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HEARING REHABILITATION IN CHILDHOOD (PART IV): SPEECH SOUND DISORDERS AND HEARING DISORDERS

Eliara Pinto Vieira Biaggio, Mariana Zago de Moraes, Márcia Keske-Soares, Piotr Henryk Skarzynski and Milaine Dominici Sanfins

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HEARING REHABILITATION IN CHILDHOOD (PART IV): SPEECH SOUND DISORDERS AND HEARING DISORDERS

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This month's bulletin addresses speech sound disorders and hearing disorders, an important topic in childhood intervention and rehabilitation. It is one of the main concerns for speech therapy in children.

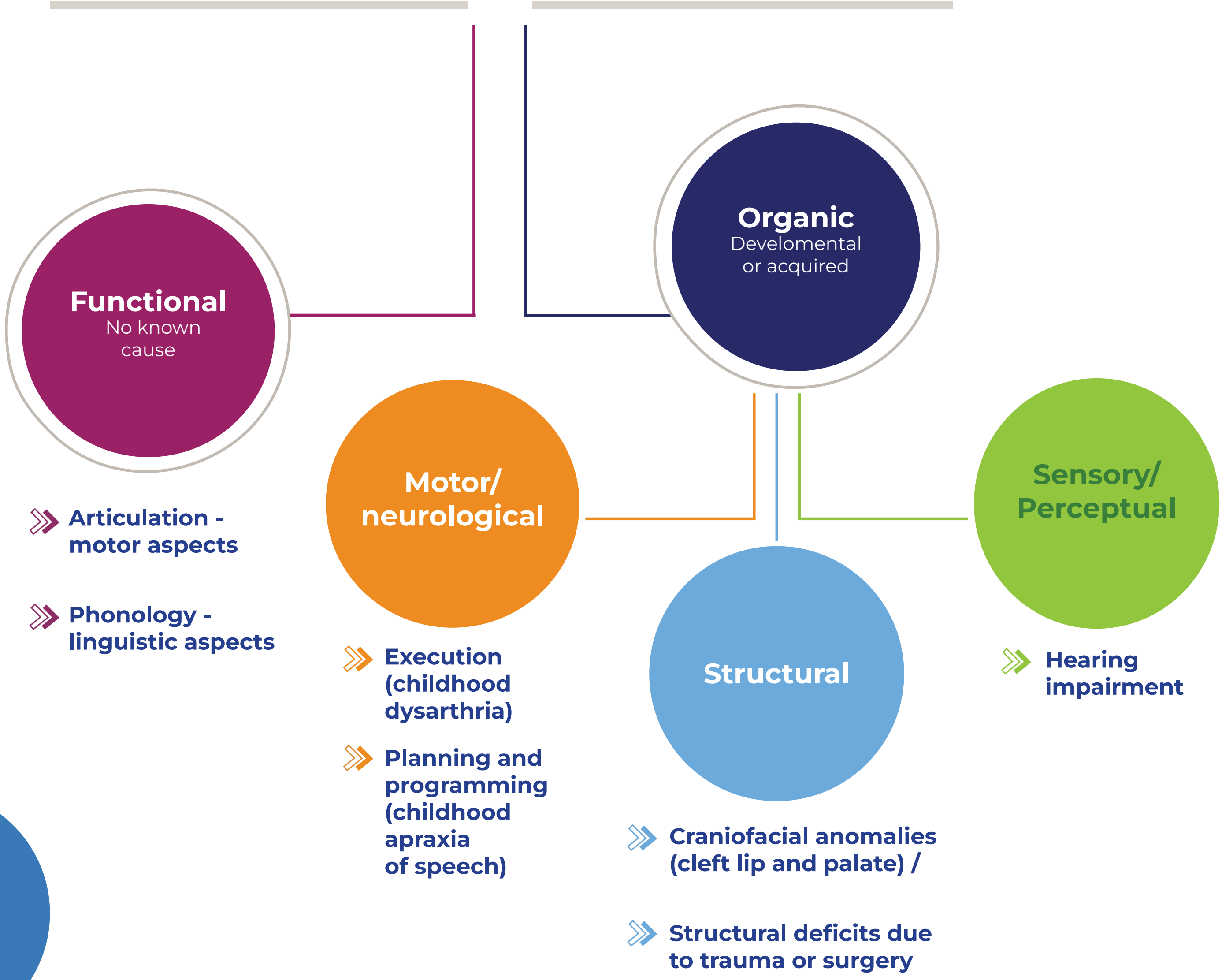
Before we begin, we emphasize that this is part 4 of our series, and we recommend reading previous bulletins that discuss the guidance that parents and caregivers can provide within the habilitation and rehabilitation process. These aspects cover enhancement of auditory and linguistic development during the early years, and the perception of speech sounds.

