brand and model, behind-the-ear type, with digital technology with six adjustment channels, output and maximum gain of 128 dB and 58 dB (2 cc coupler), respectively. Such hearing aids had NLFC activation and deactivation feature and provided two parameters for adjustment of the algorithm, jointly regulated: COF chosen of 1.5 to 6 KHz and CR range between 1.5:1 and 4:1.

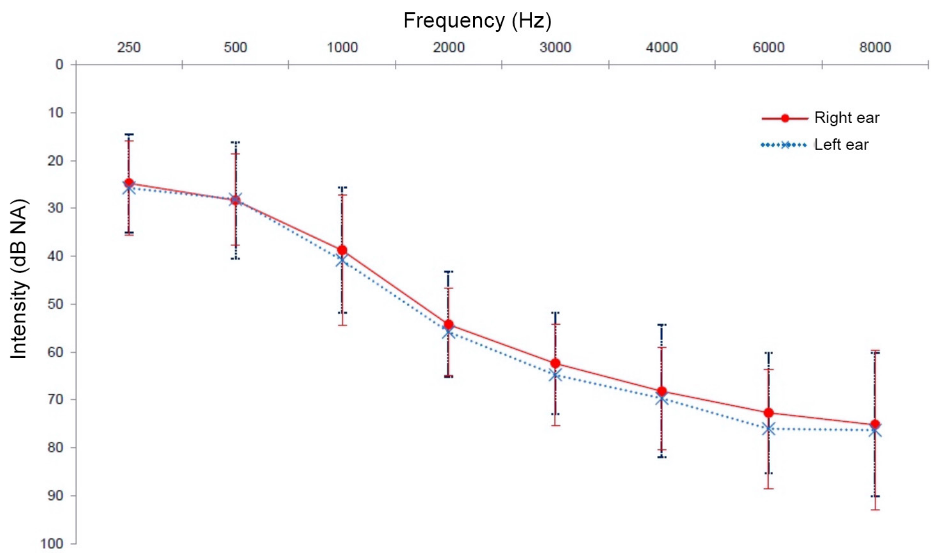


Figure 1. Mean and standard deviation of pure-tone thresholds of the left and right ears of the elderly subjects studied

Taking into account that all participants had bilateral descending hearing impairment, two hearing aids were programmed for each patient, two hearing aids without activation and two with activation of the NLFC algorithm. Programming of all hearing aids, including adjustments of gain and maximum output per frequency was performed prior to the session with the individual, by fast setting of the software, which assumes the best possible configuration for the patient's conditions. Similarly, COF and CR relating to NLFC were set. Only the acoustic feedback cancellation feature was maintained, and the other algorithms, such as control of occlusion and automatic selection of programs, were disabled. When turned on, the hearing aids were programmed to work in silence and with omnidirectional microphone. It is worth noting that the only differential between the two pairs of hearing aids used in this study was the activation or not of NLFC.

Simple invisible acrylic earmolds were used to fit the hearing aids, and the vent size was determined according to the audiometric configuration of each subject. For the programming of the hearing aids, the NAL-NL1 prescriptive method was used. Probe microphone measurements were performed prior to the tests to check the suitability of the hearing aids and to enable and disable the NLFC algorithm.

Data was collected using the List of Sentences in Portuguese test (LSP)[(13)], which allowed determining the Speech Recognition Threshold in Silence (SRTS) and in Noise (SRTN) and the Speech Recognition Percentage Index in Silence (SRPIS) and in Noise (SRPIN).

Measurements were performed in free field, in a soundproof booth using a two-channel digital audiometer, Fonix Hearing Evaluator®, FA 12 model, type I. The sentences were presented by Compact Disc Player Digital Toshiba®, model 4149, connected to the audiometer.

In order to maintain the conditions of reception constant before starting the test, the output of each VI-Meter channel of the audiometer was calibrated, setting it at zero, both the pure tone present in the first band of channel 1 and the noise present in channel 2.

To determine the SRTS and SRTN the material was applied following the procedure called "sequential, adaptive or ascending-descending strategy"[(14)]. According to this strategy, when the subject was able to correctly recognize the speech stimulus delivered, the stimulus intensity is reduced; otherwise it is increased. A response was only considered correct if the subject repeats the sentence without error or omission.

The step sizes of the sentences presentation, as recommended in the literature[(14)], are 4 dB in the first sentences until the first change in the response type, after which a step size of 2 dB is employed. However, the equipment used in this experiment did not have the feature of step sizes of 4 dB and 2 dB. Therefore, 5 dB and 2.5 dB, respectively, were used. The values of presentation of each sentence were recorded in the test protocol, and subsequently the means were calculated based on the intensity of the sentences presentation after the first change in the response type. This procedure was employed both for the thresholds of hearing in silence and in noise. In the competitive noise testing it was held constant in 65 dB SPL (A).

