

# THE PERFORMANCE OF THE ELDERLY WITH NEUROSENSORIAL HEARING LOSS IN AUDITORY PROCESSING TESTS: A LONGITUDINAL STUDY

## *O desempenho de idosos com perda auditiva neurosensorial nos testes de processamento auditivo: um estudo longitudinal*

Gabriela Cavagnoli Rodrigues da Fonseca<sup>(1)</sup>, Maria Inês Dornelles da Costa-Ferreira<sup>(2)</sup>

### ABSTRACT

**Purposes:** to verify the performance of elderly in tests of auditory processing at the delivery of the hearing aids, after a month of use and after the auditory training. **Methods:** the study was carried out with 11 elderly people, between 60 and 79 years old, wearing hearing aids, at Centro de Saúde Clélia Manfro. All patients were submitted to Speech in Noise tests, normal or expanded Random Gap Detection Test and to the binaural integration stage of the Dichotic digits test, in three different moments: at the delivery of the hearing aids, after a month of use, and after five auditory training sessions. **Results:** in relation to sex, 7 (63.64 %) were women. The mean age was 71.27 ( $\pm$  5.33). The average time of daily use of the hearing aids was 10.18 hours ( $\pm$  2.44), and of sensory deprivation was 5.82 years ( $\pm$  5.29). All participants gradually increased the scores in tests of auditory processing, reaching better performance after the auditory training, and the comparison between the three moments resulted statistically significant ( $p < 0.001$ ). **Conclusion:** the process of adaptation to the hearing aids as well as the auditory training led to an improvement in speech recognition with and without competing message as reflecting the period of acclimatization after the second evaluation and the effect of auditory training after the third assessment.

**KEYWORDS:** Hearing Loss; Auditory Perception; Hearing Aids; Correction of Hearing Impairment

### ■ INTRODUCTION

Communication is the primary means of interaction between the individual and the world and, for a perfect interaction, an intact auditory pathway is necessary. For the hearing and, consequently, for an effective communication, both the peripheral and the central auditory systems must be in perfect conditions. The disorder occurs when the individual is not able to use thoroughly the auditory stimulus, failing in one or more strategies. Any failure in the perception, analysis and full interpretation of auditory information generates a decrease in auditory function<sup>1-3</sup>.

In the case of hearing loss, the individual experiences both emotional and social instability to be able to adapt to the society, since there is a decrease in speech intelligibility which causes difficulty in maintaining social relations and dialogs, generating frustration and stress. Therefore, the individual gradually begins to become isolated<sup>4,5</sup>.

In the aging process, the hearing loss tends to happen to the majority of individuals and to cause a great impact on their quality of life<sup>1,4</sup>. Due to this sensory deprivation, there is usually an auditory processing disorder, affecting one or more auditory abilities of the individual. With the objective of minimizing all these aspects caused by hearing loss, there are strategies that may help the elderly to listen better and to understand speech again.

With the brain aging, auditory processing difficulties in elderly people with hearing loss may be potentiated, manifesting through difficulties in

<sup>(1)</sup> Faculdade Nossa Senhora de Fátima, Caxias do Sul, RS, Brasil.

<sup>(2)</sup> Curso de Fonoaudiologia do Centro Universitário Metodista do Instituto Porto Alegre, Porto Alegre, RS, Brasil.

Conflict of interest: non-existent

speech understanding in noisy situations, and in information processing both verbal and non-verbal. Thus, it is possible to infer that most patients with sensorineural hearing loss and in aging process present deficits in some ability of the auditory processing<sup>6,7</sup>.

The first step in the rehabilitation process is the selection and the adaptation of the Hearing Aid (HA), which will be selected and adapted uni- or bilaterally and will have the necessary characteristics for each individual. In addition to the auditory aspects, the non-auditory needs that limit and restrict the individual's activities in his daily life should be assessed. These aspects, affected by hearing loss, can also affect the intervention prognosis<sup>8</sup>.

However, it is known that even wearing Hearing Aids (HA), the complaints related to the difficulties in speech intelligibility remain. For this reason, it is recommended to perform an auditory training after receiving the hearing aid. During this process, activities that aim to optimize the functional gain of the hearing aid will be carried out, improving the auditory abilities that have been altered due to the sensory deprivation<sup>9</sup>.