It is often observed that when a child's development does not progress as expected, there is compromised speech intelligibility. Such speech changes are referred to as Speech Sound Disorders (SSDs). These disorders may refer to difficulties or changes in perception, motor production, or phonological representation of speech segments or their prosody.

The American Speech-Language and Hearing Association (ASHA), the largest body of speech-language pathology professionals, provides guidelines on classifying SSDs based on their origin, and subdivides them into two types: functional and organic. The flowchart below, translated and adapted from ASHA, shows functional SSDs that are idiopathic (without a known cause) and divided into articulatory and phonological disorders.

The flowchart below, translated and adapted from the consensus of this association (https://www.asha.org/practice-portal/clinical-topics/articulation-and-phonology/), presents TSF of functional origin, which are idiopathic (without known cause), being characterized by articulatory and phonological disorders.

Classification of Speech Sound Disorders



Font: adapted from the ASHA (https://www.asha.org/practice-portal/clinical-topics/articulation-and-phonology/)

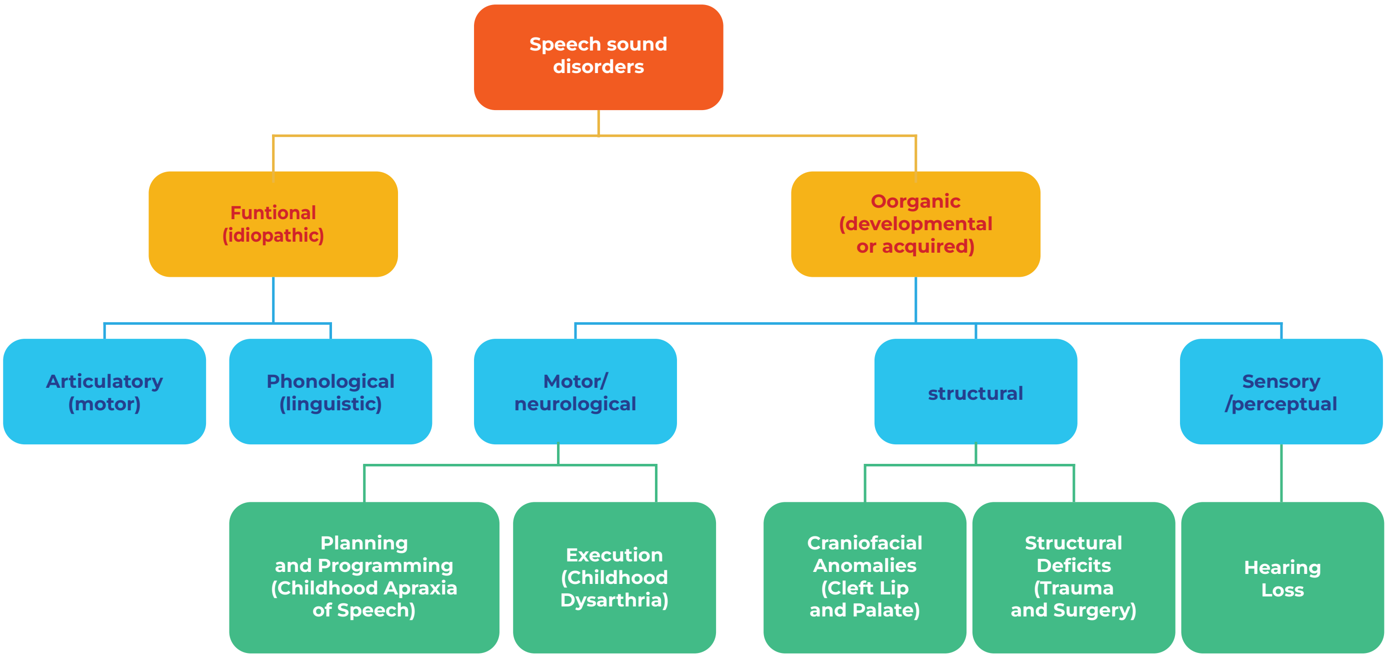
ORIGINS AND OCCURRENCES OF SSDS

Organic SSDs are of developmental or acquired causes and are related to a certain type of impairment:

