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Improving the process of auditory processing and speech decoding using the Neuroflow method in an 11-year-old CAPD patient

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Hearing disorders at the level of the central nervous system significantly affect the development of speech and language communication in children with CAPD. One of the methods aimed at improving the auditory functions, and thus the quality of speech understanding, is Active Auditory Training with the Neuroflow method. Its effectiveness will be discussed based on the example of a 10-year-old patient with hearing impairment.

Keywords: hearing impairment, Central Auditory Processing Disorders, Neuroflow ATS, child speech, case study

Hearing is one of the 5 basic senses that is of great importance for a human being, because thanks to it we acquire speech and are able to understand it. A baby is born with a physical hearing that is sensitive to sound waves with frequencies around 16–20 000 Hz (Pruszewicz, 1992: 322). Hearing allows us to receive

and transmit speech sounds and then interpret them appropriately in the brain. All hearing disorders have a negative impact on the various stages of speech formation and on the overall development of a human being. Kazimiera Krakowiak emphasizes that speech disorders in children occur on two levels: speech perception (difficult perception of sounds leads to difficulties in understanding and transmitting speech) and control of the produced sounds (no possibility of correcting sounds, which causes grammatical and intonation irregularities, speech volume disturbance) (Krakowiak, 2006: 8–10). Hearing loss usually results in speech impediments, while deafness results in serious delays in learning grammar and lexical rules and even inhibition of language development (Muzyka-Furtak, 2011: 120–121). The aim of this article is to show the effectiveness of the therapy of improving the higher auditory functions by the Neuroflow Active Auditory Training method on the example of a 10-year-old patient with Central Auditory Processing Disorders.

Central Auditory Processing Disorder (CAPD)

Due to the location of hearing damage, we can distinguish peripheral injuries of the following types: conductive, sensing or mixed, and central injuries, when the functioning of centers in the brain is disturbed. Due to the topic of the article, we will focus only on central lesions. Although global research on CAPD has been going on for several decades, despite the passage of time, a single, specific definition of this disorder has not been developed, as well as no clear diagnostic criteria and obligatory therapeutic guidelines have been proposed. Researchers are having difficulties with, for example, accurate decisions regarding the nervous processes accompanying this disorder, as well as, the indication of anatomical structures and determination of the degree of their involvement in the processing of sound information (Dajos-Krawczyńska et al., 2013: 9).

CAPD is most often defined as:

- the inability to detect, discriminate, and recognize and understand information received by the auditory route (R.W. Keith);
- difficulties in processing and understanding verbal and non-verbal stimuli, resulting from incorrect processing of these stimuli through the auditory pathway (M.H. Boone);
- inability to fully use the acoustic signal with proper reception in peripheral structures – the hearing organ does not cooperate with the brain (J. Katz);
- deficit in processing information that is specific to the auditory modality – difficulties may worsen in unfavorable acoustic conditions and due to problems in listening and understanding speech, in language development and learning (J. Jerger) (Dajos-Krawczyńska et al., 2013: 10).

World organizations have also made attempts to define the above disorders. According to the American Speech-Language Hearing Association (ASHA), central auditory processing disorders are the result of perceptual (neural) defects in the processing of auditory information in the central nervous system and the neurobiological activity underlying the formation of auditory electrophysiological potentials; the diagnosis of CAPD is possible if the dysfunction in processing the acoustic signal is not caused by cognitive factors or language difficulties, although they may coexist with CAPD (2005). In contrast, the American Academy of Audiology (AAA) points out that CAPD not only affects children, but also affects adults during the natural aging process or as a result of trauma (2010). On the other hand, the British Society of Audiology (BSA) believes that CAPDs are the result of impaired brain functioning, manifested by problems with recognition, discrimination, separation, segregation and localization of ambient sounds (2006). In a more recent definition from 2018 we read that CAPD is characterized by poor perception of speech and non-verbal sounds and has its origins in disorders of nervous function, which may include both afferent and efferent nerve pathways, as well as other nervous processing systems responsible for modulating the pathway auditory system through the CNS.

