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Effects of auditory integration disorders on language development and the use of NBAS to diagnose auditory processing disorders

Wpływ zaburzeń integracji słuchowej na rozwój mowy oraz zastosowanie skali NBAS w celu diagnostyki zaburzeń przetwarzania słuchowego

A – preparing concepts (opracowanie koncepcji i założeń)
B – formulating methods (opracowanie metod)
C – conducting research (przeprowadzenie badań)
D – processing results (opracowanie wyników)
E – interpretation and conclusions (interpretacja i wnioski)
F – editing the final version (redakcja ostatecznej wersji)

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Abstract

The occurrence of problems linked to cognitive-linguistic and auditory processing may lead to serious phonological disorders such as an incorrect use of sounds by a child. Early diagnosis of auditory processing disorders makes it possible to start the therapy quickly and enhances the child's chances of proper development. In the cerebral cortex, there is a physiological connection between auditory processing and speech production. Auditory processing disorders lead to improper development of speech and language communication. Auditory processing disorders in older children are assessed with the use of behavioural tests such as a binaural integration test, Staggered Spondaic Word (SSW) test, Dichotic Digit Test and Speech-in-noise (SIN) test. The drawbacks of these tests are that they are applied when speech production disorders already occur. They cannot be used in newborns due to the fact that they are incapable of cooperating. The NBAS scale used in physiotherapeutic diagnosis may be employed to assess processing disorders in the youngest children. This procedure is very simple and results provide early information regarding the child's auditory integration. Foreign research points to a significant correlation between auditory processing disorders and phonological disorders mainly in terms of distinguishing phonemes.

Key words: **auditory perception, speech disorders in children, NBAS**

Streszczenie

Występowanie problemów związanych z przetwarzaniem poznawczo- językowym oraz słuchowym może prowadzić do powstania poważnych zaburzeń fonologicznych, polegających m.in. na tym, że dziecko niepoprawnie używa dźwięków. Wczesne rozpoznanie zaburzeń przetwarzania słuchowego daje szansę na szybkie rozpoczęcie terapii

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i zwiększa szanse dziecka na prawidłowy rozwój. W korze mózgowej istnieje fizjologiczny związek pomiędzy procesami słuchowymi, a produkcją mowy, co powoduje, że zaburzenia tego pierwszego będą skutkowały nieprawidłowościami rozwoju mowy i komunikacji językowej. Zaburzenia przetwarzania słuchowego u starszych dzieci, ocenia się za pomocą testów behawioralnych, takich jak: test integracji dwuusznej, test słów spondejowych Staggereda, test rozdzielnousznego słyszenia na cyfrach oraz test rozumienia mowy w głośnym środowisku. Wadą tych testów jest to, że stosuje się je w sytuacji kiedy zaburzenia produkcji mowy już występują, nie można ich przeprowadzić u niemowląt, z uwagi na to, że nie są one zdolne do współpracy. Stosowana w diagnostyce fizjoterapeutycznej Skala NBAS, może być wykorzystywana do oceny zaburzeń przetwarzania u najmłodszych dzieci. Procedura jest bardzo prosta, a wyniki dają wstępną informację na temat stanu integracji słuchowej dziecka. Zagraniczne badania wskazują na istotny związek pomiędzy zaburzeniami procesów słuchowych, a wystąpieniem zaburzeń fonologicznych, głównie w zakresie rozróżniania fonemów.

Słowa kluczowe: **percepcja słuchowa, zaburzenia mowy u dzieci, skala NBAS**

Introduction

Significant correlations can be noted between auditory perception and sound production processes. The occurrence of problems linked to cognitive-linguistic and auditory processing may lead to serious phonological disorders such as an incorrect use of sounds by a child. Early diagnosis of auditory processing disorders makes it possible to start the therapy quickly and enhances the child's chances of proper development. Behavioural tests used for diagnostic purposes are carried out by otorhinolaryngologists; however, they may only be applied in older children due to the need for communication during an examination. The NBAS (Neonatal Behavioural Assessment Scale) is an important yet underestimated tool that is also used by physiotherapists. The scale enables its users to detect auditory processing disorders already in infants.

Auditory integration processes in children have been the subject of numerous studies published in recent years. However, researchers no longer focus on external auditory canal only, but also on the whole auditory system from inner ear to the cerebral cortex. Processing auditory stimuli is a very complex process. It involves not only distinguishing sounds but also phonetic decoding, temporal processes recognition as well as binaural separation and integration. Primary disorders of these processes may lead to speech development disorders.

