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Review Article

Logoaudiometry, a Study of Auditory Perception of the Word

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Abstract

Introduction: Logoaudiometry or verbal audiometry tests evaluate the patient's hearing ability to understand the spoken word by hearing. These consist of lists of words that have been perfected over time to ensure their quality, repeatability and reliability.

Objectives: To inquire about the methodology, procedures, techniques, and applications of Logoaudiometry.

Methods: A review was made in the literature on the subject. 20 references were used to better fit the theme. The Google search engine, Google Scholar and the MEDLINE and SciELO databases were used.

Analysis and Synthesis of Information: Verbal audiometry is the study of hearing in which you have to respond to verbal signals such as phonemes, words, phrases or continuous speech. This test seeks to find the uptake and discrimination of the ear for language, establishing the percentage of words understood correctly with the necessary intensity so that they are measured and expressed in relative decibels. Lists of balanced words phonetically presented loudly or in recording are used as material.

Conclusions: Within the auditory studies, logoaudiometry is a complex but important test that has clinical applications for people with prostheses, cochlear implants and/or brainstem implants, children and adults with hearing deficit in general. It complements conventional tonal audiometry.

Keywords: Logoaudiometry; Verbal Audiometry; Tests

Introduction

The spoken word is a complex acoustic signal, which is linguistically organized and allows verbal communication. Logoaudiometry or verbal audiometry tests evaluate, from lowest to greatest difficulty, the patient's hearing ability to discriminate, identify, recognize and understand this spoken word aurally [1,2].

The first verbal audiometry tests were created in the United States not for medical purposes, but to check the quality of communication equipment during World War II. They were lists of 50 words that tried to represent the spoken language (phonetic balance). In a short time, these refined and recorded lists (PAL pb-50) were being used for audiometric testing [3].

Verbal audiometry or logoaudiometry is any study of hearing in which the stimuli to which it has to respond are verbal signals, whether phonemes, words, phrases, continuous speech etc. Its purpose is to determine a person's ability to perceive spoken language. Its main clinical application is in the localization and quantification of a dysfunction in the auditory system. In the prosthetic adaptation it is essential both for the selection of the characteristics of the hearing aid and for the verification of the

quality of the adaptation. In studies conducted in children, we must bear in mind that the objective of verbal audiometry is to measure auditory perception, and not their linguistic knowledge [4].

Conventional logoaudiometry and sensitized logoaudiometry (S/R) are intended to measure the discrimination of spoken language inside and outside a noisy environment, so it is necessary to understand what it is and what its function is in language discrimination.

Language fulfills multiple functions, both individually in the general development of the individual, and collectively in relation to the integration of people in the social environment, therefore, an alteration in language, especially in the discrimination of it, affects the person in both spheres: personal and social.

Also with the development of sound recording and analysis technology, the emergence of new materials was promoted, which comply with the regulations of application in this field, standards whose objective is to guarantee the quality, repeatability and reliability of the same.

According to international regulations, if you want to obtain reliable and stable results, you should always prefer to use verbal material recorded with the highest quality [4].

This diagnostic procedure should constitute an essential examination in the auditory examination of children and patients with presbycusis, so the objective of this work is to inquire about the methodology, procedures, techniques, and applications of Logoaudiometry.

Methods

A review was carried out on the subject in the literature, using internet sources and texts of the specialty by selection of the author, 50 articles were consulted of which 20 were used to better fit the theme. The Google search engine, Google Scholar and the MEDLINE and SciELO databases were used.

Analysis and synthesis of information

To identify the phonemes of the spoken word, the ear relies on frequency bands where most of the sound energy of a sound, called formants, is concentrated.

A formant is the peak of intensity in the spectrum of a sound where more energy is concentrated at a certain frequency. The formants make it possible to distinguish the sounds of human speech, especially vowels and other sound consonant sounds.

The former with the lowest frequency is designated F1, the second F2, the third F3, etc. Normally only the first two formants are necessary to characterize a vowel, especially in languages with less than six vowels such as Spanish (Table 1). In vowels, the first two formants are mainly determined by the position of the language. F1 has a higher frequency the lower the tongue, that is, the greater the aperture a vowel has, the higher the frequency at which F1 appears (/a/is open, /i u/are closed). The F2 has greater frequency the more forward the tongue is positioned, that is, the more anterior a vowel is, the greater the F2 (/i/is anterior,/u/ is posterior). The upper formants, from the fourth to the sixth, are believed to characterize each person's individual speech, the timbre [1,2].

