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Chapter 14. MEASUREMENT STATION FOR APD DIAGNOSTICS AND THERAPY CREATED AS PART OF THE "ASSIST MED SPORT SILESIA" PROJECT

14.1. Introduction

14.1.1. State of the Art

Auditory Processing Disorder (APD) is a group of symptoms defined as problems with the correct understanding of auditory information, despite the lack of damage to peripheral hearing [1]. Usually, these types of disorders occur among school-age children. Their diagnosis criterion is related to symptomatic characteristics, i.e., school failure [2, 3].

The process of diagnosis and therapy of APD among Polish children consists of several steps. The first step is to diagnose APD in medical facilities (an audiologist diagnoses APD). The second step is to conduct therapy by an educational institution. The basis for starting the therapy is the opinion issued by the Psychological and Pedagogical Counseling Center. This opinion concerns the need for psychological and pedagogical help at school [4, 5]. Such a procedure significantly impedes the flow of information. Often, the parent constitutes the only person transmitting data between the healthcare facility and the educational institution.

The audiological diagnosis that confirms the presence of APD is time-consuming. The process requires the assessment of physiological hearing, the psychological examination of the patient's intelligence quotient, and the qualification to test higher auditory functions. The listed procedures require several visits to different medical facilities.

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Institutions must be equipped with a battery of electrophysiological tests (to assess the physiological hearing) and psychoacoustic tests (to check the level of higher auditory functions) [6]. However, the equipment is not always available in a single facility.

Among the tools for diagnosing APD (after excluding physiological hearing loss), clinical diagnostics methods prevail, i.e., psychoacoustic tests [7]. These use mainly the perception of acoustic sound parameters. Special devices enable performing considered tests. Due to the nature of sound perception, tests are divided into several categories, including temporal, dichotic, and assessing the understanding of signals with reduced redundancy. The translation of the percentage results into work with the children in school conditions is ambiguous for the teacher. Some tools allow for the presentation of the symptomatic criterion. Still, they are mainly based on English-language prototypes, often outdated, or based on determinants of a high degree of generality [8].

Specialized diagnostic tools for assessing physiological hearing require adapted rooms with specific acoustic parameters [9]. Psychoacoustic tests should be performed on children in the same facility because any change in the environment can affect the test result. Similarly, the change of a person performing the test impacts its outcomes, e.g., an inappropriate approach of the specialist to a child might distort results. However, few institutions have a set of all devices - testing the physiological hearing and higher hearing functions. The reason is due to the high cost of devices necessary for the diagnostic process. Assuming that the therapy takes place in the same location, it is essential to equip it with the required auditory stimulation tools adapted to a particular disorder profile of a patient. It increases the comfort of examined person and speeds up the diagnostic process. By linking the patient to one specific diagnostic and therapeutic unit, it will also be possible to use the results to expand the scientific knowledge about APD.

Registration of speech signals is essential for the study of the quality of the patient's speech. The parameterization of the speech signal also allows for voice diagnostics [10]. Adjusting the room to professional speech signal recording needs is necessary to include this criterion in the diagnostic process of the patient. The compilation of the recorded signal connected with all the parameters of specialist tests obtained by the child in medical tests should be performed in one location.

14.1.2. Aims and Scope

The main objective of this study is a detailed description of the measuring stand developed under the project: Silesian Engineering Support for Medicine and Sports "Assist Med Sport Silesia" in Zabrze, designed to improve the process of diagnosis and therapy of auditory processing disorders. The data obtained as part of the diagnostic process will constitute a fuzzy expert system's knowledge base. The purpose of the system will be to define the disorder profile of a patient and indicate development areas that require improvement during the therapy of auditory functions.

14.1.3. Paper Structure

The section 'Measuring station' contains a description of the proposed measuring station: the characterization of individual diagnostic-therapy devices and the set of premises. Furthermore, the section covers information about the possible employment of the equipment in diagnosing and therapy of auditory processing disorders. The section 'Conclusion' ends the article.

14.2. Measuring station

The proposed measuring stand is divided into two parts. The first part includes the purchased specialist diagnostic and therapeutic equipment. The second part is a set of visually and acoustically adjusted rooms. The set of premises will meet the requirements necessary for using the purchased equipment (e.g., the appropriate background noise level for audiometric tests). The description also contains information about the equipment dedicated to recording, processing, and evaluating the speech signal, an integral part of the rooms.

14.2.1. Devices

The measuring station includes three audiometers, two auditory-voice training systems, and a set for electrostimulation. Additional equipment consists of a set of disposable diagnostic and therapeutic tools (including spatulas, gloves, or ear specula) and reusable tools (including speech therapy vibrators with replaceable tips).