01. **Neurological**, with difficulties in the planning, programming, and motor execution of speech, referred to as Speech Motor Disorders (SMDs) such as childhood speech apraxia and dysarthria. These are described fully at https://www.asha.org/practice-portal/clinical-topics/childhood-apraxia-of-speech/

02. **Structural**, with compromised orofacial structures such as craniofacial anomalies (cleft lip and palate) or in structural deficits (traumas and surgeries), as described in https://www.asha.org/practice-portal/clinical-topics/cleft-lip-and-palate/.

03. **Sensorial/perceptual**, as in hearing losses.



Font: Classification of Speech Sound Disorders (SSDs). Source: adapted from the ASHA portal (https://www.asha.org/practice-portal/clinical-topics/articulation-and-phonology/)

This classification allows us to observe that Speech Sound Disorders (SSDs) have diverse origins and involve different conditions, indicating that the speech therapist needs to identify the clinical characteristics of each type for better differential diagnosis. **As these SSDs are predominant in pediatric clinics, it is important to assess and intervene as early as possible so that the disorders do not persist into adolescence and adulthood, causing harm to social interactions, interpersonal relationships, and professional performance**.

SYSTEM FOR CLASSIFYING SPEECH SOUND DISORDERS

For many years, most research has focused on functional disorders, as they are the most prevalent in speech therapy clinics. In recent decades, however, attention has broadened more to Speech and Language Disorders, including cases with organic origins, such as Motor Speech Disorders (MSDs), even though they have lower prevalence.

Knowledge has evolved and new concepts and understanding have come from new studies on speech production models, some of which are based on neuroimaging (Guenther, 2016; Seikel, Konstantopoulus, Drumright, 2020; Seikel, Drumright, Hudock, 2021). Prominent here is research by Shriberg and colleagues who, for over 30 years, have been working on developing a Speech Disorders Classification System (SDCS, details of which can be found at The Phonology Project (https://phonology.waisman.wisc.edu/). SDCS brings a clinical focus to SSD by considering its etiology (genomic and environmental), including risk and protective factors that may lessen or aggravate the disorder.

The neurodevelopmental substrate is the foundation of this classification. It is focused on speech processes (representation, transcoding, and motor execution) which allow biomarkers and discriminative signs to be identified which help in the differential diagnosis of SSD. The final version of this classification system has been used in genomic studies, neuroimaging, prevalence, normalization, and speech processing of children with idiopathic speech sound disorder and complex neurodevelopmental disorders.

Currently, SDCS is the most well-known and widely used clinical classification system. It identifies three types of SSD:

- **Speech delay;**
- **Speech error;**
- **Motor speech disorder, with four subtypes:**
  1. Speech Motor Delay (SMD),
  2. Childhood Apraxia of Speech (CAS),
  3. Childhood Dysarthria (CD),
  4. And the combination of CAS and CD (Shriberg et al., 2010; 2017; 2019).