Similar to the visual system, the auditory system can provide information on the surrounding environment, i.e. features connected with time and location. However, there are considerable differences between the structure and organisation of the visual and auditory system. Retinal ganglion cells are directly connected with an area of the thalamus which is responsible for vision, while the connection between auditory neurons in the cochlea and an area of the thalamus responsible for hearing has numerous "intermediate stations".

The auditory cortex, physiological and anatomical connection between hearing and speech production

The auditory cortex receives impulses from an auditory subcortical area, i.e. from a medial geniculate body. The auditory cortex may be divided into several parts, i.e. the core constituting primary projection area, areas directly adjacent to the auditory cortex core and further areas. Such a complex cortex includes several pathways responsible for auditory processing. Two of them run from the primary sensory areas to the posterior parietal cortex and posterior temporal cortex. The pathway which ends in the posterior parietal cortex is called the dorsal pathway and is responsible for spatial processing of "what" we hear. In turn, the pathway which ends in the posterior temporal cortex is called the ventral pathway and is responsible for auditory identification and sound communication, i.e. "where" we hear sound. This two-stream model is integrated in a more complex system basing on the perception-action cycle, in which perception mainly corresponds with the "what" stream, while action correlates with the "where" stream, thus playing a more sensomotor role through spatial analysis. The pathway responsible for central auditory processing also has two streams. The ventral pathway runs from the primary auditory cortex to the upper temporal sulcus and then dually to posterior middle temporal gyrus and to posterior temporal gyrus. It is responsible for perception and auditory information recognition. In turn, the dorsal pathway runs through the area of sensorimotor integration (temporal and parietal lobes area near the Sylvian fissure in the dominating hemisphere) and connects the auditory system with frontal areas responsible for speech production. The latter pathway is an anatomical structure which serves as a basis for the working verbal memory that plays a significant role in speech development [1].

Sounds have specific attributes such as tone, volume or timbre which are organised hierarchically in the cerebral cortex. Areas responsible for phonetic and lexical information in speech, i.e. specialised sub-regions constituting a sui generis tonotopic map, are located in the dorsal pathway (spatial processing - “what?”). In turn, the central ventral pathway is responsible for an auditory analysis of speech and other sounds. The phonetic and phonological analysis (left superior temporal sulcus and left inferior parietal lobule) makes it possible to detect phonemes, i.e. the smallest functional units of speech system which help to distinguish particular words. After receiving information from the somatosensory and visual cortex, this pathway invokes spatial transformation of sounds and activation of this area may be responsible for the development of orienting response in infants followed by the development of spatial representation [1].

Auditory system development

Auditory system gets myelinated from cochlear nerve to tectal lamina together with medial geniculate body at 27-29 weeks’ gestation. At this point a fetus starts to react to the sounds of acoustic vibration or stimulation *in utero* by moving or with changing heart rate. A fetus turns his or her head towards the source of stimulation. Moreover, the process of getting accustomed to hearing can be noted, i.e. the reaction decreases after several repetitions of the same aural stimulus. Significant maturation of the auditory system occurs in the period from 28 to 38-40 weeks’ gestation. The circumferences of axons increase, further parts of the auditory pathway are myelinated, the number of synaptic connections increases and marginal layers of the cerebral cortex in the temporal lobe and afferent fibres develop, which helps to evoke the cortex reaction to sounds. Further development and integration of the auditory system occurs in the first months of life, when the first aspects of learning to speak, such as phonology, prosody or dividing words occur [1].

The group at a higher risk of disorders of the auditory system development and integration includes preterm babies and infants who suffered from brain damage in the first months of life. In their research, Gallo et al. proved that auditory processing in babies born on due date differed from the processing in preterm infants. Nearly 94% of premature babies participating in the research had deficits of auditory processing [2].

Diagnosis of auditory processing disorders

The fundamental techniques applied in diagnosing auditory processing disorders include Auditory Event-Related Potentials (ERP) and Mismatch Negativity (MMN). Moreover, behavioural tests are of great significance but they can be applied in older children only.

Behavioural tests applied in diagnosing auditory processing disorders assess cortical and subcortical processes. They include, inter alia, sound discrimination test, binaural integration test, dichotic listening, monaural low redundancy speech test and temporal processing test. However, in foreign literature, the following tests are mentioned: simplified auditory processing test, Pediatric Speech Intelligibility test, Binaural Fusion Test, Staggered Spondaic Word (SSW) test, the Dichotic Digit Test and Speech-in-noise (SIN) test. In each of these tests, children’s age should be taken into account [2-5].