Hearing disorders researchers still use innovative research methods and put forward new hypotheses to explain the damage. It is possible that other, constitutive and unambiguous definitions will be developed soon, explaining all the nuances related to this disorder. It is an urgent and awaited need, because in the literature on the subject, we find disturbing data that prove that CAPD is diagnosed in even about 7% of school-age children, and is often (depending on the diagnosis center) confused with SLI, ADHD, specific reading and writing difficulties, and peripheral hearing loss (Majak, 2013: 162), which may coexist with CAPD. The causes of auditory processing disorders are also not fully known. They are usually classified in the literature into: congenital, acquired and secondary (Majak, 2013: 166).

Table 1. CAPD congenital, CAPD acquired, CAPD secondary

CAPD congenital	**CAPD acquired**	**CAPD secondary**
– changes in the brain, great commissure and LP – cutting the great commissure – genetic factors	– perinatal hypoxia – prematurity, low birth weight – mechanical injuries – poisoning with toxins, ototoxic drugs – neuroinfections and viral infections in the neonatal period – meningitis – toxoplasmosis – strokes – neurological injuries	– too late or incorrect treatment of hearing loss – recurrent exudative otitis media – inadequate acoustic environment – excessive stimulation with auditory stimuli (television, computer, internet, telephone)

Source: Walkowiak, 2020.

In addition, three clinical subprofiles are distinguished among children with CAPD, which allow the patient to be qualified to an appropriate therapeutic group and to apply therapy aimed at reducing specific deficits:

1. Hearing disorders at the phonological level – are associated with a deficit in decoding speech sounds, problems with differentiating and identifying phonemes, which results in diffi-

culties in reading and writing; children with this profile may have, for example, speech impediments, poor lexical resources, problems with building complex sentences and longer statements.
2. Disturbances in auditory attention and hearing in noise – cause difficulties in understanding speech in acoustically unfavorable conditions, distortion of speech, attention deficit, disturbances in short-term auditory memory and limited selectivity of sounds.
3. Auditory-visual integration disorders – most often manifest themselves in disorders in speech prosody, difficulties in reading, writing, drawing, dancing, finding oneself in time and space, etc. (Neuroflow, 2021).

Diagnosis and therapy of CAPD

Standard speech therapy diagnosis of hearing disorders includes: determining the cause and time of hearing damage, the possibility of receiving speech and acoustic sounds, assessment of the benefits of hearing aids, the ability to read speech from the movement of the lips, control of listening to the phonation act, assessment of the quality of the voice, respiratory tract, articulation and speech prosody etc. (Kasperuk, 2016: 9–10). The diagnosis carried out by a certified Neuroflow ATS Provider consists of: a thorough interview on the child's development, data from speech therapy and psychological diagnosis, examination of the peripheral part of the auditory system using tonal audiometry, assessment of the central part of the auditory system based on a battery of Neuroflow psychoacoustic tests, allowing to test higher functions hearing, as well as discussing the test report with the parent / guardian of the child.

Various methods of language education are used in the rehabilitation of hearing and speech in children. According to ASHA and BSA indications, the basic element of CAPD therapy (along with other forms of shaping communication skills in children with

hearing impairment) should be auditory training adapted to the patient's deficits and difficulties. According to Teri James Bellis (2003), auditory training is one of the fundamental pillars in CAPD therapy, next to the modification of the acoustic environment and the use of assistive devices, as well as the use of compensation techniques and cognitive training. The aim of such training is to influence a specific hearing deficit, and the effect of auditory stimulation, causing neuroplastic changes in the brain, is to improve the perception of acoustic stimuli and the comfort of everyday life. Out of the many auditory trainings available in Polish institutions, for example: A. Tomatis method, Fred Warnke's method, Henryk Skarżyński method, FLF method, etc. The main goal of this method is to improve the higher auditory functions and, consequently, to improve the quality of communication and learning by auditory means. The advantage of Neuroflow training may also be the improvement of linguistic or cognitive skills, e.g. the ability to remember, reason or solve problems (Strenziok, Parasuraman, Clarke, 2014: 1027–1029).

The use of phonological exercises helps to expand language competences, strengthen sequential memory, improve auditory memory, differentiate speech sounds, improve articulation and prosody, and improve communication skills. On the other hand, working with texts such as fairy tales or short stories encourages the patient to listen carefully and remember, expand lexical and syntactic knowledge, and improve narrative and communication skills.