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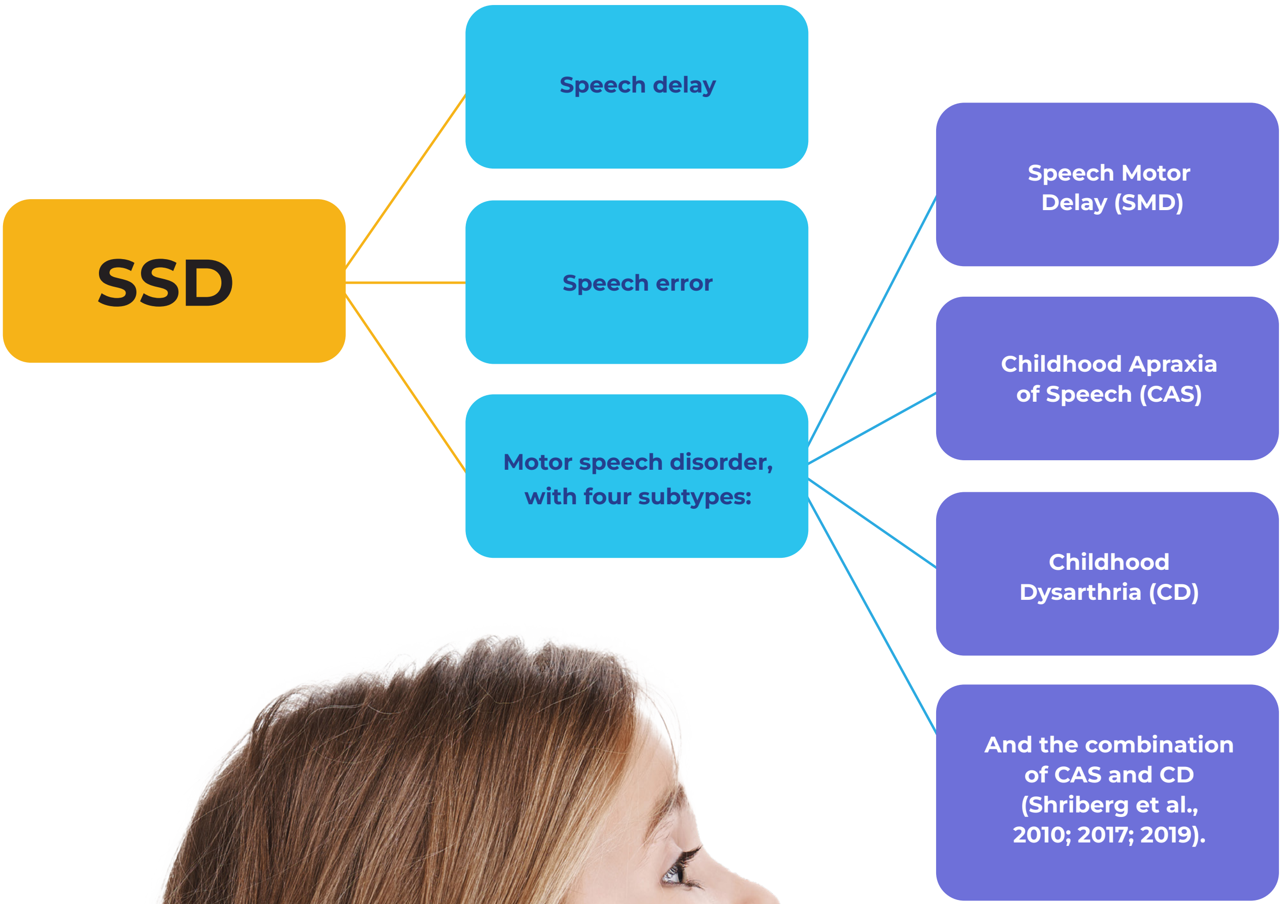

SSD
Speech delay
Speech error
Motor speech disorder, with four subtypes:
Speech Motor Delay (SMD)
Childhood Apraxia of Speech (CAS)
Childhood Dysarthria (CD)
And the combination of CAS and CD (Shriberg et al., 2010; 2017; 2019).

SPEECH DELAY

Speech Delay (also known as Phonological Disorder) has a genetic origin, with some risk and protective factors already identified, such as otitis media with effusion (OME) and developmental psychosocial involvement. However, no diagnostic markers have yet been found or determined for this type of DDS.

SPEECH ERROR

Speech Error is related to speech distortions (also known as Articulatory or Phonetic Disorder), with changes in fricatives and liquids, especially /r/. This type of SSD can be considered persistent if the error remains beyond the age of nine. The diagnostic marker for Speech Error is the analysis of formants; that is, through acoustic analysis, for example, it is possible to better determine speech distortions.

SPEECH MOTOR DISORDERS

The different types of speech motor disorders occur when there is an impairment of one or more speech motor processes (planning, programming, or execution). In addition, other characteristics are identified, such as substitution and omission of phonemes and speech inconsistency. We also observe imprecision and spatial–temporal distortions in the production of vowels and consonants, along with possible prosodic changes. SLD can appear in isolation or associated with other developmental disorders, as seen in cases of children with Autism Spectrum Disorder (ASD).

SPEECH DISORDERS CLASSIFICATION SYSTEM - SDCS

According to the Speech Disorders Classification System (SDCS), diagnostic markers have been identified for SLD.