Taking into account that the author[(15)] of the procedure observed a difference of 7 dB in the recording volume between the speech and the noise (speech below the noise level), it was adopted as a procedure for calculation of SRTS and SRTN the subtraction of 7 dB from the speech values recorded in the equipment dial.

So, the SRTS and SRTN were determined, and the latter was expressed by the signal/noise ratio (S/N), which is the difference between the level of presentation of the sentences and the noise. Therefore, for calculation of the S/N ratio, the mean value of the speech presentation levels was subtracted from the noise level. So, whenever the speech is presented below the noise level, the result will be negative, and whenever the speech is presented above the noise level, it will be positive.

For determination of SRPIS and SRPIN, the intensity of the sentences presentation was held constant at the threshold found in the SRTS and SRTN tests of each individual, when he/she was using hearing aids without activation of the NLFC algorithm. A list of sentences was presented for each condition, and during the test the response of the patients was recorded in a protocol, which allowed the analysis of the scores. It was considered as error only the word(s) omitted or repeated incorrectly[16].

All measurements of the LSP test were performed using hearing aids, and each subject underwent SRTS, SRTN, SRPIS and SRPIN tests twice: using the hearing aids with NLFC activated and NLFC deactivated. For clarity, the letters SC will follow the measures obtained with hearing aids with NLFC disabled, and with CC letter with NFLC enabled.

Initially, the subjects were tested with hearing aids without activation of NLFC. Prior to the evaluation, all subjects underwent a pre-familiarization test in which the first five sentences of list 7B, without competitive noise, were presented. To facilitate the recognition of the first sentence of each list and in order to make sure that the test was understood, during training the initial intensity of the presentation of the sentences in silence was 10-20 dB above the Speech Recognition Threshold (SRT)[17]. Then, the first ten sentences of list 1A were used for the SRTS SC. With the presentation level set at the value found in the SRTS SC test, the SRTN SC test was carried out using list 1B.

Still using the hearing aids without NLFC activation, measurements were obtained in the presence of competitive noise at a constant level of 65 dB SPL (A). The last five sentences of list 7B were used for training with competitive noise. In this case, the initial intensity of the sentences presentation was 10-20 dB above noise. After training, the list 2B was presented for the SRTS SC testing. With the intensity set at the value found in the SRTN SC, the SRPIN SC was investigated by using the list 3B.

Subsequently, the measurements were calculated following the same parameters for testing with hearing aid with activation of NLFC. Training was performed with the same sentences, either in silence or in noise, and because it was training the repetition of the sentences would not affect the results.

After training in silence, the sentences 11 to 20 of list 1A were used for determination of SRTS CC. In order to maintain the same intensity used in the test without NLFC activation and further comparison of the results, the SRPIS CC was investigated at the same intensity found in the SRTS SC. The list used for the SRPIS CC was 4B. Then, training was performed in noise conditions for further determination of SRTN CC, using list 5B. Just as in the silence test, to find out the SRPIN CC, intensity was set at the value found in SRTN SC, and list 6B was used.

In order to avoid labeling effects similar to the ones of placebo, the sample was blinded with respect to the hearing aids assessed at each test, i.e., the patient did not know whether he/she was assessed with hearing aids with NLFC activated or deactivated.

The data was analyzed descriptively and was submitted to statistical treatment by the Statistica 9.0 software. Checking for the variables normality was made using Shapiro Wilk test. Because they had normal distribution, the variables SRTS, SRPIS and SRPIN were analyzed using the paired t-test for two dependent samples. Wilcoxon non-parametric test was used to analyze the S/N ratio variable, which indicated non--normal distribution.

The confidence interval was stated at the 95% level ($p<0.05$), and the results that showed significance were indicated by an asterisk (*).

RESULTS

The descriptive measurements and comparative results of SRTS and SRPIS of subjects using hearing aids with and without NLFC activation are shown in Table 1.