The great advantage of auditory training is the activity of both the little patient, who must focus his attention on the tasks, and the parent's involvement in home listening sessions as well as supporting and motivating the client. Training with the Neuroflow method also allows you to flexibly adjust the level of difficulty of tasks to the patient. If the child responds correctly to a given command, the system automatically makes the task more difficult, and in case of failure, it makes it a little easier. In this way, the existing nerve connections are strengthened and new ones are created in the central auditory system.

Neuroflow therapy is conducted via an internet platform (technical requirements are: functional computer equipment, stereo headphones, stable internet connection), usually lasts from 6 to 8 months and is divided into 2 or 3 stages. Each of the stages is preceded by a diagnosis, on the basis of which an individual exercise program is adjusted. Sessions take place in a therapeutic facility and last up to 50 minutes or at the patient's home, 2–3 times a week for 25 minutes.

Case study

Hubert is an 11-year-old CAPD patient who has been attending speech therapy and EEG Biofeedback training for several years. He is brought up in a full family, is the second child, has an older brother without development deficits. During pregnancy, the mother was not ill and did not take any medications. The boy was born on time by caesarean section. He weighed 3200 g and scored 9 points on the Apgar scale, it is due to a general slight blue color of the body. The baby was mainly bottle fed and used a teat for a long time. In preschool age, the boy was often sick, including several times with otitis media, as well as infectious diseases: chickenpox and scarlet fever.

Data from medical history and records

The interview with his mother showed that the boy was developing properly. He sat down, stood and walked on time. Also his speech did not raise any concerns, he uttered his first words in the first year of life, and simple sentences around the age of 2. The mother was concerned about the boy's behavior, who was hyperactive, impulsive and disobedient. He did not understand commands and longer statements, especially in an unfavorable, too noisy environment. The child also has attention and concentration disorders, hence school difficulties related to learning to read and write and memorize.

The speech therapist opinion shows that the boy has multiple dyslalia in terms of improper implementation of hissing and humming sounds and rotacism. He also has considerable difficulties with auditory and visual analysis and synthesis. The boy has significant phonemic hearing disorders, low level of visual and auditory memory, significant attention deficit disorders and disturbed command perception, which make speech therapy difficult and increase learning difficulties. In the opinion of the speech therapist, the boy should have been diagnosed with Central Auditory Processing Disorders.

On the other hand, the psychological study carried out using the Wechsler Scale for Children (WISC-R) shows that the boy's general cognitive predispositions are in the lower range of average results, against the background of significant developmental disharmony in the field of visual analysis and synthesis, arithmetic, and abstract reasoning. The study performed with the shortened IQ battery from the Stanford-Binet Scale confirmed increased attention and concentration disorders as well as significant psychomotor agitation, including hyperactivity, impulsiveness, noisy and excessive talkativeness. All these disorders result in difficulties in acquiring school knowledge and a slow pace of cognitive development.

Speech therapist's diagnosis

For the purpose of the speech therapy, a SCAP form (Screening Checklist of Auditory Processing Disorders) was used. Based on the obtained results – over 50% of positive responses (10 out of 12 points), the speech therapist included the boy in the group at risk of Central Auditory Processing Disorders, which was determined by such symptoms as: short span of auditory attention, tendency to be distracted in the presence of sounds disruptive, problems with reproducing the order of events, lack of understanding of commands, difficulties with distinguishing speech sounds, speech disorders, etc.

Neuroflow diagnosis

Due to the positive result of the screening test, the patient was referred for an in-depth, multi-stage CAPD diagnosis using the Neuroflow method.

The first stage ruled out the boy's hearing loss of a peripheral nature. The test result from the threshold tone audiometry was normal (up to 20 dB).

In turn, the second stage of diagnosis was based on psychoacoustic tests from a standardized battery of Neuroflow ATS tests (visual and auditory response test, adaptive verbal test of speech understanding in noise, adaptive speech comprehension in noise test, numerical test, tone sequence test of various heights, adaptive Noise Break Detection Test, Adaptive Pitch Differentiation Test). The result of this study was confirmed, among others, by the presence of symptoms of mixed auditory processing disorders in the boy, with a predominance of phonological deficit. The right ear turned out to be the dominant ear in the hearing test, which indicates the dominance of the left hemisphere of the brain in understanding speech.