- Speech Motor Delay presents as a marker and index for speech accuracy and stability.
- Childhood Apraxia of Speech is marked by pauses in speech, such as inconsistency, changes in coarticulation, and prosody. They are red flags for diagnosis.
- In Childhood Dysarthria, the markers are indices related to the subtypes of dysarthria. The motor bases of speech (articulation, phonation, resonance, prosody, and respiration) will be affected.

> **The determination of a diagnosis of functional or organic SLD, including the subtypes already presented, demonstrates the importance of establishing a differential diagnosis between the types and subtypes of SLD. Furthermore, the processes of feedback and feedforward are essential for the development of speech.**

For the clinical professionals responsible for these children, differential diagnosis of each of these disorders is a challenge, but regardless of the subtype of SSD, it is essential to know the audiological status of these children because we know it is the biological foundation of language.

There is an interdependence between language development and hearing. We must also remember that the child is in contact with the sound world even from intrauterine life and that the auditory system is stimulus-dependent. Different sounds need to be detected, decoded, and transformed into electrical impulses, which are then conducted by nerve cells to the auditory area of the cerebral cortex in the temporal lobe. In the higher regions of the auditory pathway, there is integration with other areas responsible for speech and language (from the planning of the motor act of speech to the production of intelligible and meaningful speech).

It is worth noting that, unlike other sensory systems, the auditory system requires stimulation in order to develop fully. Auditory perception depends on innate factors (anatomy and physiology) and the interaction between the environment and auditory experience.

This means that the richer the auditory experiences in childhood are, the more new brain connections and new synapses will emerge, so that these functions are in constant development. The integrity of both the peripheral and central auditory system

is fundamental for the development of a child's speech; thus, differential diagnosis of a child with SSD should be considered essential in their rehabilitation process (Andrade and Biaggio, 2024).

The longer it takes to diagnose hearing loss, or any other hearing disorder in a child, the worse their language development will be, which will also have consequences for their intellectual development.

Hearing loss in childhood can be silent, as young children tend not to complain about not hearing well. Furthermore, at some point, almost all children can develop problems in the middle ear, which can last for days, months, or even years, potentially leading to significant impairments for speech development, as has been well documented in the literature.

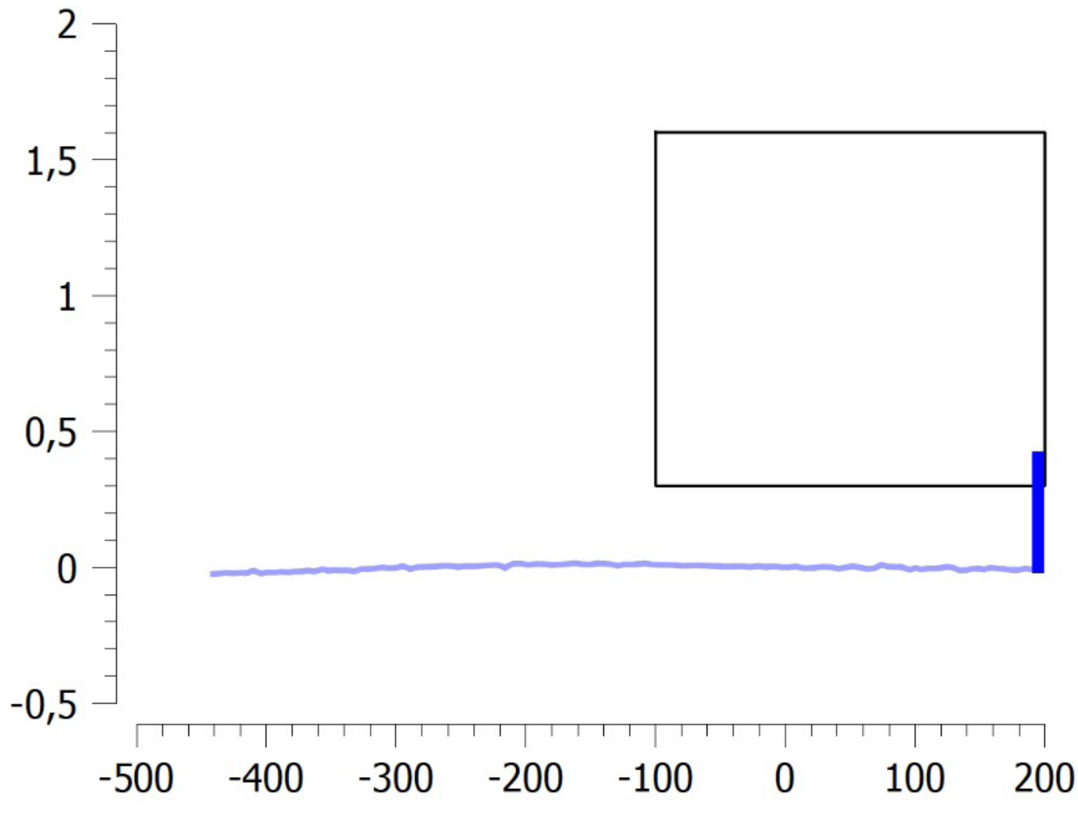
All children undergo Neonatal Hearing Screening (NHS), but an evaluation by an otolaryngologist and audiological tests should be requested if there are any signs of hearing loss or speech unintelligibility, as seen in cases of children diagnosed with different SLDs. Furthermore, all child health consultations should also include a careful check of the Child Health Booklet and questioning of the parents about whether there is any documentation of the NHS or language milestones. Regular consultations with an otolaryngologist will be necessary, both for diagnosing and treating upper respiratory tract or middle ear infections, as well as for promoting their prevention, since all of these will have an impact on speech perception.