Another point to be emphasized is the efficiency of binaural adaptation because there is a small percentage of individuals adapted bilaterally who present many complaints due to a lack of inter-hemispheric communication. Thus, the ability of bilateral speech perception becomes impoverished when compared to the same ability of the ear with better performance. Thus, the individual would need to perform an auditory training for greater effectiveness of binaural adaptation<sup>10,11</sup>.

The auditory training is a set of strategies used to rehabilitate the auditory abilities, promoting plasticity and cortical reorganization<sup>12</sup>. The auditory plasticity may be understood as the capacity of reorganization of the nerve cells by means of a variation of input stimulus through enhancement and training. Thus, the auditory processing tests lead the speech pathologist to the more appropriate type of auditory training for each individual<sup>13</sup>.

Due to the lack of studies in this area and to the importance of the comparative tests in the three moments of hearing aid fitting (on delivery, after a month of use and after the auditory training), this study aimed to verify the performance of elderly people in tests of auditory processing on the delivery of the hearing aid, after a month of using this device and after the auditory training.

## ■ METHODS

The present study was approved by the Research Ethics Committee of Faculdade Nossa Senhora

de Fátima, protocol number 340.168 /2013. The Term of Institutional Knowledge was signed by the coordinator of Centro de Saúde Auditiva. The data collection was preceded by authorization of the subjects through the signed Informed Consent Form.

It is a prospective, longitudinal and contemporary study. The instrument of study is an initial questionnaire containing data of the subject, time of sensory deprivation (period between the first diagnosis of hearing loss and the use of hearing aid) and daily time of use of hearing aid (informed by participant and confronted with the programming software of the hearing aid device); also, the records of the results of the following tests- Speech in Noise, the conventional and the expanded RGDT (the latter performed just in case the patient is not able to meet the conventional test) and Dichotic Digit.

The sample was composed of 11 subjects between 60 and 79 years old with audiological diagnosis of symmetric, mild to moderate, bilateral sensorineural hearing loss, residents in Caxias do Sul and wearing HA properly prescribed in the Health Center of average complexity of the Institution, having passed through the stages of delivery of hearing aid, revision of the device and auditory training.

In the first session was applied the advice guide, prepared by the Audiology Service, with the objective of verifying the general functioning of HA, as well as their handling and care. The patients and their families' doubts were clarified and some general guidelines were provided. It was also possible to observe the communication strategies in different environments and the use of telephone.

The subsequent sessions included tasks of stimulation of the following skills: detection, discrimination, recognition and understanding. All the performed tasks required some degree of cognitive demand (attention, memory, language and executive functions). The level of difficulty of the activities was gradual and in agreement with the results obtained in each session.

The first contact was made on the delivery of the hearing aid. After the informed consent for participation in the research, the auditory processing tests were conducted. After a month of use of HA, participants returned for the equipment checking and after five sessions of auditory training, as recommended by the Policy of Hearing Health, the same tests were performed aiming to compare the results.

In the second moment of evaluation the participant was asked about the time- in years- of auditory deprivation before looking for the health service, and the time- in hours- of daily use of the hearing

aid. By the last evaluation, this question was made once again.

For the tests of auditory processing, the participant, with supra-aural headphones and without the hearing aid, remained in an acoustic booth. The verbal tests in Portuguese<sup>14</sup> and the non-verbal test in English<sup>15</sup> are available in CD and were applied by means of a two-channel audiometer (AC 33 Interacoustics) connected to a notebook, at 40 dBNS, above the average of audiometric frequencies from 500Hz to 2000Hz of the participant.

Firstly, the test of Speech in Noise was performed. It consists of the simultaneous presentation of 25 monosyllabic words and of white noise in the same ear. Patient was requested to repeat the words he heard ignoring the ipsilateral noise. The signal-to-noise ratio used was 0 dB, i.e. monosyllables and white noise at the same intensity.

Negative relations were not used because the participants with sensorineural hearing loss tend to have great difficulty to discriminate the message. Afterwards, the same procedure was repeated in the other ear. This test evaluates the ability of auditory closure.

Soon after, the Random Gap Detection Test (RGDT), marketed by Auditec<sup>15</sup>, was applied. It consists in identifying the shorter interval between two pure tones. The participant was instructed to hear the pure tone, identify if one or two tones were heard, and inform it with his fingers<sup>16</sup>. If the participant could not respond to conventional RGDT, whose time intervals range from 0 to 40 ms, the expanded form in which the time intervals are wider, ranging from 50 to 300 ms was applied to facilitate the tones identification. The ability evaluated is the temporal resolution, required for the speech discrimination.

