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CHILDHOOD HEARING REHABILITATION (PART III): PERCEPTION OF SPEECH

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CHILDHOOD HEARING REHABILITATION (PART III): PERCEPTION OF SPEECH

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This month's newsletter discusses how children perceive speech sounds when they are undergoing hearing rehabilitation. This is the 3rd bulletin focusing on hearing rehabilitation, so we recommend reading the previous bulletins, the first of which presented guidance to parents and caregivers, while the second discussed ways of enhancing hearing and linguistic development during the early years.

As a professional in the area of hearing rehabilitation, you must have already wondered about what aspects must be considered in order to make interventions in children a success.

An adequate perception of the sounds of speech plays a fundamental role in communication, learning, and social interactions. Researchers already know that vocal production and understanding depend on good audibility of sound stimuli.

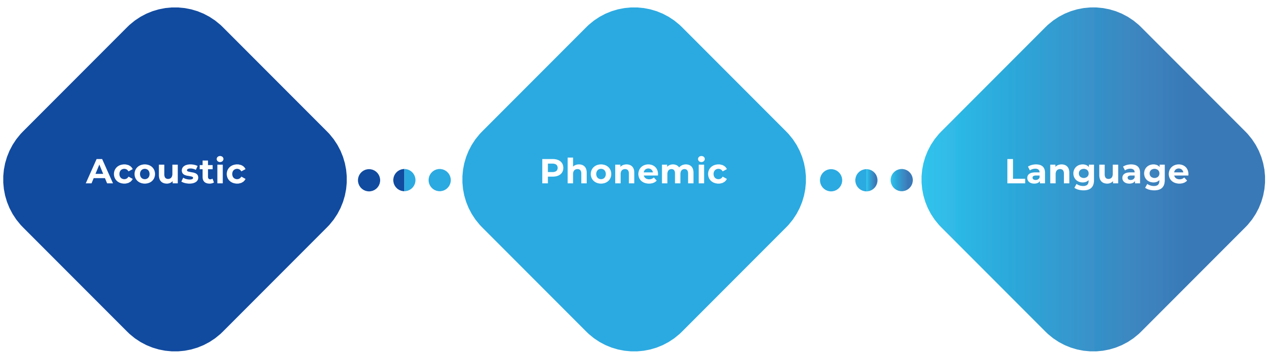
The communication process builds on three types of information processing:

- Acoustic processing;
- Phonemic processing;
- Language processing.

ACOUSTIC PROCESSING

All three processes are interlinked. Acoustic processing depends on the integrity of the hearing system, as information is received and transmitted to different structures. And this system is constantly active, even during sleep. Whether you like it or not, there will always be acoustic processing going on, and this is what makes sounds audible.

A deficiency in acoustic processing in children with a hearing loss can be ovecome by appropriate selection and adaptation of electronic devices. In this way, an input sound stimulus can be restored and hearing again takes place.



One important aspect that needs to be monitored is how well speech sounds are perceived either in an easy-to-listen environment (such as a silent environment) or in a difficult environment (such as a noisy background). There are different tests aimed at evaluating this ability in different age groups and under different hearing conditions.

The results of the speech tests in children, especially those who have received some type of hearing intervention through the provision of an electronic device, can be used to improve listening using a suitable hearing aid. If a deficit is still observed, a specialist can reevaluate the options and select a device that provides better speech audibility.

As far as speech production is concerned, there are various nuances. Speech can be at normal speed, or be slow or fast, depending on the speaker. There is a large variability in the production of speech between speakers, depending on aspects such as timbre, frequency, duration, rhythm, intensity, prosody, as well as speed.

The perception and processing of a sound stimulus as variable as speech requires rapid and effective neuronal activity, since our ears and our brain need to be able to perceive, recognize, discriminate and understand the sounds of speech from different speakers.

For intelligibility of speech, it is known that frequencies between 1000 and 3000 Hz provide important information. However, phonemes such as /s/ and /f/ are at higher frequencies, between 4000 and 5000 Hz. It is therefore essential that electronic devices are able to respond to these frequencies and that listening is comfortable and pleasant for the child.