OTITIS MEDIA

Regarding auditory disorders in childhood, middle ear alterations, such as otitis media, are undoubtedly a common diagnosis in children. Most children will have at least one episode of Acute Otitis Media (AOM) by the age of three, and by the age of six, 40% of children will have had three or more middle ear infections. In most cases, the progression of the condition is favorable, with spontaneous resolution; however, 65% of children may have Otitis Media with Effusion (OME) for two weeks, 40% may have it for a month, and 25% may have it for three months.

OME is defined as the presence of fluid in the middle ear, without symptoms of acute infection, and is a major cause of conductive hearing loss in childhood. We know that conductive impairment can have consequences for the child's development, as a child with middle ear alterations experiences inconsistent sound stimulation, which hinders the perception of speech sounds.

Moreover, such a condition can impair the perception of differences in duration between voiceless and voiced sounds (Wertzner et al, 2009), a fact directly linked to the production of intelligible speech. Thus, treatment for effusion should take into account whether there is a risk of speech, language, or learning disorders, in which case surgical treatment should be prompt. In cases without risk factors, clinical and observational treatment should be instituted before making a surgical decision.



Bioggio et al, 2024

DISORDERS OF SPEECH AND HEARING

In the therapeutic setting of Speech Therapy, we should, at a minimum, request a basic audiological evaluation for all children who exhibit impaired speech intelligibility and refer them to speech therapy services.

In pediatric audiological assessment, the first step is the anamnesis/speech therapy interview, which is essential for gathering information about auditory behavior, language development, audiological history, health, and the overall development of the child. These data are needed to guide the results of audiological evaluation.

Before the hearing test, meatoscopy is performed to check the condition of the external auditory canal, using an otoscope with good lighting and a pediatric speculum to ensure comfort and adequate visibility.

To assess auditory sensitivity, Pure Tone Audiometry should be conducted (with at least the frequencies of 0.5, 1, 2, and 4 kHz in both ears separately), Speech Audiometry, and Acoustic Immittance Measures (AIM). Regarding audiometry of children with SSDs, it is important to note that the speech therapist must adapt the procedures to ensure that auditory performance is not affected by speech production difficulties. Speech recognition tests generally rely on the verbal repetition of heard words, which can be challenging for children with unintelligible speech or those who are non-verbal. Thus, the vocabulary selected should be appropriate to the child's linguistic and cognitive level, prioritizing familiar words. Furthermore, the choice of a closed-set test, in which the child points to pictures that represent the words, is recommended so as to prevent difficulties in speech production from affecting the interpretation of the results.

