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# Aging Auditory System and Amplification

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Christiane Marques do Couto and  
Izabella dos Santos Brites

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## Abstract

The aging of auditory system determines the physical, sensory, and neural changes in the peripheral and central parts and may cause changes in the reception and sound processing. Age related hearing loss, also called presbycusis, can occur in the elderly population due to aging. The difficulty for comprehension of speech in the elderly may be due solely to hearing loss, but may be linked to degenerative issues of the central auditory system. Age is a factor that interferes with the central auditory processing. The results of auditory processing may change and more if there is the presence of peripheral hearing loss. It should be considered that the longer an individual has hearing loss, the greater the negative effects on the perception of sound and performance in listening skills. The use of hearing aids favors amplification and modification of the sound stimulus so that it reaches the eardrum with quantity increase and quality, promoting and stimulating the auditory skills. This chapter intends to make a review of the auditory processing disorder and evidence the benefit of the use of amplification in the elderly.

**Keywords:** hearing aid, auditory system, presbycusis, auditory processing, elderly

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## 1. Introduction

Advancements in health care and technological developments in the areas of preventive medicine and medical technology during the last decades have considerably extended the life expectancy of the human population. As a result, a greater number of people exceed the age of 65. This category of subjects is commonly referred to as seniors or elderly group. With the increasing age, some systems of the human body start to present functional changes such as degeneration or atrophy of neurons or tissues. People older than 65 years show an increased number of nontransmissible diseases, such as cardiac or metabolic ones [1].

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Associated with the transformation of the body and with the higher incidence of health complications, the elderly may present sensory, motor, and cognitive alterations. Cellular and molecular damage may also show up due to aging, possibly resulting in sensory loss (hearing or vision) or motor disability. In addition, cognitive changes such as decreased attention and working memory may also be present [1, 2].

All these factors may compromise the quality of life and the independence of the elderly. In addition, these changes can lead this segment of the population to a social isolation and depression [1].

The aging of the auditory system leads to physical, sensory, and neural changes in the peripheral and central portion of the system, which may also cause changes in the sections which receive and process the sound stimuli.

The objective of this chapter is to make a review of hearing loss and auditory processing, while considering the use of amplification technologies (hearing aids) and their intervention in the elderly.

## 2. Hearing

The concept of hearing is extremely complex and goes beyond the simple act of listening to a particular sound. This is a process in which motor, electrical, and biochemical changes occur along the auditory path inside the human body, which begins in the outer ear (more specifically in the pinna), and ends in the cortex, where the sound information received is decoded [3].

Sound waves generated in the environment are captured by the pinna and driven by the external acoustic meatus to the tympanic membrane, which starts a vibration process, transforming the sound waves into mechanical waves. This vibration moves the ossicles in the middle ear until it reaches the oval window, where stimulation will reach the inner ear.

The movement that begins in the inner ear promotes movement in the liquid (endolymph) that is housed in the cochlea, as well as, a change in its structures, promoting the excitement of the outer and inner hair cells, which in turn stimulate a network of nerve endings, which leads to the stimulation of the cochlear nerve to reach the central nervous system. It will be in the cerebral cortex that the stimulus will be decoded and then spatially interpreted.

As described above, hearing is an extremely complex process. What happens when the auditory system is affected by changes due to aging and it does not work properly?

### 2.1. Hearing loss and its consequences

When the auditory system presents structural changes, other disorders might be observed first, depending on the location where the hearing complications were first observed. For example, if a problem is observed in the external, middle, or inner ear, it will result in a reversible (or not) hearing loss. If a problem is present in the area of the auditory cortex, it

will generate a processing interference, which will affect the understanding and decoding of the incoming sound stimuli.

Aging processes can alter the structures of the auditory system, resulting in hearing loss and a compromise of hearing. This is the most significant and important sensory change in the lives of the elderly, which can generate a social limitation, minimizing the social function and the participation of the elderly in the society [4].

Hearing loss due to aging is called “*presbycusis*” or *age-related hearing loss* (ARHL) [5]. It is usually identified due to complains from the elderly subjects, referring to difficulties in understanding nearby sounds, especially in environments with poor acoustics. In these cases, an audiological assessment usually results in an identification of a mild-to-moderate symmetric sensorineural hearing loss, which worsens in the course of time [6].

It is well known that 80% of the population >85 years present some form of hearing loss [7]. The incidence of the hearing impairment also has gender effects, i.e., elderly men tend to be more affected than elderly women [8].

The data in the literature show that presbycusis can be classified into three types: the **sensory** presbycusis, the **neuronal** presbycusis, and the **metabolic** presbycusis [9, 10]. In the first case, it is possible to observe a lesion in the organ of Corti, which results in an audiogram with sloping configuration. In the **neuronal** presbycusis, there is a loss of spiral ganglion neurons, which leads to a worsening in speech discrimination, which does not seem compatible with hearing loss observed in the audiogram. The **metabolic** presbycusis is caused by a degeneration of the vascular stria, characterized by a vocal discrimination preserved, even in spite of the presence of flat or high frequency configuration [9, 10]. In all the three cases above, the elderly is considered to have a sensory neural hearing loss.