Speech sounds are arranged at different frequencies and levels, and this is shown as the banana audiogram (Figure 1).

This diagram makes it possible to understand the difficulties they may have in listening to certain sounds. It also allows the audiologist to explain conditions to parents and carers, since the data is presented as an easy-to-understand figure. It allows each patient, with different degrees, types, and configurations of hearing.

BANANA AUDIOGRAM

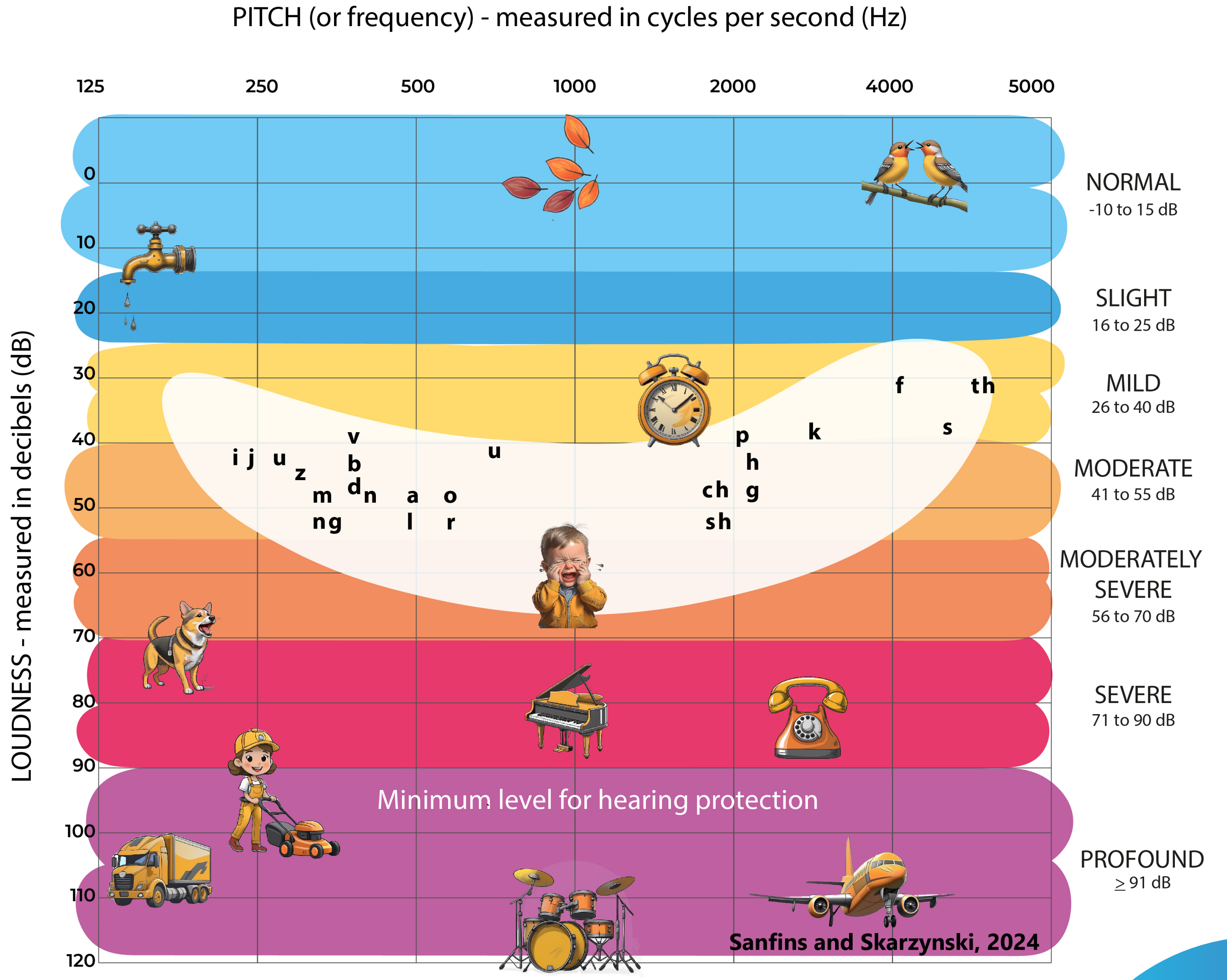


FIGURE 1: Audiogram based on the normative values of Clark et al, 1981.
Figure developed by the authors Sanfins and Skarzynski, 2024.