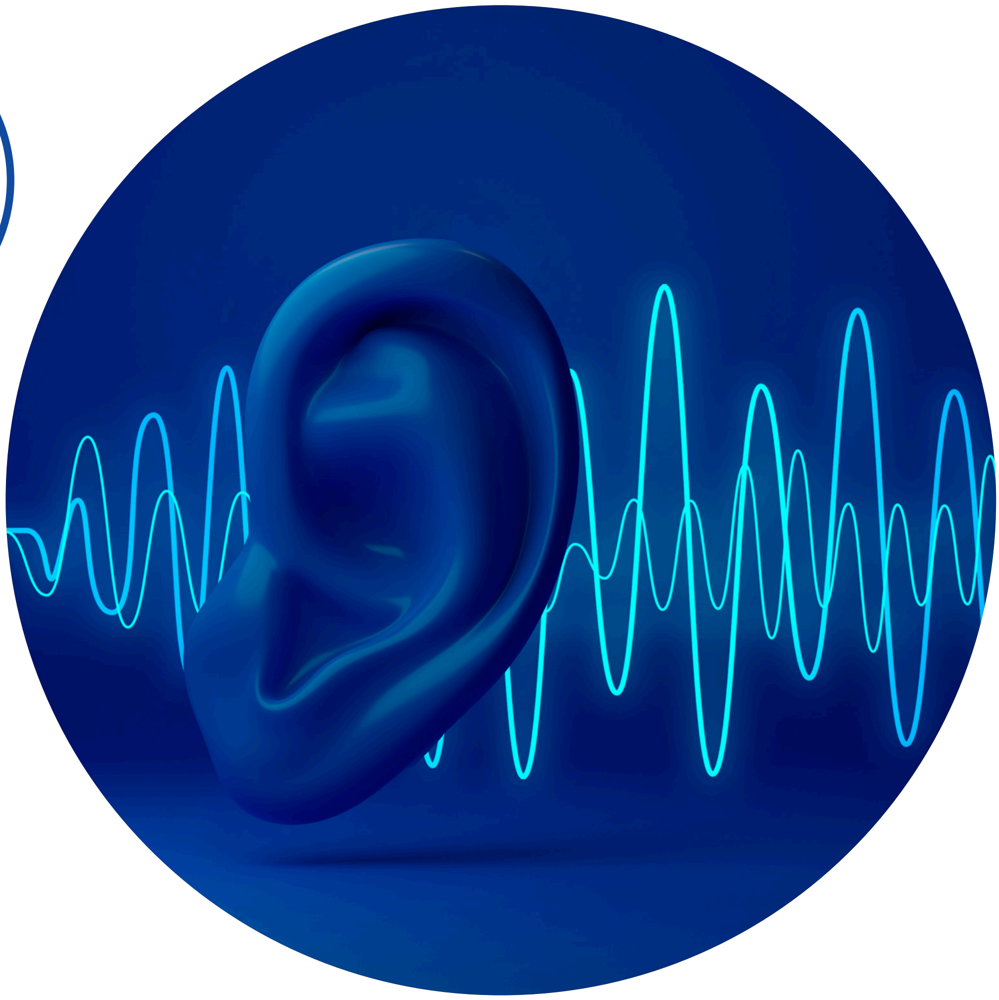
To ensure an accurate assessment of auditory perception, the speech therapist should prepare representative figures of the words used. The last procedure of the basic audiological evaluation is to analyse the conditions of the middle ear and give an overall assessment of the auditory pathways in children with SSD. This is done through the Acoustic Immittance Measures (AIM), which are valuable procedures that do not require the active participation of the child, are easy to apply, quick, and do not cause fatigue or depend on motivation for response. The AIM includes Tympanometry, using a probe with a test tone of 226Hz, and a test for Acoustic Reflexes of the stapedius muscle, performed in the same way as in adults.

These procedures are worthwhile because we now understand the impact of that changes in speech and language can have on a child's further development.

SSDS AND ASSESSMENT OF CENTRAL AUDITORY PROCESSING

After a basic audiological assessment, there is the possibility of doing an evaluation of Central Auditory Processing (CAP), depending on the symptoms described by the family or therapist and on how well the child performs in other tests (Andrade and Biaggio, 2024). We should emphasise that only children who are at least seven years old should be referred for a behavioral assessment of the CAP.

There are a range of behavioral tests for CAP, with oral repetition in a closed context and a figure-pointing task, which are especially indicated for cases of unintelligible speech. There are tests that evaluate temporal resolution, the Random Gap Detection Test (RGDT) or Gaps-in-Noise (GIN) test, directed listening tests using verbal sounds (Dichotic Digits) and non-verbal sounds (Non-verbal Dichotic) and low redundancy monotic listening tests (such as the Pediatric Speech Intelligibility or PSI, and the Synthetic Sentence Identification or SSI).