Audiometers

The **AD528** allows testing air and bone conduction and speech audiometry (Fig 14.1). It is also possible to test auditory attention, called audiolaterometric diagnosis. This test allows determining the child's ability to perceive auditory stimuli appropriately. During the examination, an auditory attention test is performed based on bone-conduction, air-conduction, auditory laterality, readiness for a sound stimulus, selectivity, and correct localization of sound. Also, the audiometer allows performing the Stenger test, the Hughson-Westlake test, and the SISI test [11]. Stenger test detects monaural deafness simulation. Hughson Westlake is an automatic pure-tone test procedure. SISI test determines the ability to perceive changes in sound intensity (loudness) and selects the nature of sensorineural hearing loss and the location of a damage. The audiometer also allows to connect active speakers to a free field, which gives ability to carry out audiometric tests in a free hearing field. This test determines the ability to understand speech at various levels. It employs loudspeakers connected to the audiometer, placed at a distance of about 1 m on both sides of the tested person - the test results in information about the degree of speech understanding of the respondent. In APD, the examination of auditory attention is essential. It allows for the determination of irregularities in the perception of sounds detected through the received air-conduction and bone-conduction. For the correct programming of therapy, it is necessary to obtain results for both types of conductivity [2].

The PATH Medical system allows performing tonal audiometry. The purpose of this test is to determine the threshold of hearing in the air-conduction and bone-conduction in the range of tested frequencies, i.e., the minimum sound intensity that the examined person can hear (Fig. 14.2). The examination is carried out in cooperation with the patient and allows for the initial determination of the nature and depth of hearing loss. The PATH Medical system will also enable the performance of MAGIC (Multiple-Choice Auditory Graphical Interactive Check) play audiometry. MAGIC is an image-based, self-monitoring test that offers a fun alternative to conventional tonal audiometry. The test is designed specifically for preschool and school children, but its usage is possible in other collaborative subjects. PATH Medical can prepare the patient before measuring physiological hearing and performing psychoacoustic tests. Due to its simple form, it reduces the effects of unprepared patients for testing. Performing tests is possible as long as the patient understands the instructions. This principle especially concerns tests of higher auditory function. Often, stress and the lack of precisely given

instructions have an impact on the results. The stage of familiarizing the patient with the examination and reducing the level of nervousness translates into credibility.

Fig. 14.1. Device visualization: Audiometer AD528 (source: https://www.interacoustics.com)
Rys. 14.1. Wizualizacja urządzenia: audiometr AD528 (źródło: https://www.interacoustics.com)

Fig. 14.2. Device visualization: The PATH Medical system (source: https://www.pathme.de)
Rys. 14.2. Wizualizacja urządzenia: system PATH Medical (źródło: https://www.pathme.de)

The Senses Examination Platform (SEP) is a mobile device for hearing, vision, speech screening (Fig. 14.3). SEP also allows hearing and speech rehabilitation in children (also with special educational needs), teenagers, and adults. The device provides early detection of hearing, sight, and speech defects, allowing assessing the physiological readiness of children to learn to read, write, and communicate at school. The device will enable to carry out: audiogram, DDT Test, GDT Test, FPT Test, DPT test, and Pure-tone test.

In addition to the hearing threshold and tonal audiometry, the described tests are considered tests of higher auditory functions necessary in the diagnosis of APD. Also, their performance is an essential element of programming therapy with auditory stimulation. Thus, the use of platform directly impacts the initial diagnosis and the initiation of the therapeutic process immediately after obtaining the results of individual tests.

Systems for auditory and vocal training

Polimodal Sensory Perception Stimulation (SPPS) is a therapeutic device that enables polysensory therapy for patients with abnormalities resulting from auditory processing disorders (Fig. 14.4). Therapy involves various human senses (hearing, sight, touch) and their integration and coordination. The basis of the therapy is primarily auditory training. It uses multiple types of filtration (including the so-called phonetic filtration), separation of the air-conduction and bone-conduction, and changes in the intensity and duration of a sound. The effect on the effectiveness of the therapy results from the division into stimulating auditory perception in terms of various auditory functions (as part of training

involuntary attention) and developing auditory attention, especially in voice and speech perception and expression. It is also crucial to stimulate auditory-visual-motor integration through active exercise. People with various disorders and difficulties resulting from limitations in auditory processing are the therapy target using SPPS. In students' case, the most common difficulties are i.a.: problems with understanding speech, difficulties in reading and writing, articulation disorders, speech disfluency, voice disorders, delayed speech development, auditory concentration, difficulties in learning foreign languages, etc. However, the therapy is prevalent among patients with APD as an alternative to other auditory stimulation types, especially those that only consider air-conduction improvement.