Vowel formants		
Vocal	**Forming F1**	**Forming F2**
u	320 HZ	700 Hz
o	500 Hz	800 Hz
a	800 Hz	1.200 Hz
e	500 Hz	1.800 Hz
i	320 HZ	2.100 Hz

Table 1: First and second formant of the vowels in Spanish. Martinez Celdrán 1986**.**

In consonants the formants are less clear, perceived mostly thanks to the effect on adjacent vowels. In the case of voiceless consonants, produced without vibration of the vocal cords, the acute frequency components predominate.

With the formants and/or points of greater energy of the different phonemes of the language, a graphic representation of the different phonemes is drawn in the clinical audiogram, considering the frequency of the same and their intensity, creating with this information a graph that resembles a banana (Figure 1). This correlates in the tonal audiogram, the auditory perception of the different phonemes in frequency and intensity, helping to understand the limitations that a person with different degrees of hearing loss can present in their discrimination of the spoken word [1].

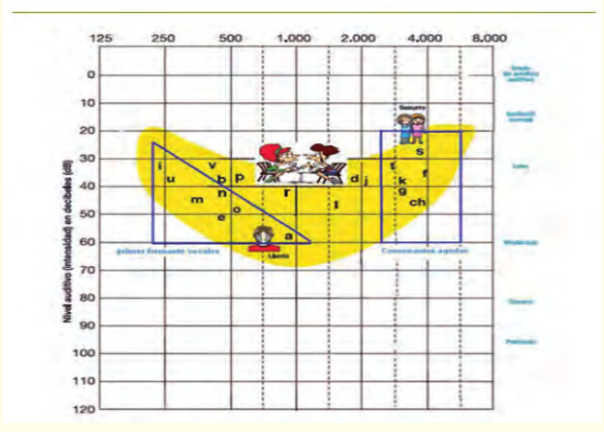

Figure 1: Audiogram with speech sounds. Note in the abscissas the number of decibels (dB) and in the ordered frequencies (Hz).

From the above figure it can be understood how it is universally accepted [3] the relationship between the tonal mean between the frequencies 500.1000 and 2000 Hz (called conversational frequencies) and the intensity at which the language is perceived.

Through logoaudiometry, it is sought to find the uptake and discrimination of the ear for language, establishing the percentage of words understood correctly with the necessary intensity so that they are measured and expressed in relative decibels. In this way it allows us to know if auditory commitment affects the communication process. It explores the sensorineural and neurophysiological aspects of hearing [4-6].

It can be said that logoaudiometry consists of two fundamental tests: the discrimination percentages test, applied in a normal audiometry and the logoaudiometric threshold search test. Usually in the clinic the term logoaudiometry is used to refer to this last test [4,7] (Figure 2).

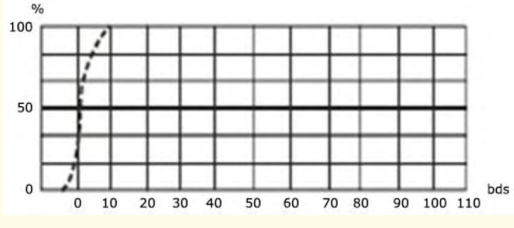

Figure 2: Logoaudiometry graph. Note in the abscissas is placed the system of percentage of words captured, repeated correctly, and on the ordered decibels of intensity to which each list was read.

Registration technique

The methodology, the necessary equipment and the composition of the verbal material for these tests are regulated by the international standards IEC 645/2 on equipment for verbal audiometry and ISO 8253-3 on tests for verbal audiometry [1-4] and AEDA-2: 2-4 [3].

The material that composes them, for standardized use, is the word isolated in phonically balanced lists at different intensities [3,7,8]. It should be borne in mind that lists of bisyllabic words, which are the most used in Spanish-speaking countries, perform better than monosyllables due to the greater number of bisyllables in the Spanish language and a greater extrinsic redundancy that translates into greater ease of recognition of the word.

Currently many authors propose different lists, but the phonetic material used to measure discrimination must meet requirements such as: having equal audibility or ability to be heard, be phonetically balanced and different, and be constituted by words familiar to the subject [4]. The use of different lists in different healthcare centres leads to logoaudiometric results that are not comparable to each other.