Table 1. Distribution of the subjects according to the SRTS and SRPIS results with hearing aids with and without activation of nonlinear frequencies compression

		Min.	Max.	Mean	p-value
SRTS (dB SPL (A)	SC	23.37	54.66	36.21	0.004*
	CC	21.21	55.00	34.53	
SRPIS (%)	SC	25.53	95.46	59.76	0.001*
	CC	37.12	100	67.40	

*Significant value ($p<0.05$) – Paired t-test for two dependent variables
Note: SRTS = Speech Recognition Threshold in Silence; SRPIS = Speech Recognition Percentage Index in Silence; SC = without nonlinear frequency compression; CC = with nonlinear frequency compression

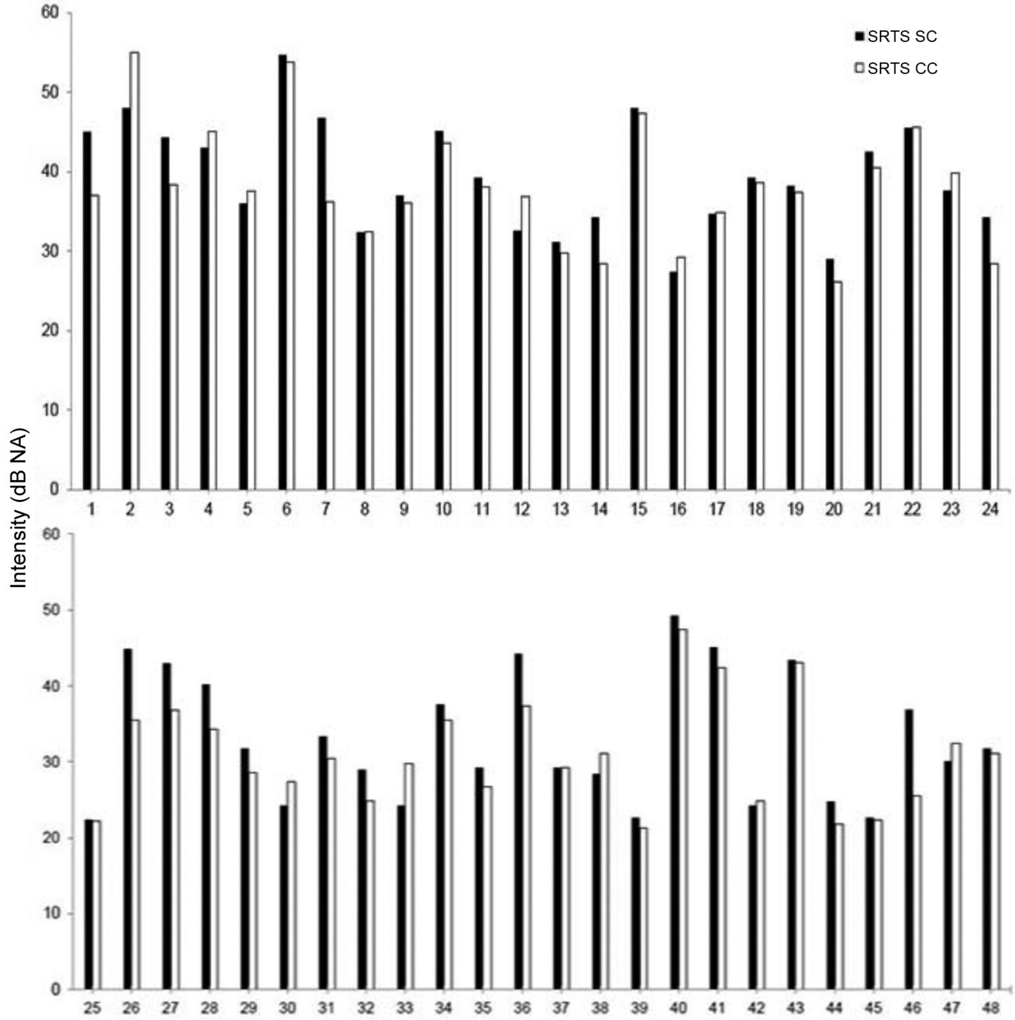
A significant difference was observed between the SRTS and SRPIS found with hearing aids with and without NLFC activation. In both measurements, CC hearing aids were the ones that showed better results.

Figures 2 and 3 illustrate the SRTS and SRPIS results for each individual using hearing aids with and without NLFC activation.

Based on the SRTS data, it was observed that 13 individuals presented similar results with SC and CC hearing aids; 25 patients showed improvement of speech recognition and ten presented worsening when using CC hearing aids.

Based on the SRPIS data, it was found that four subjects had similar results using SC and CC hearing aids; 29 patients showed better results and 15 showed worse results d with the use of CC hearing aids.

The descriptive measures and the comparative tests of SRTN, expressed by the S/N ratio and SRPIN of the subject using SC and CC hearing aids, are described in Table 2.