In addition to the traditional banana audiogram for speech, there is a new recommended format called the "string bean" speech audiogram that takes into account the importance of low-intensity hearing.

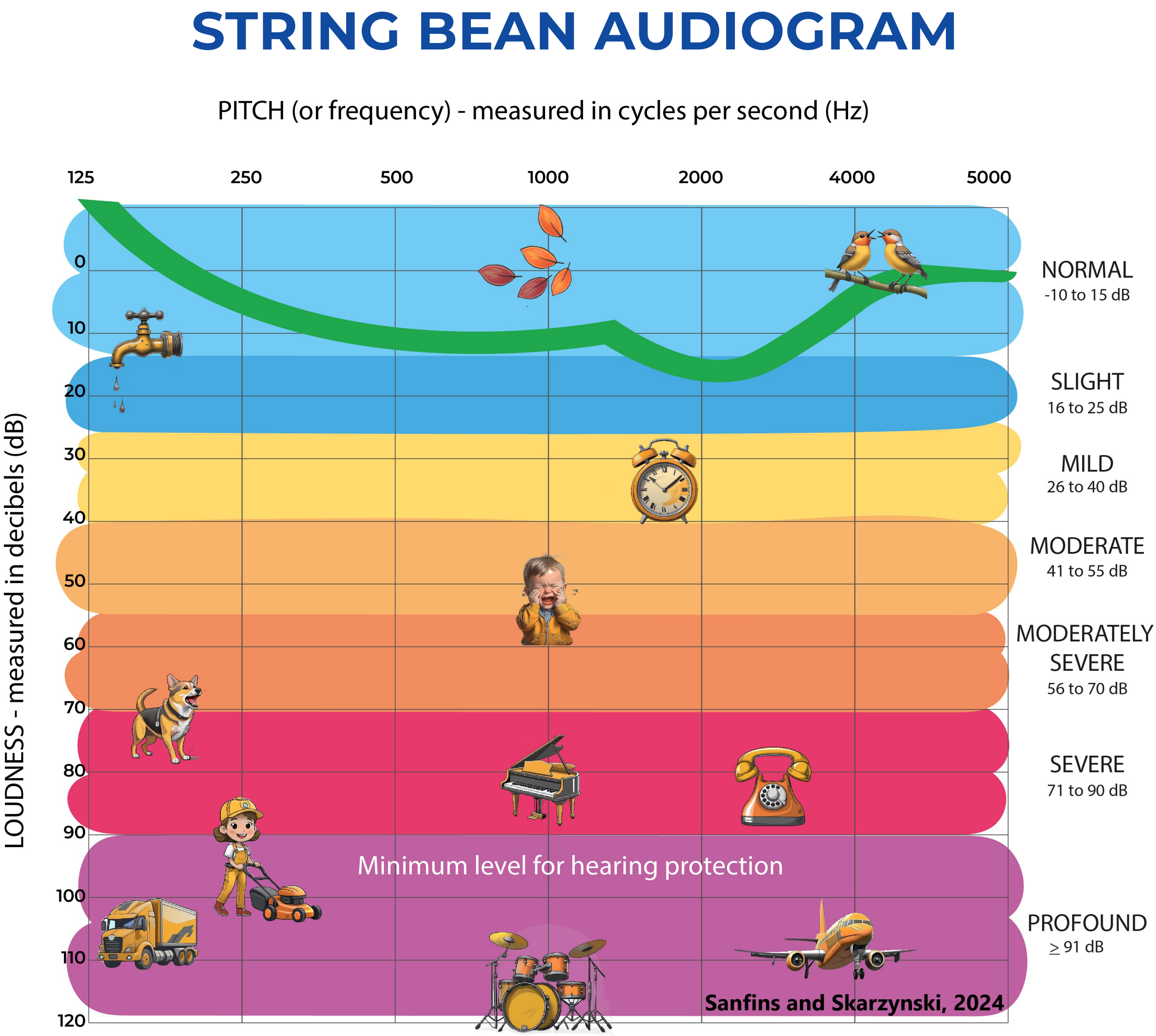


FIGURE 2: Audiogram based on the normative values of Clark et al, 1981.
Figure developed by the authors Sanfins and Skarzynski, 2024.

Especially in children with hearing loss, and where the parents have opted for the use of oral language, it is important that the brain receives as much sound information as possible. Allowing new neural connections to be established at different frequencies and intensities, the string bean audiogram shows that access to light and moderate sounds can benefit the development a child's communication.

The development of hearing skills will improve if the child is able to hear and identify all the phonemes of their native language, and it should be noted that this number varies according to the language. Access to sounds is essential, even to a child with hearing loss, as this is the only way that acoustic processing can be effectively performed. loss, as this is the only way that acoustic processing can be effectively performed.