Although word lists have many advantages for clinical practice (they are an international standard method, they are relatively fast and practical, etc.), however, they have some shortcomings, recognized since their creation, the main one of which is that they do not attend to suprasegmental phenomena (intonation, rhythm), absolutely essential in the decoding of speech. Among its disadvantages, we can also highlight the lack of naturalness of the task: with few exceptions, in no daily communicative situation we communicate by separating the words by pauses, and using only nouns.

However, they are simpler units to evaluate than sentences or texts, because variables such as the different syntactic structures of each language do not intervene in them; the processing of isolated words requires less intervention of higher cognitive processes than that of more complex units, such as sentences. In any case, the appropriate thing is to be able to have audiometric tests that use both the lists of words and the continuous speech in Spanish, as is the case with most of the languages of our environment [3,9].

The person to be examined is placed in a soundproof booth, where verbal or logoaudiometric tests will be performed through an audiometer.

The mode of presentation of the same can be live voice, through speakers (free field), insertors and/or headphones depending on the objective to be achieved. This is useful mainly for the elderly, children and people with associated pathologies, since the rhythm of presentation is adapted to the needs of the subject examined or in recording that provides greater stability, greater comfort, better calibration, greater simplicity and avoids lip-reading [1,7]. A mode of realization by air (with vibrator on the mastoid) is also described [8,10].

With the aim of discriminating, identifying, recognizing and auditorily understanding the spoken word, logoaudiometry tests last from 15 to 20 minutes, although they can be prolonged more depending on the collaboration of the same and can be passed in a closed or open context, with or without support of lip reading and must be adapted to maturing development, cognitive and linguistic of the child and/or adult [7].

A closed context is understood as the condition in which the patient has the possibility to choose, from among several previously selected answers, the one on which he is questioned. These closed choice tests involve auditory identification of the elements presented and are less difficult than those presented in an open context. They are frequently used in children with hearing impairments and in the follow-up of people implanted with cochlear implants and/or brainstem implants mainly.

The open context implies that the patient does not have previously limited answers, nor does he have in front of him any written material that helps him to answer the question raised, therefore, he requires at least the auditory recognition of the spoken word. These are the ones that are used in a routine consultation for diagnosis, also useful in the follow-up of implanted people and/or carriers of hearing aids.

Logoaudiometry in closed context

The test is carried out in a soundproof booth, with an audiometer, either with headphones/insertors or in free field with hearing aids/cochlear implant/middle ear implant, placing the examinee one meter from the speaker/speakers. The test is performed by voice or by means of a CD recording at intensity controlled by the examiner.

Graphic support is always present in the performance of the test because the young child with suspected hearing loss is able to perform a motor action, such as pointing to an image, with less difficulty than repeating words that are presented to him [1].

Some of these tests used in the Spanish language are:

- Test the Ling.
- Early Speech Perception test (ESP)

Test the ling

This is a simple test, used mainly in children, which uses 6 phonemes ("A", "I", "U", "S", "SH", "M"), different frequency, covering the spectrum of the word, the person examined must identify the sound and repeat it or point it out in the drawings in front of him [1]. Evaluates detection, discrimination, identification and sound recognition.

It can be performed even at home, by parents, every day to determine if the child is consistently responding to language, noticing any changes in hearing levels due to malfunctions of hearing aids or infections in the middle ear.

The examiner should be seated at the level of the child and with his hand in front of the mouth, avoiding labiofacial reading, sounds are initially pronounced in a normal tone of voice. As more ability to respond to sounds is gained, the distance between the two is increased to one meter trying not to leave the same time interval between each sound. It's easy for children to recognize a pattern and respond automatically, even if they don't hear the sounds.

Even if the infant is less than twelve months old, the test may be applied to see if he or she is able to detect the sounds. When they are able to consistently detect sounds they are taught to imitate them, in this way you will be sure that they can discriminate them.

The results can be compared with the following table (Figure 3).