However, it is necessary to account for other factors that may have affected the hearing of the elderly throughout life and that may have worsened the hearing loss, such as exposure to noise, cardiovascular diseases (hypertension or diabetes), or extensive use of antineoplastic drugs. Very often what we call presbycusis is the cumulative effect of aging with cochlear stress caused by other etiologies [11–13].

A decline of the linguistic functions is commonly observed in the elderly presenting hearing loss. Due to this sensorial disorder, an elderly subject loses the quality of sound information in communicating with others, which may generate at first a difficulty or trouble understanding a vocal message, and eventually drives the elderly into social isolation [14]. This situation has an impact in the lives of the elderly as well as in the people who surround the elderly, their caregivers.

These communication difficulties are global and they are changing the life of the elderly, reducing their communication skills with members of the family or friends. This difficulty can even show up with normal environmental sounds such as a telephone ring or the horn of a car, situations that can even put the elderly into a safety hazard [15].

The International Classification of Disability and Health (ICF) (World Health Organization, 2001) considers that a condition of good health depends (i) on the proper functioning of the

body and (ii) on social and environmental factors that allow the individual to perform his/her activities and be active socially. Thus, hearing loss should not be a limitation, since it is possible to perform an intervention (hearing aids, implantable hearing aids, and cochlear implants) and to manage positively the hearing impaired adult [16].

## 2.2. Hearing aids and hearing performance

When hearing loss is diagnosed, an intervention is necessary. The most immediate solution is the use of a hearing aid (HA) technology. The HA is a little apparatus placed in the external meatus and that can amplify the sounds that reach the auditory system. With a hearing aid, the person will regain the audibility even of low-intensity sounds, making it possible to resume the activities of daily life. The usage of a hearing aid is the primary treatment option indicated for individuals with nonreversible hearing loss [17].

Since elderly subjects present a symmetrical loss profile in most cases, it is possible to use two hearing aid devices and perform a binaural fitting. Two hearing aids favor a better understanding of the sound messages and a better localization of the sound source [17].

Currently, in the market, there is a wide variety of technologies for hearing aids and resources that can be used to improve hearing. The best hearing aid is indicated for each case, and for it, a process must be followed by the audiologist, thus favoring a better adaptation of the hearing aid.

This process to determine if a hearing aid should be used or not begins with an assessment and the planning of the intervention to be held. Usually, the individual is subjected to the common audiological tests such as tonal and speech audiometry as well as immittance tympanometry tests. However, these procedures can only assess hearing complications in the auditory periphery. The sufficiency of these tests is uncertain and will be further discussed below.

The HA is selected based on desired physical and electroacoustic characteristics. At this stage, the individual complains should be considered, their fine motor skills and even cognitive factors that may influence the use and adaptation of one or other technology.

Since individuals with sensorineural hearing loss have low speech discrimination in the presence of background noise, most hearing aid devices incorporate noise suppressors that amplify the speech signal over noise and directional microphones that capture best sounds from certain directions. Even in these conditions the hearing aid cannot simulate the cochlea function, for all audible sounds. The hearing aid will amplify certain sound frequencies, but still there will be loss of sound signal quality, and a number of individuals still tend to complain about the level of amplification.

The hearing aid should amplify the incoming sounds without being uncomfortable to the person who uses it. This situation is only possible due to the components and digital or electronic operation of the hearing aid, which will amplify the low-intensity sounds, transforming them into audible sounds, without however, causing discomfort in the listener.

Care must be taken in the entire process of fitting, such as the handling conditions of the hearing aid by the elderly, the size of the device, or the occurrence of feedback. If any of these

factors were not observed, the chance of the elderly not making effective use of the hearing aid is very high.

After selecting the best hearing aid for the subject case and its characteristics, the specific device performance and the individual performance with this technology must be verified through objective and subjective tests if there was an improvement in the perception of sound stimuli. The next phase consists of providing the user with proper guidance on the usage and handling of the hearing aid, enabling, after one-time use, the validation of the treatment, in other words, the perception of the impact of the intervention in the life of the new user of hearing aids [18]. Throughout this process, the audiologist should consider two important factors: the limitations in activities and participation restriction.

For this reason, even with the existing technological advancements in the field of hearing aids, some elderly subjects still complain about the amplification, signal quality, often failing to make use of this technology. Other elderly subjects, in turn, report great improvement in their lives with the use of hearing aids, accomplishing different listening tasks. So, why does it occur?

### **3. Auditory processing**

In some cases, even if the hearing aid provides audibility of the signal, it cannot improve the listening of the elderly, especially in acoustically unfavorable environments. This may occur because of the listening difficulty caused, including, but not exclusively, by periphery of the auditory system, but also by central portion, in the cortex, thereby generating a difficulty in auditory processing, with consequent difficulty decoding the acoustic signal. This difficulty is not only a result of the increase in hearing thresholds but also of a dysfunction of the auditory processing. This has to be taken into account when selecting hearing aids.

Hearing is a function of the peripheral portion of the auditory system. However, processing and understanding of this sound is a function of the central portion of the auditory system, and incorporates many features and neurological networks, involving aspects like hearing, language, and cognitive.