BANANA AND STRING BEAN AUDIOGRAM

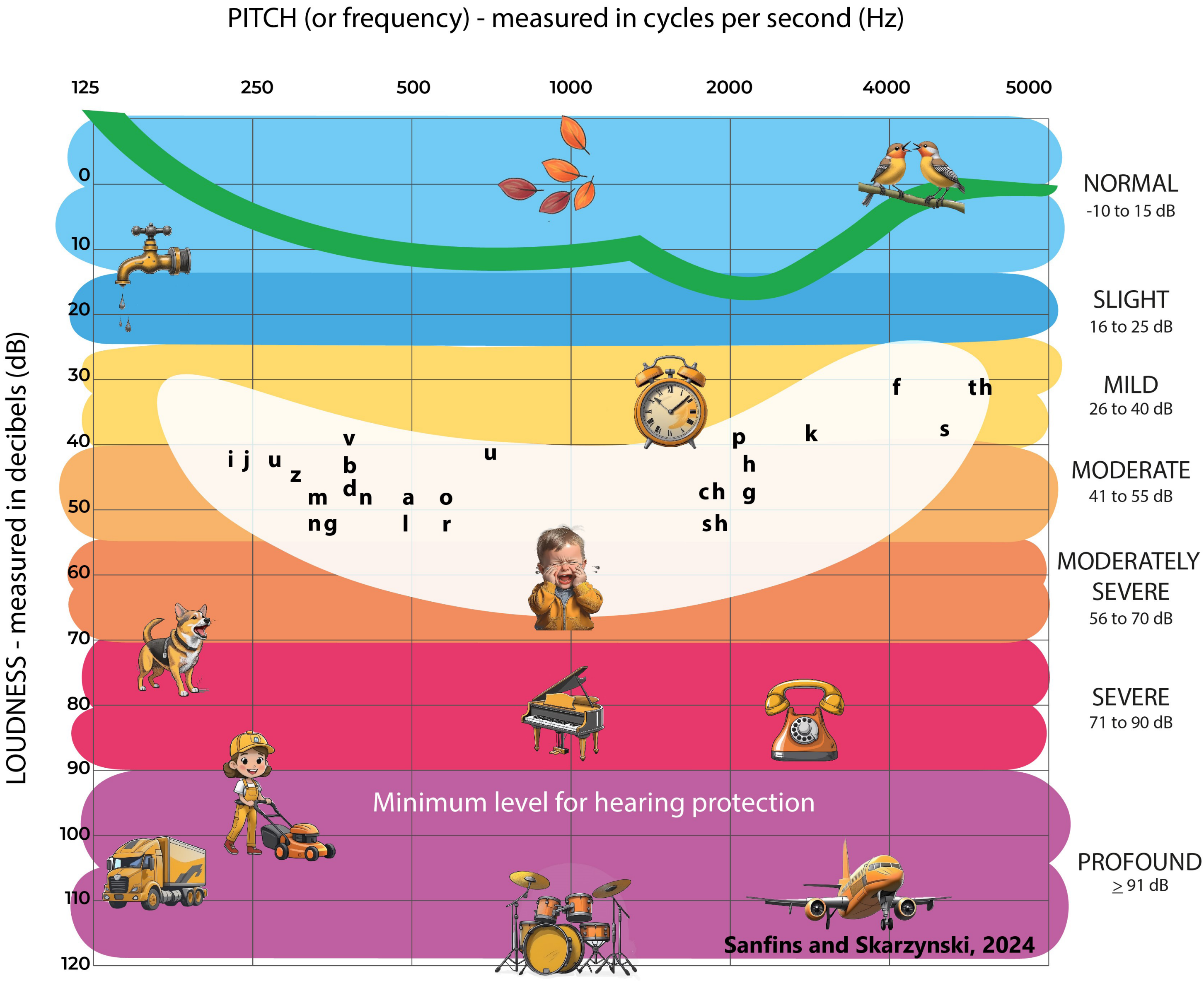


FIGURE 3: Audiogram based on the normative values of Clark et al, 1981.
Figure developed by the authors Sanfins and Skarzynski, 2024.

PHONEMIC PROCESSING

Where acoustic processing ends, phonemic processing begins. However, it is important to note that the two systems interact, and so both speech processing and understanding may be impaired if there is any impairment to one of the systems.

The identification of phonemes requires analysis in structures located in higher regions of the central nervous system (such as the sulcus and the upper left temporal gyrus). When processing a phoneme, the child hears a certain sound and then has to categorise it into the type of sound stimulus heard, **such as:**

- **was it the sound produced by a musical instrument or by a human being?**
- **is the sound stimulus /da/ or /ba/?**
- **are the words /sheep/ and /ship/ identical or not?**

Note that semantic processing involves much more than listening to a certain sound stimulus! This processing depends on the perception of the physiological and articulatory characteristics of the sound. It depends, for example, on the spectro-temporal aspects that involve the perception of the transition in speech formants as a result of movements of the vocal tract.

Both hearing children and those with hearing impairments discriminate and process vowels more quickly compared than consonants. The discrimination of consonants helps in the intelligibility of the sounds of speech, distinguishing the different words such as cell x sell x bell. Younger hearing children need greater acoustic differences and more time to differentiate consonants than older hearing children or adults.

On the other hand, the discrimination of the vowels is related to prosody, intonation, and melody. These distinctions are extremely important for correctly understanding a message, and make it possible to understand, for example, whether a speaker is happy or angry.