Note: SRTS = Speech Recognition Threshold in Silence; SC = without nonlinear frequency compression; CC = with nonlinear frequency compression

Figure 2. Comparative SRTS of each individual using SC and CC hearing aids

No significant difference between the S/N ratios and SRPIN was found with the use of SC and CC hearing aids.

Figures 4 and 5 show the S/N ratio and SRPIN of each individual using SC and CC hearing aids.

Considering the data resulting from the S/N ratio, it was found that 16 subjects showed similar results using SC and CC hearing aids; 19 showed improvement and 13 a decline in the S/N ratio with the use of CC hearing aids.

Considering the data resulting from the SRPIN, it was observed that two subjects showed similar results using SC and CC hearing aids; 26 had improvement and 20 showed a decrease with the use of CC hearing aids.

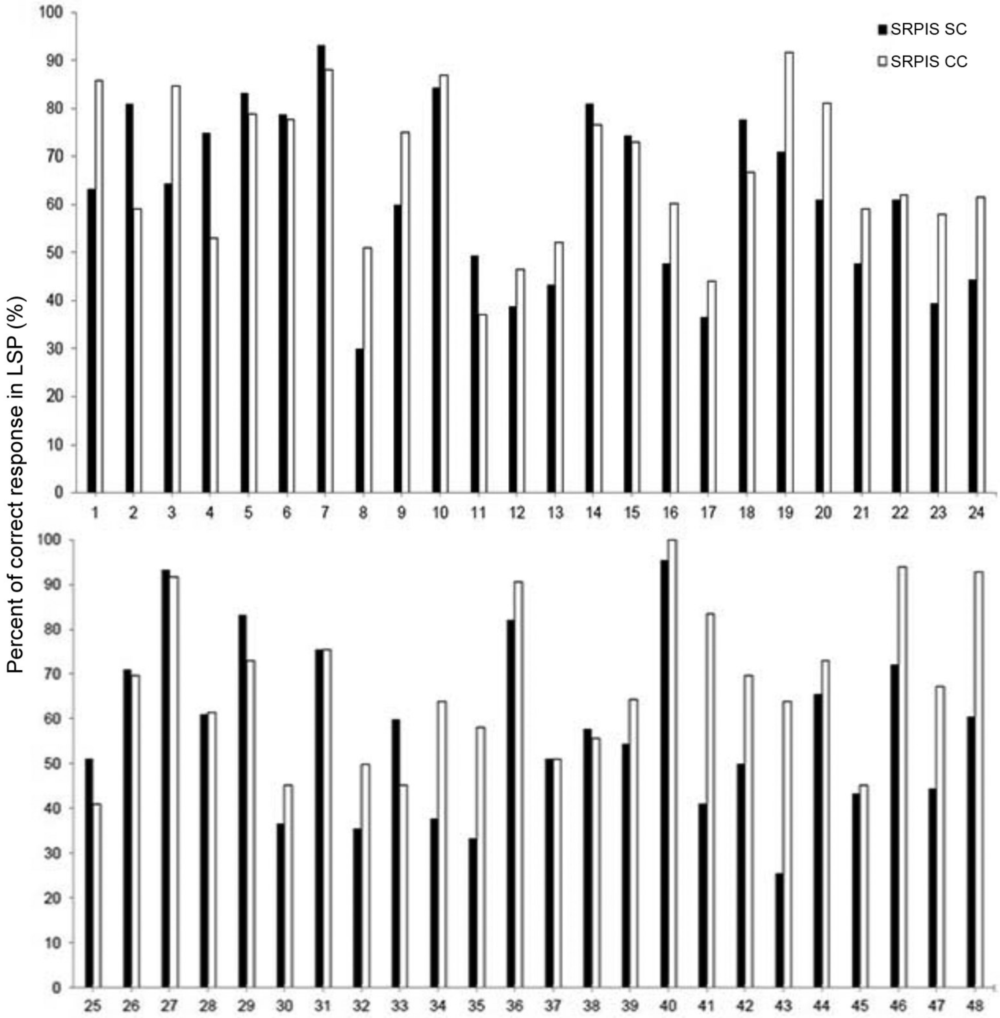
DISCUSSION

The aim of this study was not to compare the performance of elderly people with adults or children, but taking into account that there is very little literature associating the algorithm with old ages, the findings of this study were compared with studies covering other ages and similar frequency lowering resources.

The results found in silent condition (Table 1), which presented significant differences between the use of hearing aids with NLFC activated or deactivated, are in agreement with studies conducted with children and adults in which the NLFC contributed to an improved audibility of pitches at 4, 6 and 8 kHz[5] and an improved ability to identify the /s/ and /sh/ phonemes and recognize monosyllables, consonants and plurals[7,9].