Simplified auditory processing test consists of 3 tasks. The first task includes 3 sequences of sounds which are not words, the second task includes 3 sequences of words, while the third task involves locating sounds from 5 different directions. In order to perform the test, a quiet room and several specific musical instruments (bells making various sounds) are needed. Pediatric Speech Intelligibility (PSI) test may have two versions, i.e. PSI with Ipsilateral Competitive Message (PSI-MCI), which applies two separate stimuli in the same ear, and PSI with

Contralateral Competitive Messages (PSI-MCC), which applies two separate stimuli in each ear. Verbal stimuli in the PSI test consist of 10 words or phrases that have to be identified by indicating an object which is mentioned [4,5].

Binaural Fusion Test assesses auditory brainstem sensitivity. It includes a list of acoustically distorted monosyllabic words. During Staggered Spondaic Word Test, words are presented simultaneously to two ears, i.e. the first syllable is presented to one ear, while the second syllable to the other ear. The aim of the test is to assess the transfer of a signal between hemispheres, divided attention and binaural integration. Dichotic Digit Test assesses binaural integration and separation. It involves presenting different stimuli to both ears simultaneously and asking the examined individual to repeat the word or words while ignoring the other stimulus. In Speech-in-noise test, a list of words is presented ipsilaterally and is distorted by "white noise" [6,7].

The above-mentioned behavioural tests make it possible to assess such elements of auditory processing as sound discrimination, sound location, selective attention, recognising temporal processes or the efficiency of auditory processes in the situation when sounds are distorted by noises or competing sounds [7].

However, behavioural tests cannot be applied in infants due to the fact that they are not able to cooperate. The research shows that the combination of auditory stimulation with visual tasks and neurodevelopmental tests may prove effective in detecting correlations between early auditory processing deficits and further disorders of speech acquisition. Auditory processing of non-verbal stimuli may be assessed with the use of a behavioural test based on the rule of two-alternative forced choice and go/no-go task. These tests assess the ability to learn randomness and to distinguish between intentional and non-intentional auditory stimuli [1].

The sensory system consists of numerous systems which significantly correlate with one another. In order to assess auditory processing, complex tools which take into account numerous elements of this system should be used. Certain components of infantile and developmental scales focus on behaviours depending on auditory processing, e.g. imitating words and gestures in the Uzgiris-Hunt Scale. Due to the fact that language and gestures are believed to be related, it may be concluded that imitation in the Uzgiris-Hunt Scale may represent a bridge between early auditory processing and cognitive functions. Also, the Neonatal Behavioral Assessment Scale (NBAS) is a signifinant tool of assessing, inter alia, the auditory system [1].

NBAS

The Neonatal Behavioral Assesment Scale (NBAS), also known as the Brazelton Neonatal Assessment Scale (BNAS) was developed in the 1970s in order to assess behaviours of newborns and infants as well as interactions between them and the examiner. The main aim of the scale is to learn the way in which a newborn adapts to life outside the womb [8].

The NBAS is a tool which is often applied in examining newborns. It is used, inter alia, to examine high-risk groups (e.g. preterm babies or babies of mothers who drank alcohol or took cocaine during pregnancy), to assess the effects of anaesthetics used during the delivery on a newborn's behaviours, to evaluate infants' reactions to faces and voices of their mothers who suffer from postnatal depression or to determine behavioural differences between genders in the infancy period. The NBAS is also applied in order to raise parents' awareness of newborns' behaviours and to compare children from various cultures and predict individual differences in interactions between a mother and a child [9].

In the last 30 years, the number of studies on neonatal behaviours has increased considerably and revealed such new facts as newborns' ability to follow with their eyes, to hear and locate sounds and their preference to look at faces. Newborns are social beings predisposed to interactions with their guardians from the very beginning and are able to create indispensable care ensuring successful adaptation. A newborn is attracted by a mother's voice, can imitate her facial expression and distinguish her face from that of a stranger. After over 3 decades of extensive research on behaviours and development of newborns, it may be concluded that their adaptive functions are organised in a complicated manner but at the same time they are fully prepared for further development and they play an active role in this development [8,9].

The studies with the use of the NBAS showed that neonatal behaviours cannot be perceived only as biologically determined behaviours.

A newborn's behaviour from birth is not genotypical but phenotypical and is affected, inter alia, by intrauterine nutrition, past infections, taken medications or stimulants and other numerous factors. They affect the fetus during pregnancy by interacting with genetic resources and lead to certain behaviours. Numerous studies have indicated that a newborn is already strongly shaped prior to the delivery and such routine perinatal situations as giving medications to a mother, anaesthesia or oxygen deficiency episodes affect their further reactions and behaviours. A newborn's patterns of behaviour are determined at the moment of birth by genes, while its further development depends on both biological and environmental factors [9].