And finally the Dichotic Digit test, stage of binaural integration, was applied. It consists of the simultaneous presentation of two pairs of digits, each pair presented in one ear. The participants were instructed to repeat the four digits heard in both ears. The purpose of the test is to evaluate the function of binaural integration<sup>14,17</sup>.

The statistical package used was the SAS System for Windows (Statistical Analysis System)

version 9.2. To describe the profile of the sample, according to the variables in study, analyses of the categorical variable (gender), with values of absolute frequency (n) and percentage ( % ), and of the continuous variables (age, times and test scores) were made, with average values, standard deviation, minimum and maximum values, median and quartiles.

To compare the values of the auditory processing tests among the three assessments, the Friedman test and the Wilcoxon's tests were used for the comparison between two assessments, due to the small size of the sample and absence of normal distribution of scores. To compare the performance in the tests according to the gender the Mann-Whitney test was used, due to the absence of normal distribution of the variables.

To analyze the relationship between the tests and the numerical variables we used the Spearman correlation coefficient. The level of significance in this study was 5 %, i.e.,  $P < 0.05$ .

## ■ RESULTS

Of the 11 participants, 7 (63.64 %) were female and 4 (36.36 %) were males. The minimum age was 61 and the maximum, 78, being 71.27 ( $\pm 5.33$ ) the average age obtained.

As to the number of hours of use of HA, the minimum daily time was 7 hours and the maximum was 16 hours, with an average of 10.18 hours ( $\pm 2.44$ ). All participants maintained their answers in the two moments they were questioned about the daily time of use of hearing aid. Besides the participants' information, the time was checked in the software used to adjust the hearing aid.

In relation to the time of sensory deprivation, i.e., the period between the first diagnosis of hearing loss and the first use of HA, the minimum time was 2 years, maximum, 20 years and the average was 5.82 years ( $\pm 5.29$ ). Table 1 shows the participants' performance in the auditory processing tests carried out in the three moments of collection (when the hearing aid was delivered, after a month of use and after the auditory training).

**Table 1 - Average Performance and standard deviation obtained by participants in auditory processing tests carried out in the three moments of data collection (n= 11)**

	Hearing Aid Delivery	After a month of use	After auditory training	*P-Value
Speech in Noise RE (%)	33,82 (±13,55)	42,18 (±12,82)	54,18 (±12,54)	p<0,001 = 1#2, 1#3, 2#3
Speech in Noise LE (%)	31,64 (±14,58)	42,91 (±15,71)	53,82 (±14,13)	p<0,001 = 1#2, 1#3, 2#3
Dichotic Digit Bi RE (%)	57,73 (±22,98)	69,09 (±19,76)	77,95 (±16,69)	p<0,001 = 1#2, 1#3, 2#3
Dichotic Digit Bi LE (%)	59,32 (±24,65)	68,41 (±19,05)	81,14 (±14,72)	p<0,001 = 1#2, 1#3, 2#3
RGDT BE (ms)	36,07 (±35,14)	29,93 (±29,13)	18,11 (±21,21)	p<0,001 = 1#2, 1#3, 2#3

Caption: RE=right ear; LE=left ear; BE=both ears; Bi=binaural integration; ms=milliseconds \* P-Value for the Friedman test for related samples for comparison between 3 assessments, followed by the Wilcoxon test for related samples for comparison between two assessments.

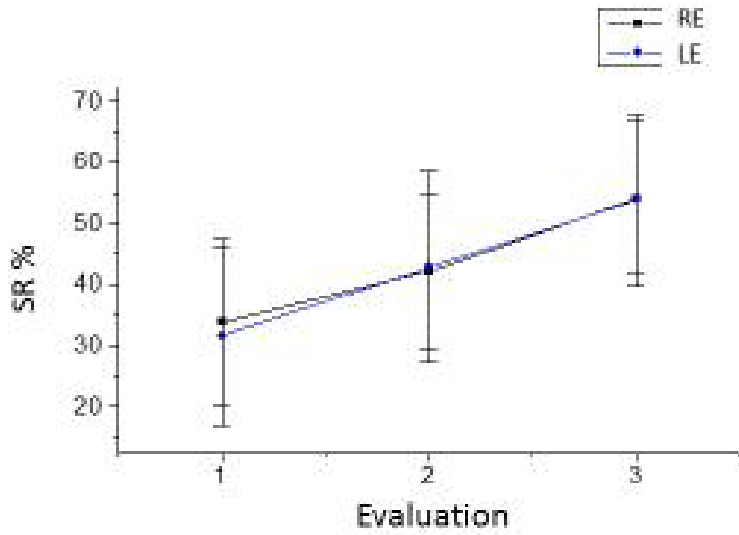
The data collected in the three assessment moments were compared and the results were statistically significant  $p<0.001$ , according to the Figures 1, 2 and 3. Figure 1 shows the participants' performance in the Speech in Noise test, for both ears, in the three assessment moments.