Researchers have identified that a prerequisite for language development is a long period of hearing speech before actual vocal production begins. Given this, it can easily be imagined that children with a hearing loss need early and intensive intervention so that they can improve their ability to perceive speech sounds. Being provided with speech sounds, such as in a program of therapeutic intervention based on simple and complex sound stimuli (such as speech sounds), will allow semantic processing to begin and become effective.

One method for analysis of speech phonemes is a test called Ling sounds. Currently, there is a six-sound version of Ling and a reduced version with three Ling sounds. The 6-sound test evaluates how certain types of phonemes ([a], [i], [u], [o], [m], and [s]) are heard, which have been chosen to provide low, medium, and high frequency speech information. In the simplified 3-sound version, it is also possible to evaluate low, medium, and high frequency with the presentation of ([ba], [ʃ], and [s]). Ideally, sounds should be presented through a pre-recorded voice system, thus avoiding bias between different evaluators.

Within a standard audiological battery, analysis of speech perception and recognition are fundamental parts of acoustic, phonemic, and linguistic processing. The challenge of investigating how speech sounds are perceived depends on the age of the child being assessed. In the first months of a child's life, attention paid to the mother's voice already provides us with many clues of how the child is responding to sound. With the passing of extra months, apart from the mother's voice itself, the discrimination of the maternal voice from that of other speakers shows an advance in the processing of sound information and the level of the baby's neural connections. At the end of the first year and beyond, the baby has already entered the world of linguistic processing, being able to differentiate /ba/ (ball) from /bah or bah-bah/ (bottle).