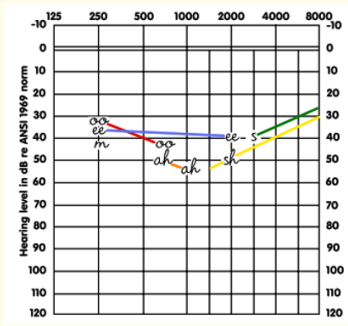

Figure 3

Early word perception test

Aimed mainly at children, it is designed by J. Moog and A. Geers of the *"Central Institute for the Deaf"* and has an adaptation to the Spanish language. 2 versions have been developed: standard, for children aged between 4 and 15 years and simplified, for children from 2 to 4 years. Its objective is to categorize the perception of the word in those patients with profound hearing loss [1,2]. There are four categories defined by the following characteristics:

- **Category 1**: No perception of auditory patterns. Children are unable to discriminate audibly even between words that differ in their duration (e.g., sun vs. ball).
- **Category 2**: Perception of auditory patterns. This includes children who have developed minimal skills in word perception. At the lower level children begin to discriminate between words from a closed series that differ in duration. At the upper level they perform this discrimination of duration and also of words with different accentuation (e.g., duck vs. baby).
- **Category 3**: Limited word identification. It includes children who demonstrate a minimal ability to use spectral information or intonation. They are able to discriminate between words of stress and similar duration when presented in closed series and when the words contain highly differentiated vowels (e.g., dog vs. chair).
- **Category 4:** Consistent word identification. It demonstrates a great facility for the use of spectral information in the discrimination of monosyllabic words. They differentiate between monosyllables presented in a relatively large closed series (e.g., 12 possibilities).

Standard version

Consists of 3 graphics with 12 images each.

Simplified version

As in the previous version, the same objectives are evaluated. It is an emergency test in which those objects, toys, that are familiar to the child (ball, car, etc.) are used, and there is no prepared list. Before starting, it is necessary to carry out a pre-training in order for the child to discriminate pairs of objects of different lengths, starting with visual and auditory support. You must respond correctly to 6 consecutive items, before considering that the task has been understood by the child. At least 4 objects are selected based on the child's interests. It will take 6 correct answers to move to the top category [1,2].

Logoaudiometry in open context

The test is performed in a soundproof booth, the person is tested using headphones or insertors or in the free field without/with hearing aids or cochlear implant or middle ear implant. In the latter situation, the patient is located one meter from each speaker. The intensity of stimulation is controlled by the examiner. The test is performed loudly in patients under 10 years of age or by means of a CD recording in those over this age and the presentation is unique, without allowing the repetition of the item.

Each list of words and/or phrases are presented at different intensities and the child or adult upon hearing them should repeat them. It is considered a correct answer when the examinee repeats the same word without altering any phoneme and correctly repeats the words that make up the sentence, the results are expressed in percentages, no support of lip reading is used, nor of graphic material. In Spanish the most frequent words are bisyllables. It is noted in each intensity, the number of terms understood, which will allow to build the Intelligibility curve [1,11-13].

It begins in a norm-listening subject at an intensity of 40dB at which a normal subject captures 100% of the words. Progressively the intensity is lowered from 10 to 10 dB until it commits some failure in its repetitions. Then you increase 15dB and the words are presented, you go down from 5 to 5 dB until you reach 50% of correct repetitions and you continue to go down until you reach 0% of correct repetitions. An italic S-shaped curve is obtained, called the Intelligibility curve. This curve is represented in a graph, in which the axis of abscissas is determined by the intensity in decibels of the auditory stimulus and the axis of ordinates is determined by the percentage of words repeated correctly [1-3,14].

The following thresholds are defined and should be noted on this curve:

- Voice detectibility threshold
- Audibility Threshold
- Verbal Reception Threshold
- Percentage of Discrimination
- Threshold of discrimination or maximum understanding.

Threshold or liminal tests

They look for the point of minimum intensity to which the subject responds according to what we expect from him. Usually each ear is studied separately and the result obtained is recorded in decibels or decibels (dB) of intensity [3]. Below will be detailed about the different nominations and the methodology for each of them.