For a long time, it was believed that only the basic audiological evaluation has been sufficient for diagnosis and intervention in the elderly. Alternatively, the central auditory processing tests should be performed only in individuals with thresholds within normal standard, so that this test is widely used in children with complaints of learning disability without another diagnosis or change detected [19]. However, it is possible to use the auditory processing test with adults and elderly. Several studies [20] on the auditory processing in the elderly or people with hearing loss began to be realized and it looks for the answer of this population, in a way to create a normal answer for this population and investigate if these results can change answer or feeling of the elderly with HA.

It is necessary to consider that it is not only the peripheral portion of the auditory system that is influenced by age, but all the auditory system undergoes aging interference. There may be



a drop in auditory skills not only because of a peripheral alteration, but because of a difficulty in working and operating with sounds and auditory skills [21, 22].

Besides the hearing loss, the elderly have trouble in auditory processing. This fact is proven by research showing that older adults with hearing loss perform worse than adults or young people with similar hearing loss. This occurs because there is a deterioration of the central auditory system in the elderly, which generates auditory processing disorder [20]. Especially in the elderly, the acoustic signal that enters the system is distorted due to peripheral hearing loss because of aging (presbycusis) [23], what compromised more the auditory processing. If the whole system is taken into account, only amplification of sound will not be enough, because there can be a change in the processing of this sound in the central portion of the auditory system (cortex). Therefore, this interferes with the fitting of hearing aids, reducing satisfaction and their effective use.

In 1996, the American Speech-Language-Hearing Association characterized and defined “*central auditory process are the auditory system mechanisms and process responsible for the following behavioral phenomenal: sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition including temporal resolution, temporal masking, temporal integration and temporal ordering, auditory performance decrements with competing acoustic signals and auditory performance decrements with degraded acoustic signals*” [24].

It is important to evaluate what these abilities mean. When someone can detect from which direction the sound is coming, the person is using the sound localization. When someone can organize or memorize auditory information according to the time, they are developing the temporal ordering ability. When someone understands the auditory information in the competitive noise, they are performing the auditory closure. When someone understands the auditory information from the junction of the information provided in each ear, they are doing binaural synthesis.

In children the auditory processing disorder justifies learning or language disorders. When the sound has not been processed properly, dealing with language issues is difficult, resulting in reading and writing problems. In adults, this change can be detected only when specific or elaborate tasks of listening are requested. In the elderly, the auditory processing difficulty is perceived when the individual does not fit to the hearing aid.

### **3.1. Auditory processing evaluation**

Therefore, to detect the presence of auditory processing disorders, it is necessary to perform an evaluation, which is conducted in a soundproof booth, using headphones. The assessment is carried out with different tests, which evaluate the individual auditory skills, such as sound localization, temporal ordering, auditory closure, binaural synthesis, and figure background.

These skills are evaluated using different procedures (**Table 1**), which can be applied in more than one session. Moreover, these tests can be applied in monaural or binaural form, i.e., in order to evaluate just one ear or the binaural integration (both ears). Each test has a specific orientation (purpose) and a specific stimulus. It is not necessary to apply all of the tests. On

Procedure	Skill
Sound localization	Sound localization
Memory for verbal sounds	Temporal ordination
Memory for nonverbal sounds	Temporal ordination
Speech with noise	Auditory closure
Dichotic digits	Integration binaural
Staggered spondaic word (SSW)	Integration binaural
Frequency and duration standard	Temporal processing
Gaps in noise (GIN)	Temporal processing
Identification of synthetic sentences	Figure background

**Table 1.** Auditory processing tests and auditory abilities.

the other hand, it is necessary to focus on the hearing loss type and its configuration to decide which test is the most important to be performed or can be possibly applied. This analysis is important because the tests are applied with an audible level over the hearing threshold.

Therefore, according to the hearing loss level, one particular test may not be applied because the sound level necessary on that test cannot be reached due to the limitation of the equipment. This aspect will be discussed later on.

### 3.2. Auditory processing in the elderly

Research comparing young and old individuals, whose hearing level is within the normal range, observed that even with normal thresholds, there is a reduction in speech understanding with background noise with the increase of the age of the individuals for short messages (consonants) or for long messages (phrases) [25].

The main complaint of the elderly is the difficulty to understand speech. There are three hypotheses that justify the difficulty to understand speech in the elderly: peripheral hearing loss, central hearing loss, and cognitive impairment. According to studies, despite being the most accepted hypothesis, only peripheral hearing loss may not generate the difficulties to understand the speech in the elderly [26]. In contrast, it adds that changes in auditory processing could enhance the difficulty that the elderly have to identify speech [27].

It is clear that the elderly has auditory processing disorder, since it is difficult for them to decode phonemes, the perception of rapidly changing speech decoding of verbal and non-verbal sounds and a slowing in interhemispheric transmission [28]. These changes associated with the peripheral hearing loss create a difficulty to understand speech, especially if it occurs in an acoustically unfavorable environment.

In addition to the hearing impairment, either peripheral or central, a decline in cognitive function can also negatively impact the processing of sound information, impairing speech understanding [29]. With the increase of age there is a decrease in attention span and in working



memory, slower brain processing, and reduction in the ability to reduce the environmental interference for speech understanding [6].

Factors such as working memory and speech processing speed influence speech recognition in noise. Studies have shown that the elderly who has a good cognitive performance obtained good results, which were better than those who had poorer performance, indicating that for processing the acoustic signal there is a cognitive interference condition [30].