LANGUAGE PROCESSING

Following acoustic and phonemic processing, linguistic processing occurs. At this stage, there is a co-dependence of acoustic and semantic processing. Moreover, vocal production with meaning and comprehension derives from functional acoustic, phonemic, and linguistic processing. Faced with the high complexity of linguistic processing, there is participation of complex structures of the nervous system such as the callosal body and especially the left brain hemisphere.

Linguistic processing results from the assignment of meaning to the sound messages heard. Speech can be uttered in environments considered ideal for communication, i.e. in quiet environments, but also in surroundings with many competing sounds and noise. In the presence of competitive sounds and the listener's need to focus on the main message, there is the activation of another brain area, the portion of the frontal cortex that acts as a signaller of whether information is important or can be disregarded as irrelevant. At the same time, there are other tasks that need to be enabled in order for the main message to be focused on. Executive functions, attentive processes, and inhibitory control also need to be in place, revealing how complex linguistic processing really is.

Children who need hearing habilitation/rehabilitation should be exposed early to listening experiences in different environments and conditions so that they have access to the three basic types of sound information processing. Nevertheless, language is complex and involves many elements. There needs to be analysis of linguistic elements that consist of the literal meaning of a certain sound; there is also analysis of paralinguistic elements which consist of modification of the significance of a particular sound depending on various environmental contexts and even the speaker.

The use of electronic devices makes it possible for individuals to have access to speech recognition, but such devices cannot always follow prosody, so the meaning can never be guaranteed. The limited clues as to prosody can limit the communication process and can sometimes provide an inadequate, or even inaccurate, perception as to the emotional state of the speaker. For example, the uttering of a phrase like "Good morning!" can have different senses depending on the prosodic pattern and can convey information about the speaker's state of mind, whether joy, sadness, enthusiasm, anger, or something else.

Scientists have found that, especially in patients with hearing loss, prosody is often reduced, since electronic devices tend to provide a robotic type of voice quality, even with technological advances. This difficulty might be due to the need to analyze different acoustic aspects such as the fundamental frequency, the harmonics, and the intensity and duration of a sound stimulus. Of all the acoustic features, the most relevant for the perception of the emotional condition of a speaker is the analysis of the fundamental frequency.

Studies have shown that children using cochlear implants retain good skill in differentiating simple contrasts in facial emotions. One promising theory is that gaps in hearing might be supplemented by visual analysis of the speaker's face. However, in all communication processes, there is not always the possibility of being face-to-face with your interlocutor, so this visual feature ceases to bring the benefits and the use of the isolated hearing skills will be more demanded within the communication process.

Concomitantly with the development of linguistic skills occurs development of cognitive skills; thus, the plasticity of the nervous system can benefit from therapeutic intervention in both areas.

To conclude, a sound stimulus entering the hearing system goes through several processing stages before the meaning of the message contained in it can be deciphered. Hearing is the primary source of understanding and expression of an individual. So the first years of a child's life are crucial for the development of the three processes – acoustic, semantic, and linguistic – for both a child born with normal hearing and for a child born with some kind of hearing loss.

In the presence of alteration in the hearing system, electronic devices such as individual sound amplifiers, cochlear implants, and support systems such as FM transmitters can be beneficial when selected and adapted in a way that takes into account the specific characteristics of the patient.

Within the process of hearing rehabilitation, the accurate perception of speech stimuli is primary, since speech is the sound stimulus that the individual will be exposed to for much of their day. The perception of speech is crucial in enabling an exchange between a person and their peers in different contexts and in different experiences. All these exchanges will promote language development and positively raise the overall quality of life of the patient.

It is therefore important that there is an accurate evaluation and monitoring of how an individual perceives speech sounds, no matter what their age, since any impairment here can trigger changes in a child's development and affect their oral language, writing, reading ability, sociability, and academic or professional performance.

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