Fig. 14.3. Device visualization: The Senses Examination Platform (source: https://csim.pl)
Rys. 14.3. Wizualizacja urządzenia: Platforma do Badań Zmysłów (źródło: https://csim.pl)

Fig. 14.4. Device visualization: Polimodal Sensory Perception Stimulation (source: https://csim.pl)
Rys. 14.4. Wizualizacja urządzenia: Stymulator Polimodalnej Percepcji Sensorycznej (źródło: https://csim.pl)

Forbrain is used for auditory and voice training (Fig. 14.5). The primary purpose of the device is to train the brain, which improves auditory attention, pronunciation, and fluency of speech. Also, the employment of the device enhances short-term memory and the skills of correct reading and writing. The operation of the device uses auditory-voice feedback, as well as bone and air-conduction. Forbrain transmits the content in two paths: air via air earphones and bone through bone earphones (additionally reinforced by the device). Proper operation of the auditory-vocal feedback relates to auditory discrimination, phonological awareness, and rhythm perception. In the case of APD, this coupling is usually disturbed. It results in, among others, an inability to understand speech in noise, deterioration of phonological awareness, and rhythm perception. Using the device supports the improvement of auditory attention.

A set of electrostimulation devices

The electrostimulation system supports muscle training (Fig. 14.6). The possibility of stimulating the orofacial areas enables the employment of this system in speech therapy. This type of stimulation is necessary for the event of difficulties resulting from the incorrect distribution of muscle tone. One of the APD profiles includes impaired visual-auditory-motor coordination. Usually, students with the predominant profile additionally have problems with oral apraxia and articulation kinetics. Thus, appropriate stimulation of the face muscles and the mouth interior significantly accelerates the therapeutic progress of process. The device enables electrostimulation. It consists of a set of electrodes, such as point labile electrodes (ball, cone, needle, mushroom shaped) and area electrodes. This type of equipment supports the therapy of impaired speech functions, often coexisting with auditory processing disorders. Correcting the abnormalities in the disturbed distribution of muscle tone is also advisable due to the possibility of translating these disorders into impaired sensorineural-visual integration of patients. The electrostimulation device can generate two types of currents: TENS (Transcutaneous Electrical Nerve Stimulation) and EMS (Electrical Muscle Stimulation). The currents help in orofacial disorders, e.g., hypersensitivity of the ear area and head area, preventing auditory stimulation with headphones in patients with APD.

Fig. 14.5. Device visualization: Forbrain (source: https://pl.forbrain.com/)
Rys. 14.5. Device visualization: Forbrain (source: https://pl.forbrain.com/)

Fig. 14.6. Electrostimulation devices with a various set of electrodes (source: https://ecostim.pl/)
Rys. 14.6. Wizualizacja urządzenia: urządzenia do elektrostymulacji z różnym zestawem elektrod (źródło: https://ecostim.pl/)

14.2.2. Rooms

The described measuring stand consists of two rooms (Fig. 14.7). The first one is an audiometric laboratory/acoustic measurement laboratory, and the second one is a control room. The audiometric/acoustic measurement laboratory will be used to carry out diagnostic and therapeutic processes (using the equipment described in the section 'Devices') and record acoustic signals. A local LAN computer network will integrate the devices included in the measurement stand. Furthermore, the Dante network will transmit the acoustic signal. The design of the laboratory equipment allows recording speech signals in the digital domain. The microphones set enables recording the acoustic signal both with a single microphone (SHURE SM 7B model) and with a set of five measuring microphones (Sonarworks XREF20). The primary role of the control room will include collecting, describing, evaluating, and analyzing the recorded data. The listening system installed in the control room will consist of a GENELEC 8020DPM loudspeaker set and Beyerdynamic DT770 M listening headphones.