Figure 2 shows the performance in the RGDT and Figure 3, the performance in binaural integration for the Dichotic Digit test.

The performance in the Speech in Noise and Dichotic Digit tests (expressed by percentage of correct answers) was directly proportional, i.e., the performance increased as the three phases of data

collection were considered. Regarding the RGDT, a descending graph may be observed, but this is also an indicator of an increase in performance, since it is expressed in milliseconds.

The participants' performance in auditory processing tests was compared according to the sex, but no statistically significant differences were identified. After the auditory training, the analysis of the correlation between the variables showed that the lower the performance in the Speech in Noise test for the right ear, the greater the time of sensory deprivation ( $r = -0,68692$ ;  $p = 0.0195$ ), as shown in Figure 4.

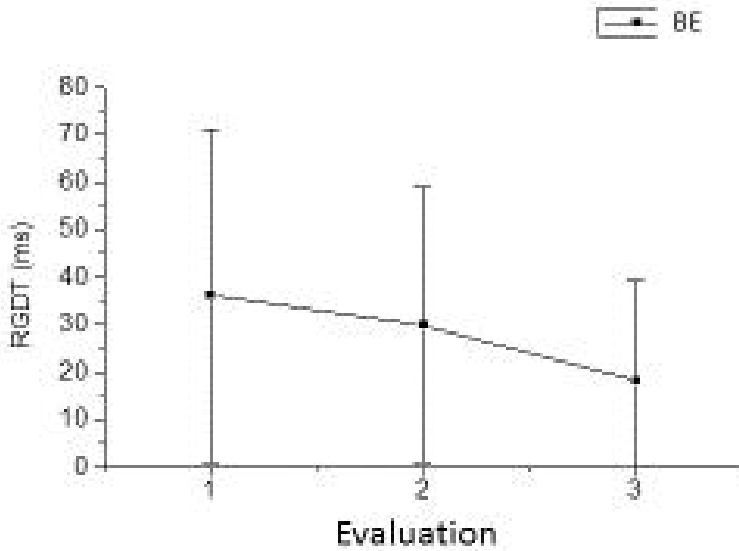


\*P Value =  $p < 0,001 = 1 \neq 2, 1 \neq 3, 2 \neq 3$

SN-Speech in Noise; RE-right ear. Friedman Test and Wilcoxon Test

\*Pvalue-for the Friedman test for the related samples for comparison between 3 assessments, followed by the Wilcoxon test for related samples for comparison between 2 assessments

**Figure 1 - Performance of the participants in the Speech in Noise test for both ears when comparing the three moments of evaluation (n=11).**

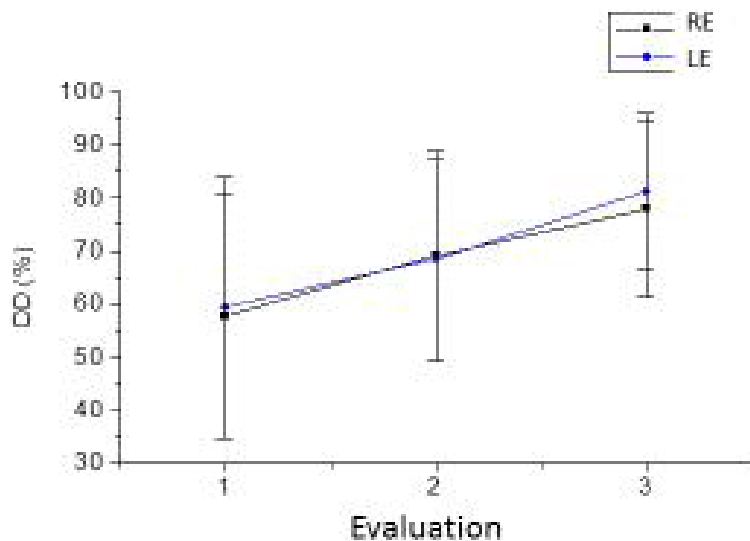


P Value =  $p < 0,001 = 1 \neq 2, 1 \neq 3, 2 \neq 3$

caption: RGDT=Random Gap Detection Test; BE=both ears. Friedman and Wilcoxon tests