On the other hand, the present study is not in agreement with a research that evaluated in adults the ability to recognize monosyllables and consonants in silence, comparing the conventional amplification with that in which NLFC was activated, and no significant difference was found[8].

Other frequency-lowering methods, e.g., transposition, showed good results in silence in experiments conducted with adult and elderly persons, with improved detection and recognition of fricatives and other consonantal sounds[18-20].



Note: SRPIS = Speech Recognition Percentage Index in Silence; SC = without nonlinear frequency compression; CC = with nonlinear frequency compression

Figure 3. Comparative SRPIN of each individual with SC and CC hearing aids

Table 2. Distribution of the individuals according to the SRTN and SRPIN results using hearing aids with and without activation of nonlinear frequencies compression

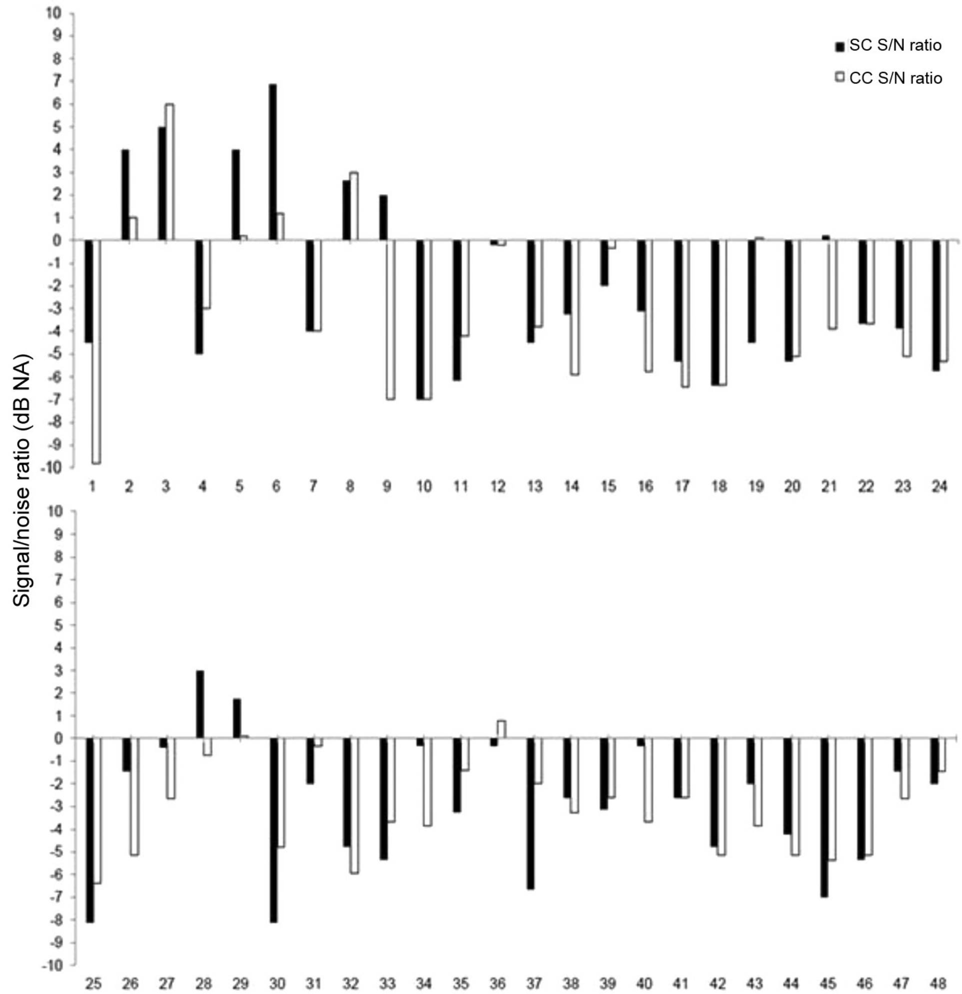
		Min.	Max.	Mean	p-value
S/N ratio (dB SPL (A)	SC	-8.12	6.88	-2.53	0.163
	CC	-9.80	6.00	-3.16	
SRPIN (%)	SC	3.57	90.09	60.12	0.302
	CC	7.77	97.68	62.32	

Wilcoxon test (S/N ratio); Paired t-test for two dependent variables (SRPIN) ($p<0.05$)
Note: S/N ratio = Signal/noise ratio; SRPIN = speech recognition percentage index in noise; SC = without nonlinear frequency compression; CC = with nonlinear frequency compression

It should be noted that most of the studies mentioned earlier were conducted with subjects with prior experience in the use of hearing aids, often users of conventional amplification. In addition, they were longitudinal researches in which the subjects had had previous home experience with the use of NLFC, which facilitated the adaptation to the new compressed signal. The evaluations were made during this period.