- Threshold of detectibility of the voice or speech awearness Thershold (SAT) which translated means "level of voice perception": the person evaluated listens to the auditory stimulus provided, but does not understand it since it only manages to capture murmurs. This threshold is located in individuals without hearing problems around 5 dB HL [5,9,10].
- Hearing Detection Threshold (UDP): It is the minimum intensity at which the subject notices that he is being spoken, but does not understand the language [3]. The person answers the first word correctly.
- Threshold of uptake, intelligibility or Speech Reception (URV) or speech reception Threshold (SRT), which is the minimum auditory level at which 50% of the words presented can be identified, which is approximately 15 dB above the tonal threshold of conversational frequencies. For the determination of the threshold of verbal reception, it is recommended to use polysyllabic words in Spanish, which are of high frequency of use, have great redundancy and similar difficulty between the words with all this they manage to go from with few dB of difference of very low discriminations (20%) to very high discriminations (80%) [1,5,9]. The purpose of the SRT is: to corroborate the result obtained in the audiometry, to provide an indication of the auditory sensitivity in the perception of language and also serves as a basis for being able to find the speech Discrimination (SD) or level of discrimination of the language [10,15,16].
- Percentage of discrimination or sensitivity, or speech discrimination that is the proportion of words included at a level of intensity located at 35 dB above the threshold of intelligibility [1,9]. During this test, monosyllabic and bisyllabic words are used in order to find the highest level of discrimination (SRT and SD) and trisyllabic words to find the minimum levels, i.e. the SAT [10]. We present the subject with a list of 25 words, if he repeats them correctly, lower 10 dB and present another. Continue to go down and present a word until the answer is incorrect. The discrimination thus obtained will be the maximum discrimination of that patient. The result should indicate the percentage of discrimination and at what intensity it has been obtained [4,17].
- Threshold of discrimination or maximum comprehension, which is defined by the order that marks the percentage of maximum discrimination at the peak [1]. In the subject with normal hearing it reaches 100% and represents the largest number of words repeated correctly [9]. In many cases it is appropriate to measure discrimination at low intensities. To do this, 10 dB is lowered from the lowest intensity tested [4,18].

The normal form of intelligibility curve of the word in S italic will vary depending on the type of hearing loss. Thus, in transmission or conductive hearing loss, the recognition of isolated bisyllabic words will reach a recognition greater than 90% of the words presented at a higher intensity, that is, the morphology of the normal hearing curve is maintained, displaced in intensity.

In sensorineural hearing loss, the recognition of isolated bisyllabic words is limited, even raising the intensity to a comfortable level, the auditory recognition of the words is not increased, as the time factor and/or frequency factor are affected. When the lesion is retrocochlear, the maximum intelligibility obtained at the lowest possible intensity decreases by more than 20% with increasing intensity (roll over effect) [1].

The verbal reception threshold (URV) greater than 15 dB in relation to tonal audiometry, indicates a dissociation between tonal and verbal audiometry, which orients towards simulator, not good collaboration on the part of the subject examined, not correct calibration [1,19,20].

Material verbal:

We must take into account the importance of sound formants in phonematic identification (Table 1) and that the sound spectrum of the spoken word extends from the low frequencies to the high frequencies, being those between 250-4,000 Hz, the ones that offer the most information of the different phonemes [1] and the most important tones 500, 1000 and 2000 Hz [1,9].

To perform this test, the patient must repeat the words and/or phrases once heard. In this sense there is a marked difference depending on the type of patient to be evaluated.

The use of recorded material allows a standardization of the evaluation conditions, however, the live presentation allows greater flexibility during the evaluation, which is particularly useful in young children. The advantages of a recorded material are: visual communication between the hearing care professional and the patient without risk of the latter reading the lips, repetition of the test without the examiner being exhausted, absence of regional accent in the words [13,14].

In Spanish-speaking countries such as Mexico, Argentina, others in Latin America and Spain, the pioneers in the design of this type of lists were Tato, Lorente, Sanjurjo and Bello [10,11]. Aurelia Cancel, Quirós, Morgante, Rosenblut and De Cruz also deserve mention [3,13].

Later Berruecos and Rodríguez in 1967 established 4 phonetically balanced lists taking into account the idioms of the Mexican population [9,10]. Based on Colombian research focused on the validation of a list of words taking into account the Colombian sociocultural environment, Oramas and Rodríguez stand out, who designed the Ibero Speech Recognition Thershold Lists (LI-SRT) [10].

The lists of standardized bisyllabic words developed by Marrero-Cárdenas [1] as well as lists of words from the P.I.P. Test of Furmanski and collaborators (word identification test) are also recognized [11,12,21].

In recent years, in Chile, according to surveys, the known terms are the preferred material for the pediatric population unlike adults where the Farfán and Palacio lists are mainly used [13].

Bisyllabic test (Marrero-Cárdenas): [1,8]

This acoustic material is made up of lists of standardized bisyllabic words belonging to everyday vocabulary, developed by Marrero-Cárdenas in Spanish. Composed of 15 lists with 20 bisyllabic words each, for children and 20 lists with 25 bisyllabic words each for adults. The words are from everyday vocabulary, must have the same number of syllables, a similar difficulty and appear on the list with the same proportion as in spoken language (>20%); all phonemes of spoken language must be represented.