\* P-Value for the Friedman test for related samples for comparison between 3 assessments, followed by the Wilcoxon test for related samples for comparison between 2 assessments

**Figure 2 - Performance of the participants in the test Random Gap Detection Test for both ears when comparing the three moments of evaluation (n= 11).**

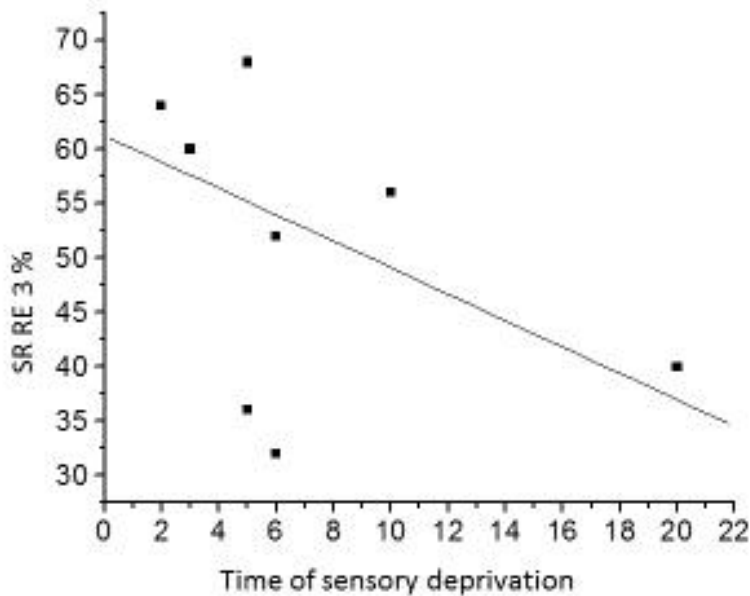


P value =  $p < 0,001 = 1 \neq 2, 1 \neq 3, 2 \neq 3$

caption: DD=dicótico de dígitos; RE=right ear; LE=left ear. Friedman and Wilcoxon tests

\* P-value for the Friedman test for the related samples for comparison between the 3 assessments, followed by Wilcoxon test for related samples for comparison between 2 assessments.

**Figure 3 - Participants' performance in the stage of binaural integration of Dichotic Digit test for both ears when comparing the three moments of assessment (n= 11).**



P value =  $p < 0,05$

caption: SN=Speech in Noise; RE=right ear. Coefficient of Spearman

\* p value for coefficient of Spearman

**Figure 4 - Correlation between the performance in the test of Speech in Noise for the right ear done after the auditory training and the time of sensory deprivation.**

## ■ DISCUSSION

This study started with an 18-participant sample, but seven were excluded due to lack of adherence to the auditory training. Even showing the importance of auditory training to improve the adaptation of the hearing aid and the speech understanding, it was found that this whole process is not yet part of the culture of participant sample. Therefore, it is necessary a wider dissemination of information about the importance of the auditory training after the hearing aid adaptation, aiming to increase the elderly adherence to the auditory training.

Eleven elderly people, aged between 60 and 79, being the average age 71.27, participated in this research. Another study that evaluated individuals in the same age group had an average age of 70.8 for elderly users of HA<sup>7</sup>. In relation to daily use of hearing aid, other studies have reported findings similar to those in the present work<sup>18,19</sup>.

According to a recent survey, 46.67% of the subjects used the hearing aid for eight or more hours per day<sup>18</sup>. Another study had an average of 8.6 hours per day, and 60.5% of the participants reported wearing it for eight or more hours per day<sup>19</sup>. In this study, the average daily use of the hearing aid was 10.18 hours. Thus, it is possible to conclude that the majority of the elderly people wore the hearing aid the totality of time, contributing to a more rapid adaptation.