These cognitive changes associated with the decline in hearing thresholds and a worsening in hearing generates a change in perception and speech understanding in noise. These factors result in a decline in the elderly quality of life and can lead to social isolation [31].

### **3.3. Auditory processing evaluation in the elderly**

Nowadays, we have the idea that there is a correlation between auditory processing tests and hearing loss and that the elderly performs worse than adults. Because of that, recent research includes study of the auditory processing and hearing loss, and look for a way to evaluate and intervene with this population.

In the elderly, it is essential to consider the presence of peripheral hearing loss, but as it is a poor signal that reaches the cerebral cortex due to peripheral hearing loss, cognition of the elderly is fundamental for a better understanding of the message. Additionally, the auditory cortex of individuals in this portion of the population tends to atrophy, which causes a change in auditory processing, i.e., the sound that enters the system is already an altered sound, and it worsens because of the way this is processed [31].

Studies show that seniors who have changes in auditory processing tend to perform a self-assessment of the hearing handicap worse than those who have no auditory processing disorder, showing that it is necessary for a better evaluation of each individual [32].

Some researches specify types of responses that can be obtained for each case. Individuals with low- and high-frequency hearing loss show difficulty in monotonic tasks. In turn, the elderly with hearing loss in high frequency or normal hearing can perform well on these tests. Therefore, audiological characteristics of the hearing loss have to be taken into account to select the processing test and understand the results achieved [33].

Many factors have to be considered to assess auditory processing in the elderly. In addition to care in the test selection, it is important to consider the age of the assessed person. It is known that when comparing the performance of adults with the elderly performance, the elderly will have a lower performance than adults, those observed even in the presence of similar hearing loss. This occurs because there is a deterioration of the central auditory system, which generates an auditory processing disorder in the elderly. This context interferes negatively with the hearing aids' fitting, reducing the satisfaction of the elderly in relation to these devices, resulting in a noneffective use [22].

To evaluate how the elderly process this sound, or their listening skills, it can map out a more detailed and correct rehabilitation plan for each case. If there is the presence of peripheral hearing loss, hearing aids must be fitted. However, with a broader look at the elderly's

auditory system and their greatest difficulties, a better hearing aid fitting is possible, as well as the indication of a therapy or auditory training.

However, still in the assessment phase, it is important that the evaluator considers the presence of peripheral hearing loss when selecting and evaluating the results of tests of auditory processing, since not all tests can be applied in cases of peripheral hearing loss. It is necessary to select tests that do not suffer interference from hearing loss. Still, there is the degree of limitation of loss, with the possible application in symmetrical hearing loss, from mild to moderate (hearing loss up to 55 dB HL) [34].

Some authors suggest that the battery used to assess auditory processing should have dichotic tests, temporal processing tests, low redundancy monaural tests, and binaural interaction tests [34, 35].

Specifically to evaluate the binaural interaction, it is suggested to use the dichotic digits test. Studies show that there is a drop in performance of the left ear in the dichotic listening in the elderly. This generates a change in interhemispheric transfer of the acoustic signal, which is due to the deterioration of the callosum corpus [36]. This change in dichotic listening can alter also in working memory and selective attention, suggesting cognitive impairment [37, 38].

It is important to explain that in the dichotic test, four numbers are introduced. First of all, two numbers will be shown, at same time, but each one in each ear. Immediately after, other two numbers are shown in the same way. The listener has to pay attention and tell which numbers he listened and/or what numbers were heard in each ear.

In this age group (elderly), more problems are observed with listening skills figure background and closing, which affect the listening speech in noise in acoustically unfavorable environments. In addition, changes in auditory temporal processing are also observed in the elderly and widely discussed in the literature [39]. It is believed that the elderly people experience changes in auditory temporal processing, which can be detected both in frequency and in test duration [6].

In the temporal tests, three stimuli in sequence are presented, and the assessed individual has to name or reproduce the sound, and thick or thin the frequency test, or long and short in duration test.

The hearing performance worsens with the presentation of a complex or an acoustically unfavorable environment stimulus. Added to this, the elderly has great difficulty with sequencing activities, which involve auditory processing and cognition [40].

#### **4. Auditory neuronal plasticity**

The elderly with hearing loss suffer from the beginning of the hearing loss installation, sensory deprivation by having hearing restricted to some sounds. Thus, the introduction of sound stimuli, through the hearing aid, even after the privation period, can cause changes in the sensory system responsible for transmitting acoustic information.

The adaptation of hearing aids promotes neuronal plasticity. Neural networks are generated and areas of the brain that were not stimulated become stimulated, favoring the adaptation of the hearing aid and social reintegration of the elderly. In addition, the adaptation of the hearing aid can contribute to the stabilization of the hearing loss, namely, the reintroduction of certain sounds by the hearing aid can promote a positive plasticity (structural and functional reorganization of the central auditory system).

The longer an individual stays with hearing loss and without the use of hearing aids, the greater the negative effects on the perception of sound and performance in listening skills. The use of hearing aids favors amplification and modification of the sound stimulus so that it reaches the eardrum with quantity increase and quality, and promotes and stimulates the auditory skills.