A compilation of the findings of this study with others would indicate that the algorithm has shown goods results in silence anyway. So, it can be seen that the in new signal processing devices and because the sound reception is not so natural, this is overcome by using the residual hearing more effectively. In addition, by making sounds audible even at higher frequencies, which are not in the range of the adaptation frequency of conventional hearing aids, NLFC provides increased transmission of high-frequency acoustic information to be perceived at low frequencies. So, besides restoring the audibility of high frequencies or because of this there is also improved speech recognition, as found in this study.

Because the SRPIS has been evaluated with the same value found in the SRTS, which corresponds to approximately 50% of the correct responses in the sentences recognition, it can be stated that the perception of the individual with respect to the intensity of presentation of the sentences was relatively



Note: S/N ratio = signal/noise ratio; SC = without nonlinear frequency compression; CC = with nonlinear frequency compression

Figure 4. Comparative S/N ratio of each individual using SC ad CC hearing aids

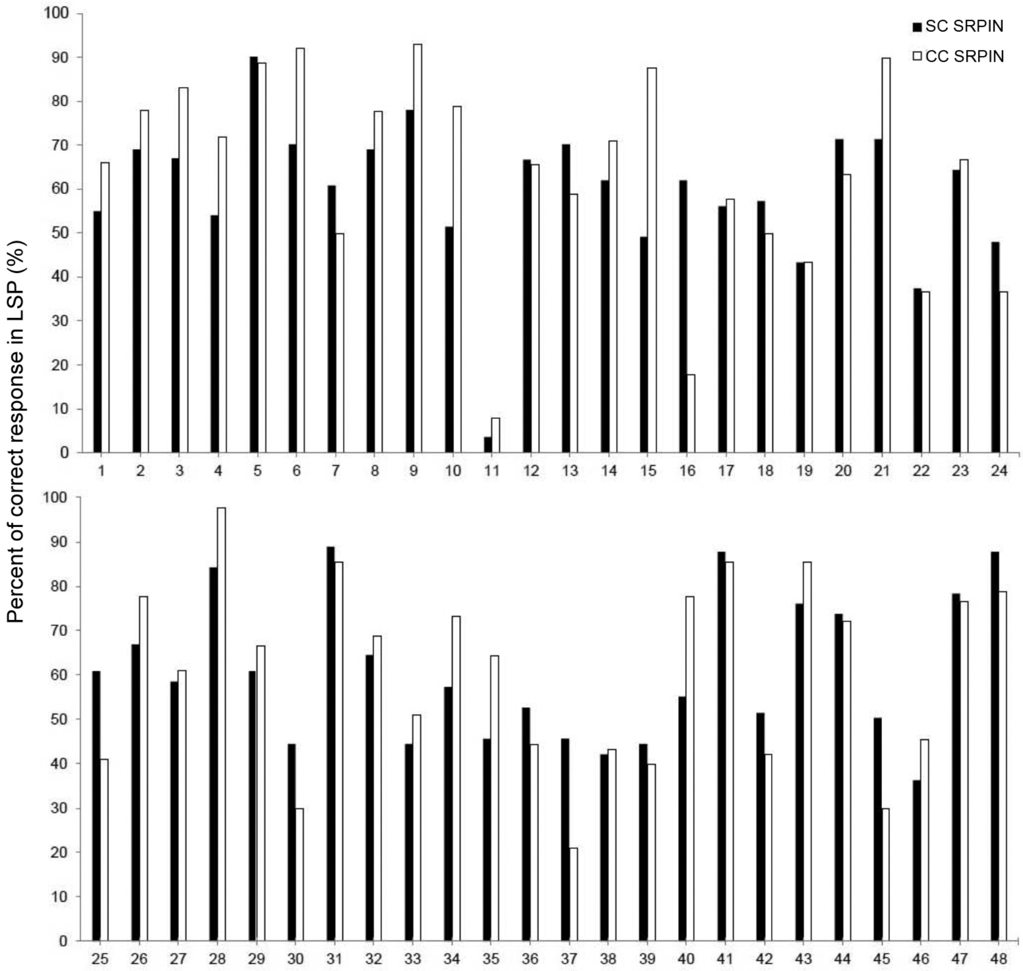
low. Thus, the positive measures with the use of NLFC, when compared to conventional amplification, corroborate the idea that NLFC can be a feature that enhances audibility of soft sounds where other adjustments, due to limitations of gain or occurrence of acoustic feedback, for example, were not efficient. Positive responses to low-pitched sounds have been reported earlier by other studies[20,21].