In relation to sensory deprivation, several studies have shown that elderly people with hearing loss increased the scores in tests of auditory processing and improved their quality of life with the adaptation of the HA<sup>20,21</sup>. A recent study compared the scores from the self-assessment questionnaire Abbreviate Profile of Hearing Aid Benefit (APHAB), with and without the use of HA, and showed positive differences in the sub-scales Facility for of Communication, Reverberation and Environmental Noise after the use of the hearing aid<sup>20</sup>.

Another study analyzed the results of auditory processing tests performed by the elderly without complaints and noted that the results in the tests became worse with age, identifying, at an early stage, the degenerative processes of the central auditory nervous system, characteristic of age<sup>21</sup>. With this data, it is possible to infer that the auditory processing may be altered in the elderly without complaints. In the case of hearing loss, such degenerative process may be reinforced, turning into greater difficulties.

Based on this assumption, it is essential that the hearing aid fitting be performed as early as possible to reduce the time of sensory deprivation, thus minimizing the difficulties presented by the elderly.

According to the foregoing, the recognition and the speech understanding require the integrity of the auditory abilities mediated by the central auditory nervous system. Thus, the test of Speech in Noise aims to evaluate the ability of auditory closure, ability to understand the whole - word or message, even when incomplete, as well as the ability of figure-ground, that means recognition of the message in a noisy environment<sup>22</sup>.

Another skill essential for the understanding of the message is the temporal resolution, assessed by RGDT test. It is responsible for understanding both the continuous speech and its isolated segments; based on this assumption, changes of temporal resolution result in difficulties to identify small variations of acoustic speech and in difficulty to produce correct speech sounds or to interpret the message heard<sup>23,24</sup>. With the aging, the speech recognition become altered, and when it is associated with a hearing loss this difficulty is reinforced<sup>25</sup>.

A study was carried out with 42 elderly people with sensorineural hearing loss, divided into two groups: the experimental and the control group. Only the experimental group performed the auditory training, but both performed the tests of Listening with Digits and Speech in Noise. The study showed that, after the completion of the auditory training with the experimental group, there was statistically significant difference in the results of both performed tests<sup>3</sup>.

In this study, as shown in figures 1 and 2, after the hearing aid fitting and the auditory training there was considerable improvement in auditory discrimination of the participants in the study, emphasizing the importance of auditory training after the adaptation.

In the dichotic tests with verbal message it is expected advantage for the right ear in right-handed individuals. The association between this advantage and the verbal discrimination can be explained by the neural process involved in the passage of verbal sounds from the cochlea to the cortex, since it is known that there is a more intense activation of the cortex contralateral to the stimulated ear.

Thus, since the left cortex is responsible for the linguistic aspects, it receives the information more rapidly from the right ear, while the information coming from the left ear is forwarded to the right cortex and, from this, to the left via corpus callosum<sup>26</sup>. This path may be slower in the elderly due to deterioration of the corpus callosum.

In case of discrepancy between the percentages of correct answers in the binaural integration stage of the dichotic digit test, it characterizes binaural interference<sup>27</sup>. In this study, as presented in table 1, comparing right and left ear, it was not observed discrepancy in the results and thus, absence of

binaural interference. A recent study examined individuals wearing HA, some with preference for binaural and some for monaural use.

Participants who opted for binaural adaptation had statistically significant better scores compared to those who have opted for monaural, suggesting the absence of binaural interference<sup>28</sup>. As the three assessments in different moments were compared, there was a statistically significant improvement in the results after the second and the third assessment, showing the relevance of adaptation of the HA and of the auditory training of these individuals.

Between the first and the second evaluation, the individual spent a period of acclimatization. The literature reveals that there is an improvement in recognition of speech, over time, after the hearing aid fitting. As the individual is once again exposed to the acoustical environment, he learns to use, through amplification, the new speech clues available. This phenomenon was called "perceptual acclimatization". This period lasts from 4 to 12 weeks on average, but according to some studies, up to six months after the adaptation<sup>29</sup>. Considering this, this period is essential for the speech pathologist and for the patients in their process of adaptation of the hearing aid<sup>30</sup>. This study showed significant improvement in all three tests, after a four-week period of acclimatization, as shown in figures 1, 2 and 3, corroborating with other recent findings in the literature. A recent study conducted tests of Sentences Recognition Thresholds in Noise and in Silence, before the hearing aid fitting, after two weeks of use and after three months of use. 80% of the participants presented improvement between the first and the second evaluation, and 82.5%, between the first and the third, indicating the influence of acclimatization on the improvement in auditory processing tests<sup>31</sup>. Another study, already mentioned, has brought the same findings: the SSW test was performed by individuals with sensorineural hearing loss, some without hearing aid fitting and some already wearing HA for from 4 months to 6 years.