Due to the improvement of the quality of sound that reaches the central auditory system, it is believed that after auditory stimulation for a certain period of time, the elderly tends to improve his auditory perception because there is a greater stimulation of the auditory cortex. This theory is grounded by the theory of brain plasticity, or because of high stimulation, which happens with the use of hearing aids: the brain region responsible for the understanding of the function and process the auditory information creates new neural network (plasticity), thus, generating a better performance of the individual. When this occurs, the elderly has a better hearing performance, because in fact there were positive brain changes.

In some cases, there is indication of auditory training, so that the auditory cortex can be potentially stimulated and thus there will be an improvement in hearing. Several surveys show that the auditory training is suitable for adults and the elderly with hearing loss, since this therapeutic resource improves perception and hearing in noisy or acoustically unfavorable environments.

Even with those seniors who have mild hearing loss, satisfaction with the use of hearing aids will not be great because of auditory processing disorders. Research claim that therein lies the importance of ear training because it will occur with an improvement in electrophysiological response (latency wave III in ABR) in auditory localization and speech understanding in noise [41].

This training becomes complementary to the use of hearing aids. Thus, it will be through training that the individual with hearing loss will be able to hone your listening skills so there is a better understanding of speech [42].

The auditory training can assist in the recognition of sounds that were not already heard and others that can be modified by technology, such as the lowering frequency that seeks to dislocate a high-frequency sound to a lower one.

The professional who will make the indication of the treatment must have concepts of neuroscience and aging, which should be considered at the time of the hearing aid selection and type of auditory training. Moreover, it is necessary to consider that there is brain reorganization and acclimatization with hearing aids and that these processes are closely related to cognition [43].

All this care and to look further, beyond the peripheral hearing loss, is essential for the individual with hearing aid, and notices an improvement in his understanding of speech.

The presence of hearing loss can lead to changes in the mood of the elderly and social change, taking them into isolation. Because of this, it is important to evaluate the benefits of hearing aids and how the technology can change the life and the neurologic system of the elderly.

## 5. The benefit of hearing aids

Modification is generated by the use of hearing aid. Benefit is the difference in the auditory performance of the individual with and without the use of this technological resource. It is expected that whenever the benefit obtained is positive, an improvement in auditory responses occurs. This is possible, as already mentioned above, due to neuronal plasticity, with no improvement in hearing thresholds or in the response of the cochlear hair cells, but with a change in the cortex, with better auditory responses.

The modification of auditory responses does not happen only by the input of the sound stimulus of higher quality or more audible. Rather, it is this better quality signal entering the hearing system that makes possible a change in neural networks, generating a better response in auditory sensation.

However, a positive benefit is not always observed. In some cases, the benefit is negative or zero, i.e., the elderly does not perceive changes in hearing with the hearing aid or even refers to a worsening. In these cases, the adaptation of the hearing aid becomes more difficult and the elderly will not make proper use of the device.

The benefit can be measured by objective and subjective tests. Objective tests assess quantitatively the improvement in hearing performance with the use of hearing aid. Usually, speech is used in noise test, functional gain, insertion responses, among other tests [44]. Speech in noise test is conducted in a soundproof booth, with calibration and standardization. It is supposed to get better performance with hearing aid.

Alongside, there are the subjective tests, such as self-assessment questionnaire, which are answered by individuals and seek to assess the feeling the individual has about the improvement in their hearing.

For many services, the subjective test has greater influence and relevance than the objective tests, since these show that the elderly are thinking about the hearing aid, as is its performance in communication activities and may differ from the data obtained in objective tests and influence more on whether or not to use the hearing aid.

The main questionnaires are HHIE (Hearing Handicap Inventory for the Elderly) [45], the APHAB (Abbreviated Profile of Hearing Aid Benefit) [46], and the COSI (Client Oriented Scale of Improvement) [47]. These questionnaires can be used alone or in a combined form and should be applied before and after using the device for the measurement of the benefit.

The HHIE seeks to assess the psychosocial effects of hearing deficiency in the elderly. The questionnaire contains 25 questions that are divided into two scales: social and emotional.

By means of these scales it is possible to assess how much the situations of difficult listening affect the individual's behavior and emotional response front to these situations. There are three possible answers: yes, no, and sometimes.

APHAB seeks to assess the hearing disability associated with hearing loss and how it was reduced after using the hearing aid. Therefore, this questionnaire should be applied before the use of hearing aid and after adaptation.

COSI focuses on individual listening difficulties. Before the adaptation, the individual must choose five categories in which I would like to hear well. For evaluation, two scales are used, a relative scale, which assesses the degree of change, and an absolute scale, which records the individual's final skill listening situations.

It is known that even being subjective, the benefit is influenced by cognitive issues, as with cognitive issue preserved, a more effective use of hearing aid will be made, and also the understanding of the auditory information, as well as the ability to understand speech in noisy environments [48]. In others, research is possible to see that the cognitive can change with the benefit of hearing aids [49].

The modification in many categories is just possible to be measured after 1 year of the use of hearing aid [48]. After 4 months of use of the hearing aid, it is possible to see a change in the quality of life of the elderly. Nevertheless, bigger modification in other categories is just perceived after 12 months of the use of this technology [49]. Some research looks for modification in the benefit after this period, like evaluating the benefit after 24 months of use. However, no significant differences have been observed because an acclimatization had occurred [50].