Neuroflow ATS therapy

Based on the results obtained, and with the consent of the patient's parents and the speech therapist, auditory training with the use of the Neuroflow method was introduced into the therapy. Hearing rehabilitation was carried out in several stages.

The first stage, which lasted about 4 months (meetings were held twice a week for 45 minutes in the therapist's office or at home), consisted of tasks aimed at: improving speech decoding in noise, improving auditory memory, improving the process of varying the pitch and listening comprehension.

The boy's task during the session was to listen to the sentences in noisy and repeat it aloud. Usually, the exercise performed by the

patient was grammatically correct, but often there were changes in the order of sentences or replacing words with synonyms.

The post-stage re-diagnosis showed that the boy had a significant improvement in the understanding of speech in noise and a slight improvement in auditory memory (the boy reproduced sequences up to 6 elements). Significant difficulties were still observed in the area of pitch differentiation.

In the second stage of therapy, which lasted almost 9 months, the main focus was on improving phonological functions, such as: differentiating the frequency of sounds, differentiating voiced and voiceless phonemes, performing operations on phonemes and improving listening comprehension. The exercises were mainly based on working with syllables. The syllables were administered to the over-ear headphones in an alternated order, so that the patient could mentally form the correct word and pronounce it aloud. Moreover, an additional task for the boy was to memorize nursery rhymes and songs. After the second stage of therapy and another rediagnosis, progress was made in the understanding of speech in noise, short-term auditory memory and the differentiation of slight changes in pitch in sentences. The following areas still required improvement: selection of auditory information and differentiation of changes in the frequency of sounds.

The last third stage of auditory training (lasting about 7 months) was devoted to: improving phonological functions (operations on phonemes, phonemic hearing exercises, rhyme-based exercises), improving auditory memory, improving listening comprehension and selecting auditory information. The exercises at this stage were mainly based on words that were given to the patient's left and right ear in a variable order, and the boy's task was to repeat them aloud in any order. The patient usually repeated up to 4 words. In addition, the boy's homework was to read his favorite texts aloud.

Summary

Rehabilitation of a patient with a hearing deficit is extremely difficult and requires enormous patience and cooperation from all parties: from the child, his parents and the therapist himself. Early surdology diagnosis and thorough stimulation of auditory perception are also of great importance, so that the child can communicate effectively with the world through speech. The effectiveness of the therapeutic process is sometimes difficult to determine and depends on many factors, including from: causes and type of hearing impairment, patient's age, his level of intelligence, social conditions of the patient's family, motivation to exercise, frequency of meetings with the therapist, applied therapy methods, etc. The therapy plan must always be adapted to the individual needs of the child and modified during therapeutic work.

In the rehabilitation of hearing and speech, various methods of language education are used, e.g. auditory-verbal, verbal-tonal, simultaneous-sequential learning to read, logo-rhythmics, etc. The first methods used in speech therapy for a 10-year-old boy with CAPD, as well as the subsequent EEG training – Biofeedback did not bring the expected results, hence the speech therapist leading the child's therapy, in consultation with the parents, referred them to auditory training using the Neuroflow ATS method. The effect of several months of therapy was a significant improvement in speech understanding in noise and an improvement in auditory memory. In addition, the patient began to function much better in the home and school environment – he has no major problems with remembering and understanding longer commands, he is better at reading and writing by listening, he is able to focus his attention and concentrate on a given task longer. The phonological sphere of the language still requires improvement, so that the boy does not lose his successes and constantly develops his linguistic and communication skills. According to Andrzej Senderski:

(…) even healthy children often have problems with focusing and keeping attention to what they hear for a longer time – unfortunately, this is partly due to the challenges and burdens that the modern world and its information noise impose on the child. How effectively the brain processes auditory stimuli affects the ease of learning and communicating. There is no other way to master a given field than regular exercise with increasing levels of difficulty, but one that motivates, not depresses. This is how our auditory training program works (Neuroflow, 2021; Senderski, 2014: 78–80).

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