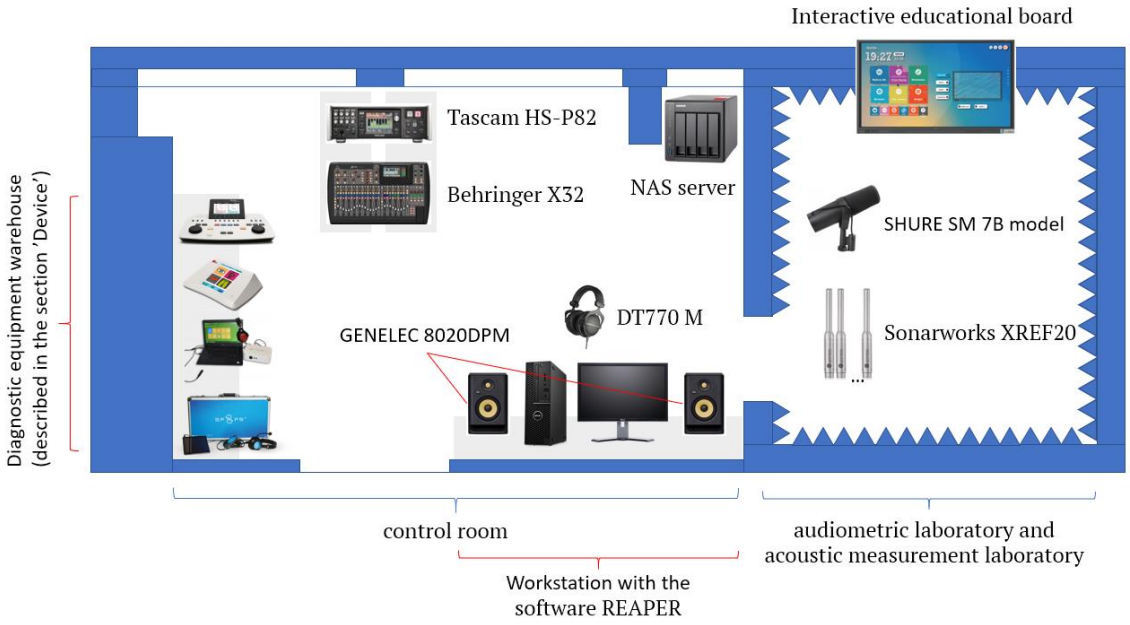

Fig. 14.7. Scheme of measuring stand consisting of two rooms: audiometric laboratory/acoustic measurement laboratory (right part) and control room (left part)

Rys. 14.7. Wizualizacja urządzenia: schemat stanowiska pomiarowego składającego się z dwóch pomieszczeń: laboratorium audiometrycznego/laboratorium pomiarów akustycznych (część prawa) i pokoju kontrolnego (część lewa)

Additionally, the project involves a high-class workstation, which connects a 32-channel DANTE expansion card and a Behringer X32 signal mixer with the Tascam HS-P82 audio recorder. The workstation has multitrack recording and audio processing software

called REAPER. Additional equipment is a NAS server, which enables storing and collecting of the material.

The rooms included in the considered measuring station will meet the permissible sound level requirements in rooms specified in the PNB 0215102:2018 standard. Regarding the rooms' specifications, the maximum acceptable A sound level should not exceed 30 dB. The standard PNB 021513:201510P determines the room's acoustic insulation requirements against airborne and impact sounds. For the described room, airborne noise insulation should be R'A1 $\geq$ 55 dB. In general communication (corridors, lobbies, staircases), the walls' airborne sound insulation should be R'A1 $\geq$ 48 dB. The applied standard PNB 021514:201506 defines the permissible reverberation time requirements for each of the discussed rooms individually. The reverberation time in the frequency domain (200-8000 Hz) should be uniform and should not exceed 0.3 seconds to ensure comfort when performing acoustic measurements and conducting diagnostic and therapeutic tests. The room design for therapy and diagnosis also includes visual adaptation for children in preschool and early school age. The use of light colors of upholstery in the room and the image of the photo wallpaper placed on the damping cover reduces the stress of the child during diagnostic and therapeutic activities. Additional equipment such as multimedia therapeutic programs, tablets, and an interactive educational board allows the use of an extra audiovisual layer to increase the attractiveness of activities.

14.3. Conclusion

The APD diagnostic process requires specialized equipment and specialists from various fields [12]. The determination of whether a child has a problem with auditory processing requires audiological, otolaryngological, and speech therapy evaluation. Early diagnosis of the child is crucial, although many diagnostic tools/tests require the appropriate age of the examined person (7, 8 years). This situation translates directly into the number of undiagnosed children and the late start of the therapy. The stand for the diagnosis and treatment of APD discussed in this study allows for a comprehensive psychophysical assessment and diagnosis of problems with the patient's auditory processing. Also, it will enable the expansion of knowledge in the field of APD and the development of new tests to accelerate the diagnosis process.

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Abstract

A measuring station for auditory processing disorders (APD/CAPD) diagnosis and therapy is being built as a part of the project The Silesian Engineering Support Center for Medicine and Sports, "Assist Med Sport Silesia". The designed measuring station includes audiometers, electro-stimulators, auditory-voice training devices, and devices recording the speech signal. The measuring equipment will be installed in a set of premises visually adapted to preschool children and subjected to acoustic adaptation enabling audiological research. The measuring station will allow for comprehensive audiological and speech therapy diagnosis and patient therapy (mainly children in preschool and early school age). The usage of the proposed measuring station will broaden the knowledge of APD, especially the diagnosis of this disorder. The primary purpose of the article is to describe the proposed measurement station.

Keywords: measurement station, auditory processing disorders, hearing diagnosis, speech signal, Assist Med Sport Silesia.