Many researches look for the benefit of the use of hearing aids. All of them show that the elderly have a significant change in their life to return to social activities and trying again new communication activities. In addition, it is possible to see a reduction in the emotional problems or social isolation [51].

One study evaluated the handicap (Hearing Handicap Inventory for Elderly, HHIE) before and after 6 months of use of hearing aids. One hundred and fifteen (115) elderly were divided into two groups according to the result of the dichotic digits test (normal or abnormal result). After 6 months there was a significant improvement only in the group with normal dichotic test digits. The author also states that the differences observed between the groups are not justified by memory issues, attention, or difficulty in fine motor. However, the central auditory processing, which when altered generates negative influence on the process of adaptation in the elderly [52].

Therefore, measuring the benefit is essential for a correct assessment of the hearing aid gains possible, as well as checking how the use of this technology is favoring a new neural network.

## 6. Final considerations

In assessing the issue and the hearing status in the elderly, many factors have to be taken into consideration so that appropriate amplification will be proposed and so the elderly make actual use of hearing aids and have the proper advantages.



With the beginning of the use of auditory processing tests to assess the elderly with hearing loss, a new scenario in audiology was established and became an integral care for the elderly hearing.

It is not enough to just consider the degree of peripheral hearing loss but also it is necessary to consider how listening skills are changed, so that a better fitting is indicated, as well as the attempted use of complementary technologies.

That way not only searches the degree of peripheral loss, but searches around which hearing abilities are altered. So, this way it is possible to select a better technology for the elderly. Considering what skills are altered, you can check which technology or which feature of the hearing aid can be used, favoring a better listening and speech understanding by the elderly, which will generate an effective use of the device.

In addition, having a better hearing, the elderly tend to relate better with people, not isolating or minimizing their quality of life and autonomy. Rather, they can develop their daily tasks more independently, which favors their mental, cognitive, and economic conditions.

## Glossary

Age-related hearing loss (ARHL)	A synonym of presbycusis
Abbreviated Profile of Hearing Aid Benefit (APHAB)	A shortened version of the Profile of Hearing Aid Benefit, self-assessment, disability-based inventory that can be used to document the outcome of a hearing aid fitting
Client Oriented Scale of Improvement (COSI)	It is a clinical tool developed by NAL (National Acoustic Laboratories) for outcomes measurement. It is an assessment questionnaire for clinicians to use which allows them to document their client's goals/needs and measures improvements in hearing ability
Dichotic digits Test	This is an auditory processing test, which evaluates the ability to reproduce four digits (numbers), which are displayed in pairs, one on each ear, simultaneously
Frequency and Duration Standard	This is an auditory processing test, which assesses the ability to distinguish and name bass and treble, long and short stimuli.
GIN (Gaps-in-Noise) Test	This is an auditory processing test that evaluates which the lowest range in which you can see the occurrence of two auditory stimuli
Hearing Aid (HA)	HA is a little apparatus placed in the external meatus and that can amplify the sounds that reach the auditory system
Hearing Handicap Inventory for the Elderly (HHIE)	Is a 25-item self-assessment scale composed of two subscales (emotional and social/situational)
Identification of Synthetic Sentences	This is a test that evaluates the ability to understand speech in environments with competitive speech noise
Memory for verbal sounds	This is an auditory processing test that evaluates the memorizing ability of verbal sounds when they are presented in a particular sequence and must be played in the same sequence

Memory for nonverbal sounds	This is an auditory processing test that evaluates the memorizing ability of nonverbal sounds when they are presented in a particular sequence and must be played in the same sequence
Speech with noise	This is an auditory processing test, which evaluates the ability to understand speech in environments with background noise
Staggered Spondee Word (SSW) test	This is auditory processing test that evaluates the individual's ability to hear four words in sequence, the first in one ear, the second and third, both simultaneously, one in each ear and the last in the contralateral ear to what the first word was presented
Presbycusis	Loss of the hearing acuity in the elderly (i.e. >65 years) subjects
Sound localization	This is an auditory processing test that evaluates the ability to localize sound stimulus

## Author details

Christiane Marques do Couto\* and Izabella dos Santos Brites

\*Address all correspondence to: christianemcouto@hotmail.com

Department of Human Development and Rehabilitation, Faculty of Medical Sciences, University of Campinas – UNICAMP, Campinas, SP, Brazil

## References

- [1] WHO. World report on ageing and Health. Geneva, Who Press, 2015. 247 p. ISBN 978 92 4 069481 1.
- [2] Li, K.Z.H., Lindersberger, U. Relations between sensory/sensorimotor and cognitive function. *Neurosci. Biobehav. Rev.* 2002;26(7);777–783. DOI: 10.1016/S0149-7634(02)00073-8
- [3] Gelfand, S. A. *Essentials of Audiology*. 4th ed. New York, Thieme, 2015. 639 p. ISBN:9781604068627
- [4] Crews, J.E., Campbell, V.A. Vision impairment and hearing loss among community – dwelling older Americans: Implications for health and functioning. *Am. J. Public Health.* 2004;94(5);823–829. DOI: 10.2105/AJPH.94.5.823
- [5] Schmiedt, R.A. The physiology of cochlear presbycusis. In: Gordon-Salant, S. et al. (eds.), *The Aging Auditory System*. Springer-Verlag, New York. 2010. Vol. 34; pp. 9–38. ISBN:978-1-44190993-0. DOI 10.1007/978-1-4419-0993-0
- [6] Wingfield, A., Tun, P.A., McCoy, S.L. Hearing loss in older adulthood – what is and how it interacts with cognitive performance. *Curr. Directions Psychol. Sci.* 2005;14(3);144–148. DOI:10.1111/j.0963-7214.2005.00356.x
- [7] Parham, K. et al. Comprehensive management of presbycusis: central and peripheral. *Otolaryngol. Head Neck Surg.* 2013;148(4); 537–539. DOI: 10.1177/0194599813477596