The number of subjects who achieved better results with NLFC was nearly twice as much of those with conventional amplification. Furthermore, the fact that in some cases the extension of the benefit received from the use of the algorithm has been irrefutable evidence, the positive effects of NLFC would not be accomplished with conventional amplification of high frequencies, due to the limitations already known.

Whereas in the present study more than 60% of the subjects presented some improvement in speech recognition when using hearing aids with NLFC, in an experiment carried out with 17 subjects using the same resource, eight of them, which corresponds to 47% of the sample, showed significant improvement of phonemes recognition when the algorithm was used[7]. In another study, the improvement in hearing corresponded to half of that found in this research: 22 subjects were evaluated in the identification of /s/ and /sh/ and only seven, i.e., 30% showed improvement. Also, in the recognition of plurals, the index increased to 35% of subjects who showed improved hearing and dropped to 19% in the evaluation of consonants recognition[9].

The difference between the reported individual improvement rates increases when compared to studies conducted with five or seven subjects, in which only 20% and 14%, respectively, showed improved recognition of monosyllables and consonants when experiencing frequency-lowering methods[8,19].

The type of stimulus used to obtain the data of the present research can explain the greater number of subjects who benefitted from NLFC, compared to other studies. Reported distortions of consonantal sounds, especially fricatives, and confusion between phonemes, as described by other studies[8,18,19], were not common in this research. As the patients were evaluated by means of sentences, the linguistic context



Note: SRPIN = Speech Recognition Percentage Index in noise; SC = without nonlinear frequency compression; CC = with nonlinear frequency compression

Figure 5. Comparative SRPIN of each individual using SC and CC hearing aids

of the phoneme might have facilitated the distinction from other phonemes that could become similar after compression. A typical example of such confusion occurs between /sh/ and /s/, where the first phoneme has dominant energy between 2000 and 4000 Hz, which corresponds to the frequency range in which the phoneme /s/ will be audible after frequencies lowering[20].

In spite of that, it is believed that the type of stimulus used will not invalidate the favorable results of NLFC. On the contrary, it values them in that the sentences simulate better the daily communication situations to which the patient will be exposed.

The worst performances presented by some individuals, when evaluated with the use of hearing aids with NLFC, may be explained by a series of individual factors, such as educational level, cognition and hearing abilities, among others.

Authors point out that data analysis, such as the frequency in which hearing loss becomes more severe and the difference of thresholds by octave would help the interpretation of individual performance differences, once the subjects with a steep slope in the audiometric curve tend to obtain fewer benefits than those with moderate decline[7,8]. The CR analysis also becomes interesting because the higher the CR applied the greater the distortion of the sound signal and, likely, the worse the subjects' performance[8]. Thus, these aspects should be taken into consideration in future studies.

With respect to the data relating to the speech recognition in silence, it should be taken into account that they were obtained in the first contact with the patients using hearing aids. Some authors emphasize that due to the spectral alterations caused by NLFC, the period of acclimatization may be longer than that with conventional hearing aids. Their studies reported an improvement in the aspects assessed after using the algorithm for some months[9,20,22]. In addition, they pointed that in some cases training is important to help users to be familiarized with the new speech signal[18,19,23]. Therefore, it is believed that after acclimatization the results would be even better.

The results found in competitive noise conditions (Table 2), which shows that there was no significant difference in the performance with the use of hearing aids with the NLFC activated or deactivated, agree with the findings of previous studies, in which the performance of hearing aids with frequency lowering was similar to that of conventional devices, and in noise conditions several tests also used sentences as stimulus(5,8,19).

Still, some authors reported that frequency lowering might compromise the speech recognition in noise(24). Hypotheses have been made as to possible disadvantages in using this technology in such situations. One of them would be that high-frequency noises, not audible before, would be perceived, making the new S/N ratio not sufficient to enhance the speech recognition by listeners(5).

An alternative to overcome such aspects would be the use of frequency transposition/compression, developed to act specifically on fricative and/or affricative consonants(18,25). Although one of the studies had resulted in greater mishearing of phonemes after using this resource(18), another work, developed by Brazilian researchers, had good results in normal-hearing individuals and in simulation of dead zones in the cochlea, in high frequencies(25).