SSDS AND ELECTROPHYSIOLOGICAL ASSESSMENT OF HEARING

Electrophysiological tests of hearing are procedures that allow for the objective assessment of the auditory system, both peripheral and central, since they avoid relying on the child's conscious response. They are an excellent option for evaluating hearing in addition to the behavioral assessments listed above. For children with SSD, Auditory Evoked Potentials (AEPs) provide diagnostic information about how certain regions of the auditory pathway respond to complex stimuli, such as speech.

The Frequency-Following Response (FFR) is another complementary technique for assessing children with various speech and language disorders, since responses are altered in specific contexts. For example, in Phonological Disorder (PD), neural coding of complex sounds is disrupted, pointing to a physiological basis for speech processing (Ferreira et al., 2019), and the FFR is a reliable and useful assessment tool. Studies indicate it is effective in cases of Childhood Apraxia of Speech, where children show significant increases in the latencies of waves V, A, and C, suggesting that this disorder may not be exclusively motor (Marques et al., 2021). In the future the FFR may establish itself as the preferred AEP for cases of SSD, as the FFR can assess neural activity in response to complex auditory stimuli, allowing for the study of how the acoustic components of speech are encoded by the CANS.

The coding of complex sounds is an essential skill for the proper perception of speech. The FFR can provide insight into the temporal and spectral processing of verbal elements (Kraus et al, 2017; Sanfins et al., 2019; Skoe and Kraus, 2010). Study of how the perception of speech sounds occurs in higher regions of the auditory pathway, including the inferior colliculus and even the auditory cortex (Schüller et al. 2023), can be a useful tool for diagnosing different speech sound disorders.

DISORDERS OF SPEECH SOUNDS AND STIMULATION OF AUDITORY SKILLS

Strategies to promote auditory skills in children with Speech Sound Disorders (SSDs) is necessary in speech therapy and in clinical practice. Even without a formal CAP assessment, a few minutes of a session should be dedicated to stimulating auditory skills, as this will enhance speech perception, motor production, and phonological representation.

Depending on demand, children diagnosed with disorders in the development of auditory skills should be included in Auditory Training (AT) programs, alongside speech rehabilitation therapy. The use of mobile apps in conjunction with speech therapy can also be worthwhile. Although there are presently only a few publications that directly investigate the effects of these interventions on phonological skills, a positive impact on auditory skills is evident and can only benefit the therapeutic process.

FINAL CONSIDERATIONS

We conclude that hearing plays a crucial role in the development of oral language, and its early assessment and monitoring is essential to prevent negative impacts on language and speech development, especially in children with Speech Sound Disorders.

In children with unintelligible speech, assessment of auditory sensitivity should always be considered, as ruling out a hearing loss will help therapeutic progress. The behavioral assessment of Central Auditory Processing (CAP) is indicated for specific cases.

The use of AEPs can provide worthwhile information. In cases of peripheral or central auditory changes, rehabilitation is possible, and for peripheral cases, a medical referral is essential. In the presence of CAP, there are a number of alternatives for stimulating auditory skills, as mentioned above.

Strategies for auditory stimulation are essential for successful therapy, and it is important that speech therapists integrate these approaches into the treatment of children with Speech Sound Disorders.

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- Specialist in ENT, pediatric ENT, audiology and phoniatrics, and public health. Participated in the 3rd Stakeholders Consultation meeting during which the World Hearing Forum of WHO was announced;
- Member of the Roster of Experts on Digital Health of WHO, Vice-President and Institutional Representative of ISfTeH;
- President-elect of International Advisory Board of AAOHNS, member of Congress and Meeting Department of EAONO, Regional Representative of Europe of ISA, VicePresident of HearRing Group, Auditor of EFAS, member of the Facial Nerve Stimulation Steering Committee;
- Board Secretary of the Polish Society of Otorhinolaryngologists, Phoniatrists and Audiologists. Member of Hearing Committee (2018–19);
- Goodwill Ambassador representing Poland at the AAOHNSF 2021 Annual Meeting & OTO Experience, and since 2021 a member of Implantable Hearing Devices Committee and Otology & Neurotology Education Committee of AAOHNS;
- Consultant Committee of International Experts of CPAM-VBMS (by special invitation), honorary member of ORL Danube Society, and honorary member of Société Française d'Oto-Rhino-Laryngologie;
- Member of the Council of National Science Center;
- Expert and member of numerous national organizations.