- [8] Gopinath, B. et al. Prevalence of age-related hearing loss in older adults: Blue Mountain Study. *Arch. Intern. Med.* 2009;169(4);415–416. DOI:10.1001/archinternmed.2008.597
- [9] Schuknecht, H.F. Further observations on the pathology of presbycusis. *Arch. Otolaryngol.* 1964;80;369–382. Available from: <http://dx.doi.org/10.1001/archotol.1964.00750040381003>.
- [10] Rizk, H.G., Linthicum Jr., F.H. Histopathologic categorization of presbycusis. *Otol. Neurotol.* 2012;33;23–24. DOI: 10.1097/MAO.0b013e31821f84ee
- [11] Martins, K. et al. Genetic and audiologic study in elderly with sensorineural hearing loss. *CoDAS.* 2013;25(3);224–228. DOI:10.1590/S2317-17822013000300006
- [12] Kid III, A.R., Bao, J. Recent advances in the study of age-related hearing loss – a mini review. *Gerontology.* 2012;58(6);490–496. DOI: 10.1159/000338588
- [13] Yamasoba, T. et al. Current concepts in age-related hearing loss: epidemiology and mechanistic pathways. *Hear Res.* 2013;303;30–38. DOI: 10.1016/j.heares.2013.01.021.
- [14] Gilad, C., Glorig, A. Presbycusis: the aging ear. Part I. *J. Am. Aud. Soc.* 1979;4(5);195–206.
- [15] Dalton, D.S. et al. The impact of hearing loss on quality of life in older adults. *The Gerontologist.* 2003;43(5);661–668. DOI:10.1093/geront/43.5.661
- [16] WHO. The International Classification of Disability and Health (ICF). 2001. Available from: [http://psychiatr.ru/download/1313?view=name=CF\\_18.pdf](http://psychiatr.ru/download/1313?view=name=CF_18.pdf)
- [17] Dillon, H. *Hearing Aids.* Thieme. 2014;57(7);493. Available from: <http://dx.doi.org/10.3342/kjorl-hns.2014.57.7.493>
- [18] American Speech-Hearing-Language Association. Guidelines for hearing aid fitting for adults. *ASHA.* 1997;2;123–130. DOI:10.1044/policy.GL1998-00012.
- [19] Moore, D.R. Auditory processing disorder (APD): definition, diagnosis, neural basis and intervention. *Audiol. Med.* 2006;1(1);4–11. DOI:10.1080/16513860600568573
- [20] Stach, B. A. et al. Special hearing aid considerations in elderly patients with auditory processing disorders. *Ear Hearing.* 1991;12(6);131–138. Available from: <http://dx.doi.org/10.1097/00003446-199112001-00007>
- [21] Humes, L. et al. Central presbycusis: a review and evaluation of the evidence. *J. Am. Acad. Audiol.* 2012;23;635–666. DOI: 10.3766/jaaa.23.8.5
- [22] Gates, G. Central presbycusis: an emerging view. *Otolaryngol. Head Neck Surg.* 2012;147(1);1–2. DOI: 10.1177/0194599812446282
- [23] Rosdina, A.K. et al. Self-reported hearing loss among elderly Malaysians. *Malaysian Family Phys.* 2010;5(2);91–94.
- [24] American Speech-Hearing-Language Association. Central auditory processing: current status of research and implications for clinical practice. *ASHA.* 1996;5;41–54.
- [25] Fullgrabe, C., Moore, B.C.J., Stone, M.A. Age-group differences in speech identification despite matched audiometrically normal hearing: contributions from auditory temporal processing and cognition. *Front. Aging Neurosci.* 2014;6;1–25.