The users of HA obtained better results when compared to non-users, also showing the effectiveness of acclimatization in the adaptation process of hearing aid and in the rehabilitation of auditory abilities<sup>7</sup>.

After the second evaluation, the auditory training was performed, in five sessions, as recommended by the policy of hearing health described in decree

GM/MS No 2,073<sup>32</sup> and, after the completion of those sessions, each participant was reassessed, showing improvement, with scores statistically significant in all tests, as shown in figures 1, 2 and 3. This fact reinforces other findings in the literature<sup>12,33</sup>.

A study compared the results of an auditory processing test of a group of elderly users of HA, without training, with the results of another group of users of HA that had received auditory training. Assessments were made at the initial stage and at the end of the study. The elderly people who had performed the auditory training obtained significant improvement between the two assessments. When compared with the group without auditory training, they obtained scores significantly better. On the basis of these data, it should be highlighted the importance of auditory training to maximize the gain of the hearing aid and to enhance the skills of auditory discrimination and binaural integration<sup>33</sup>.

Figure 4 shows that the longer the duration of sensory deprivation, the lower the results in the test of speech in noise in both ears, but getting values statistically significant only for the right ear. From these data, it can be inferred that the time of hearing deprivation was an indicator of the worst outcomes in figure-ground skill and in auditory closure. No other researches that could reinforce this finding were found in the literature. Thus, there is a need to carry out further studies to investigate the relationship between time of sensory deprivation and the figure-ground and the auditory closure skills.

## ■ CONCLUSION

Comparing the results of the tests of auditory processing, in the three assessment moments, we could see a gradual improvement in RGDT, Speech in Noise and Dichotic Digit tests performed during the delivery of the hearing aid, after a month of use and after the auditory training, reflecting the validity of the acclimatization period after the second evaluation and the effect of auditory training after the third assessment.

Based on the results of this study, it can be concluded that the adaptation of the HA and the auditory training promote auditory plasticity and thus, the neuronal reorganization of the auditory pathways, contributing to the rehabilitation of figure-ground and auditory closure, temporal resolution and binaural integration skills.



**RESUMO**

**Objetivos:** verificar o desempenho de idosos nos testes de processamento auditivo na entrega do Aparelho de Amplificação Sonora Individual, após um mês de uso deste dispositivo e após o treinamento auditivo. **Métodos:** o estudo foi realizado com 11 idosos, entre 60 e 79 anos, protetizados num Centro de Saúde. Todos foram submetidos aos testes Fala no Ruído, Random Gap Detection Test normal ou expandido e Dicótico de Dígitos na etapa de integração binaural em três momentos: na entrega do Aparelho de Amplificação Sonora Individual, após um mês de uso do mesmo e após as cinco sessões de treinamento auditivo. **Resultados:** em relação ao sexo, 7 (63,64%) eram mulheres. A média de idade foi 71,27 ( $\pm 5,33$ ) anos. O tempo médio de uso diário do Aparelho de Amplificação Sonora Individual foi de 10,18 horas ( $\pm 2,44$ ) e o de privação sensorial foi 5,82 anos ( $\pm 5,29$ ). Todos os participantes aumentaram os escores nos testes de processamento auditivo gradativamente, obtendo melhor desempenho após o treinamento auditivo, sendo o comparativo entre os três momentos estatisticamente significantes ( $p < 0,001$ ). **Conclusão:** o processo de adaptação do Aparelho de Amplificação Sonora Individual bem como o treinamento auditivo proporcionou melhora no reconhecimento de fala com e sem mensagem competitiva pois refletindo o período de aclimatização após a segunda avaliação e o efeito do treinamento auditivo após a terceira avaliação.

**DESCRITORES:** Perda Auditiva; Percepção Auditiva; Auxiliares de Audição; Correção de Deficiência Auditiva

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Mailing address:

Maria Inês Dornelles da Costa Ferreira  
Rua Luis Afonso, 158 - Apartamento 702,  
Cidade Baixa  
Porto Alegre – RS – Brasil  
CEP: 90050-310  
E-mail: [costa.ferreira@terra.com.br](mailto:costa.ferreira@terra.com.br)