List of words by Tato and others: [11,12]

It consists of 12 lists of 25 bass balanced phonetically balanced bisyllabic words. For this, 10,000 words taken from newspaper articles, stories, pieces of magazines were used.

CID sentences test: [1]

It consists of 100 sentences distributed in 10 lists, which the patient has to repeat without any visual or graphic help. The answers are valued, counting each of the keywords that make up the sentence and that are underlined in the lists. The results are presented in the form of percentages. The test is an adaptation to the Spanish language of the "Every day sentences test" (CID). It has been carried out by the ENT Department of the University of Navarra following the guidelines and supervision of J. Moog and A. Geers of the "Central Institute for the Deaf" (St. Louis, USA).

HINT phrases: [1]

It consists of noise phrases presented through a CD and the adult/child must repeat the phrase presented. Used in children from 6 years of age. Developed by Nilsson and adapted to Spanish by Huarte. It consists of 240 phrases in Spanish, 20 phrases in 12 lists.

They are presented with/without noise through a CD and the subject must repeat the phrase presented. The peculiarity of these lists is that the noise is adaptive and determine the level of intensity necessary to reach 50% recognition of the sentences. The lists maintain the phonemic distribution. It is available in several languages.

Sensitized speech therapy (speech discrimination in noise): [1,15,16]

It is all kinds of special logoaudiometry that uses some artifice to modify or distort some quality of the voice or the spoken message (Quirós 1980).

It is aimed at identifying deficits in sensory processing that affect hearing and comprehension of the spoken word. Studies such as that of Amaya E., *et al*. [17] suggest that the use of this test in conjunction with tonal audiometry is necessary for an annual audiological control. In these patients, a dissociation between liminal tonal audiometry and verbal audiometry is observed, which determines a non-peripheral auditory pathology or an auditory processing disorder.

It includes a series of tests in which verbal stimuli higher than the threshold of verbal reception are used. The presentation is in monotic listening, that is, a stimulus or two stimuli in the same ear, simultaneously. Or didicotic listening, where they present a stimulus or two stimuli in both ears, simultaneously.

To carry out these sensitized verbal tests, different parameters must be modified using filters, reductions and masking noises [1]. Some of these tests are: Carhart logoaudiometry, Alternating voice test, Lombard test, Logoaudiometry with filters, Speech compression test, acentual_BOCCA logoaudiometry, Calearo and Lazzaroni logoaudiometry and message speed, Speech in noise test, Binaural integration test.

Masking in logoaudiometry

The evaluation of language decoding in noise is necessary because very few real conversational exchanges take place in environmental conditions such as those of soundproof cameras, so the noise gives a certain degree of "ecological" naturalness. It is also known as one of the main complaints of hearing aid users the difficulty in understanding speech in noise. In addition, you can have two very similar tonal audiometry and results of verbal discrimination in similar isolated words that hide very different hearing losses [3,22-25].

The opposite ear should be masked whenever there is suspicion that it may intervene in the results of the ear in test, that is, when the difference between the threshold of intelligibility of the ear in test and the bony pathway of the opposite ear is greater than 40dB, intensity that corresponds to the interaural attenuation. The masking noise used is "speech noise".

Failing that, it can be masked with white noise. The method used in tonal audiometry cannot be applied here, since in this we work with intensities at threshold while in verbal tests we maintain levels above the tonal threshold [1,4,23].

Applications

In addition to determining the ability of a person to perceive spoken language giving diagnostic confirmation of hearing loss and even pseudohipoacusis in simulating people, logoaudiometry has clinical application in the topographic localization and quantification of an auditory dysfunction. It evaluates the performance of the different technical aids such as cochlear implants or middle ear implants or hearing aids, and guides in the follow-up of the users of these devices, being important for the prosthetic adaptation and the selection of the characteristics of the hearing aid. It is part of the evaluation of central auditory processing disorders. Its results can be crossed with those of tonal audiometry comparing them to verify the finding of an alteration. Study the existence of central hearing loss using special vocal tests [1,4,18].

Conclusions

Within the auditory studies, logoaudiometry is a complex and important test with clinical applications of interest for the study and follow-up of people with prostheses, cochlear implants and/or brainstem implants, children and adults with hearing deficit in general. It is a complementary test to conventional tonal audiometry.

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