- [26] Humes, L.E. Speech understanding in the elderly. *J. Am. Acad. Audiol.* 1996;7;161–167. DOI:10.3389/fnagi.2014.00347
- [27] Humes, L.E., Christopherson, L. Speech identification difficulties of hearing-impaired elderly persons: the contributions of auditory processing deficits. *J. Speech Language Hearing Res.* 1991;34;686–693. Available from: <http://dx.doi.org/10.1044/jshr.3403.686>
- [28] Rajan, R., Cainer, E. Ageing without hearing loss or cognitive impairment causes a decrease in speech intelligibility only in informational maskers. *Neuroscience.* 2008;154;784–795. DOI:10.1016/j.neuroscience.2008.03.067
- [29] Moore, D.R. Relation between speech-in-noise threshold, hearing loss and cognition from 40–69 years of age. *PLoS One.* 2014;9(9);107720. DOI: 10.1371/journal.pone.0107720
- [30] Lunner, T. Cognitive function in relation to hearing aid use. *Intl. J. Audiol.* 2003;42;49–58. DOI:10.3109/14992020309074624
- [31] Cardin, V. Effects of aging and adult-onset of hearing loss on cortical auditory regions. *Front. Neurosci.* 2016;10;1–12. DOI:10.3389/fnins.2016.60199
- [32] Jerger, J., Oliver, T.A., Pirozzolo, F. Impact of central auditory processing disorder and cognitive deficit on the self-assessment of hearing handicap in the elderly. *J. Am. Acad. Audiol.* 1990;1;75–80.
- [33] Cox, L.C. et al. Monotonic auditory processing disorders: tests in the older adult population. *J. Am. Acad. Audiol.* 2008;19(4);293–308. Available from: <http://dx.doi.org/10.3766/jaaa.19.4.3>
- [34] American Speech-Language-Hearing Association (ASHA). (Central) Auditory Processing Disorders [Technical Report]. 2005. Available from: <http://www.asha.org/docs/html/tr2005-00043.html>.
- [35] Bellis, T.J. Comprehensive central auditory assessment. In: BELLIS, T.J. *Assessment and Management of central auditory processing disorders in the educational setting from science to practice.* 2nd ed. NY: Delmar Thompsons Learning, 2003.
- [36] Idrizbegovic, E. et al. Central auditory function in early Alzheimer's disease and in mild cognitive impairment. *Age Ageing.* 2011;40(2);249–254. DOI: 10.1093/ageing/afq168
- [37] Roup, C.M., Wiley, T.L., Wilson, R.H. Dichotic word recognition in young and older adults. *J. Am. Acad. Audiol.* 2007;17(4);230–240. Available from: <http://dx.doi.org/10.3766/jaaa.17.4.2>
- [38] Stewart, R., Wingfield, A. Hearing loss and cognitive effort in older adults' report accuracy for verbal materials. *J. Am. Acad. Audiol.* 2009;20(2);147–154. <http://dx.doi.org/10.3766/jaaa.20.2.7>
- [39] Fitzgibbons, P.J., Gordon-Salant, S. Age-related differences in discrimination of temporal intervals in accented tone sequences. *Hearing Res.* 2010;264;41–47. DOI: 10.1016/j.heares.2009.11.008 DOI:10.1016%2Fj.heares.2009.11.008

- [40] Gordon-Salant, S. Auditory temporal processing in elderly listeners. *J. Am. Acad. Audiol.* 1996;7;183–189.
- [41] Gil, D., Iorio, M.C.M. Formal auditory training in adult hearing aid users. *Clin. Sci.* 2010;65(2);165–174. DOI:10.1590/S1807-593220100000200008
- [42] Dubno, J.R. Benefits of auditory training for aided listening by older adults. *Am. J. Audiol.* 2013;22(2);335–338. DOI:10.1044/1059-0889(2013/12-0080)
- [43] Pichora-Fuller, M.K., Singh, G. Effects of age on auditory and cognitive processing: implications for hearing aid fitting and audiologic rehabilitation. *Trend. Amplif.* 2006;10(1);29–59. DOI: 10.1177/108471380601000103
- [44] Weinstein, B.E. Outcome measures in the hearing aid fitting. *Trend. Amplif.* 1997;2(4); 117–137. DOI: 10.1177/108471389700200402
- [45] Ventry L, Weinsten, B.E. The hearing handicap inventory for the elderly: a new tool. *Ear Hear.* 1982;3;128–134. Available from: <http://dx.doi.org/10.1097/00003446-198205000-00006>
- [46] Cox, R.M., Alexander, G.C. The abbreviated profile of hearing aid benefit. *Ear Hear.* 1995;16(2);176–183. Available from: <http://dx.doi.org/10.1097/00003446-199504000-00005>
- [47] Dillon, H., James, A., Ginis, J. Client oriented scale of improvement (COSI) and its relationship to several other measures of benefit and satisfaction provided by hearing aids. *J. Am. Acad. Audiol.* 1996;8;27–43.
- [48] Naylor, G., Elberling, C. Benefit from hearing aids in relation to the interaction between the user and the environment. *Int. J. Audiol.* 2003;42. DOI: <http://dx.doi.org/10.3109/14992020309074627>
- [49] Mukrow, C.D., Tuley, M.R., Aguilar, C. Sustained benefits of hearing aids. *J. Speech Language Hearing Res.* 1992;35;1402–1405. DOI: 10.1044/jshr.3506.1402
- [50] Humes, L.E., Wilson, D.L., Barlow, N.N., Garner, C. Chances in hearing aid benefit following 1 or 2 years of hearing aid use by older adults. *J. Speech Language Hearing Res.* 2002;445;772–782. DOI:10.1044/1092-4388
- [51] Newman, C.W., Weinstein, B.E. The hearing handicap inventory for the elderly as a measure: of hearing aid benefit. *Ear Hearing.* 1988. Available from: <https://doi.org/10.1097/00003446-198804000-00006>
- [52] Chmiel, R, Jerger, J. Hearing aid use, central auditory disorders and hearing handicap in elderly persons. *J. Am. Acad. Audiol.* 1996;7;190–202.