However, NLFC still is an alternative that after acclimatization may provide greater satisfaction and benefits in speech recognition by subjects with descending hearing loss, even in acoustically unfavorable environments. This is corroborated by previous studies that revealed that the daily exposure to the compressed signal by patients using hearing aids with frequency lowering could lead them to recognize more easily the altered signal in noise(4,20,22).

As clearly demonstrated by researchers, the fact that the resource does not show negative effects in in-noise speech recognition may be considered an important and positive finding for using it in situations where speech occurs concurrently with a competitive signal(20). It is believed that with the activation of algorithms and the use of directional microphone to reduce noise, which were deactivated in the present study, the benefits of NLFC in this condition would be greater, especially after the acclimatization period, as mentioned earlier in this study.

The improved S/N ratio and SRPIN of individuals using hearing aids with activated NLFC (Figures 4 and 5), as found in this study, is similar to that reported in an experiment conducted with 11 adults and elderly subjects, in which seven of them had their performance improved in recognizing sentences in noise with the use of NLFC(4). But in experiments conducted with smaller size samples showed a smaller proportion of subjects who benefitted from the use of the algorithm, when exposed to competitive signals(8,19). It should be noted that in the present study the benefit provided with the use of the algorithm was not so pronounced as that observed in silence, which is consistent with the fact that there was no difference in the analysis of the group, in noise condition.

It is worth noting that if for young normal individuals speech recognition in competitive noisy environments demands much more effort than in silent environments, for hearing-impaired elderly persons such difficulty is much greater.

For many authors, hearing impairment would not be the primary factor responsible for the differences in the hearing abilities of adult and elderly persons(26-28), but rather the diffuse effect of aging, which affects the central nervous system and the cortical processing(28).

Although no specific test to evaluate the auditory processing has been applied in the present research it is well known that elderly persons have difficulty in the auditory processing of speech signals distorted by noise(29). The results of this study agree with the above statement since in silence the subjects were able to benefit from increased acoustic information transmitted with NLFC, even with distorted signal. But when evaluated in noise, the difficulties in the auditory processing arising from the aging process became more evident, once in this condition there were two negative active factors: noise and the distortion from the new signal processing.

Changes during aging also lead to a decreased functional S/N ratio, requiring adjustments in this ratio with a louder speech signal for the message to be recognized in competitive noise. The findings of this study corroborate the foregoing description, once such adjustment can be provided by NLFC, a fact that was observed in more than 40% of the older persons that showed some improvement when the algorithm was used in noise conditions. It is believed that the elderly persons who had such benefit would likely present better results in tasks of auditory processing than the 30% who had their performance diminished, in the same condition.

Furthermore, it is known that the speech recognition in such situations requires non-auditory abilities, such as attention (focus on a particular sound), inhibitory control (ignoring irrelevant sound) and memory (recalling the speech information). But such abilities may also be impaired with aging(30) and might have impacted negatively the results found in noise.

Considering the reported results, it is believed that hearing training may help elderly people get used to the distortions caused by NLFC and stimulate their auditory and non-auditory abilities, which would maximize the advantages that some of them already had with the use NLFC and even be beneficial to those who have not shown them yet(18,20,23).

By comparing the results in conditions of silence (SRPIS) and noise (SRPIN) with NLFC activated, it caught our attention in this research the fact that 14 subjects showed worsening speech recognition in silence, and 11 subjects showed improvement in silence and worsening in noise. It was observed that more than 50% of the sampled subjects showed improvement in the speech recognition with the use of the resource in one condition and worsening in other.

Changes in the auditory processing level that were likely presented by some patients can explain part of the data described above. Also, it should be noted that the hearing aids setting was performed generally and automatically the default program of the software. Therefore, finer adjustments might result in more positive performances in both situations, noise and silence. Even so, the findings suggest that in some cases the use of different programs would be interesting considering the diverse situations to which the patient will be exposed, either with NLFC activated or not.

Considering the above, it can be affirmed that the findings of this study demonstrated that elderly persons are able to deal with changes in signal processing and distortions caused by NLFC, and may also benefit, even in the first time, from the improved audibility provided by the algorithm. Anyway, it should be emphasized that individual aspects such as daily life, occupation, educational level, and hearing and cognitive skills should be taken into consideration when deciding on the use or not of the algorithm.

CONCLUSION

In silence, the use of hearing aids with NLFC provided greater benefits in speech recognition by elderly persons than when using hearing aids without NLFC. In-noise speech recognition by the elderly persons was similar to that using hearing aids with NLFC activated or deactivated.

Based on this study, it can be suggested that elderly persons with sloping hearing loss can benefit from the use of hearing aids with NLFC, especially in silent environments.

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