The NBAS may be used to assess babies from the moment of birth to the end of the second month of life. It was designed so that it could describe adaptation and developmental processes in newborns, particularly their ability to self-regulate in this period. In terms of development, the NBAS makes it possible to evaluate behavioural changes on a regular basis by describing processes of integrating various spheres and systems of behaviour in the period of 2 months. A newborn faces a variety of hierarchically organised developmental challenges and tries to adapt to the new animate and inanimate world outside the womb. It includes abilities to regulate physiological or autonomic system in the first place, followed by abilities to regulate states, motor behaviours and, finally, effective interaction. The elements of the NBAS include the following four fields of neurobehavioral functioning:

- Autonomic/physiological regulation: adaptation abilities of a newborn's central nervous system, revealing themselves through changes in skin colour or tremors
- Motor organisation: the quality of movements, muscle tone, level of activity, level of motor integration
- Organisation and regulation of states: behavioural agitation and lability, or an ability to regulate states at the time of increased stimulation
- Attention/social interaction: ability to react to visual and auditory stimuli, and the quality of a newborn's general alertness [10].

The Brazelton Scale can be used to describe the current state of the autonomic system and musculoskeletal system of newborns, their levels of consciousness and social skills. All the above elements interact with one another and undergo the process of integration in the neonatal period. Repetitive observations with the use of the NBAS may reveal the way in which these systems integrate in time and what influence environmental factors exert on this integration. The systems integrate in a hierarchical manner, i.e. autonomic regulations precede motor organisation which is followed by the regulation of states, while social skills are integrated in the final stage. Moreover, according to the development model which the NBAS is based on, the final effects of the development result from interactions between the body attributes and environmental factors. Therefore, the environment in which a baby grows up has to be taken into consideration while performing observations [10].

The NBAS assesses the repertoire of a newborn's behaviours with the use of 28 items, where each item can be given a maximum of 9 points. The scale also assesses the neurological state of a newborn with the use of 20 items, where each item can be given a maximum of 4 points. The items which assess reflexes are aimed at identifying serious neurological disorders but they do not provide diagnosis. In the 1980s, additional items assessing the range and quality of high-risk children in greater detail were introduced in the NBAS [10].

The NBAS may be applied in all full-term infants until they are 2 months old. Owing to additional elements, it may also be used to assess healthy pre-term babies from 37 weeks' gestational age, while in the case of babies born very early with serious disorders, it is possible to apply the scale in the second month of their corrected age. It is apparent that the NBAS cannot be used in the case of newborns who require neonatal intensive therapy, multichannel monitoring, oxygen or parenteral nutrition. In such situations, the immaturity of a newborn's systems is accompanied by stress connected with the life out of the womb, so a baby should not be subjected to additional stress connected with the examination [10].

The 28 items assessing a newborn's behaviours and 18 out of 20 reflexes can be divided into groups according to the established rules. Therefore, conducting the test in a proper order is easier to remember. In our study, the following groups were distinguished:

1. ***Adaptive functions group,*** which includes such items as regulating the states, response decrement to light, rattle or bell, response

decrement to taking away the blanket, response decrement to tactile stimulation of the foot.

2. ***Motor-oral group***, which includes plantar reflex, Babinski reflex, foot clonus, passive tone in lower and upper limbs, rooting reflex, sucking reflex, galbellar reflex.
3. ***Trunk group***, which includes palmar grasp reflex, traction test, axillary suspension test, walking/stepping reflex, creeping reflex, Galant reflex, vestibular reflex and embrace reflex.
4. ***Vestibular group***, which includes defence reflexes, asymmetrical tonic neck reflex, Moro reflex.
5. ***Social interactions,*** which includes animate and inanimate visual and auditory orientation assessed together or separately [10].

In order to use the NBAS to assess auditory integration disorders, the tests of response decrement to rattle and bell or animate and inanimate auditory orientation can be applied. The ways of testing and assessing these elements are presented below.

Adaptive functions – response decrement to rattle and bell

All the elements of the first group (adaptive functions) are best tested during a sleeping state (state 1) or in a transitional, drowsy state (state 2), or optionally during somnolence (state 3). If a newborn does not react to the stimuli twice during a sleeping state, he or she should be delicately woken up by taking away a blanket, taking off a piece of clothing or rocking a cradle [10].

Response decrement to rattle

The test was designed in order to assess a newborn's ability to catch unpleasant, disturbing sounds and to get used to these sounds. To perform the test, the examiner should shake the rattle at a 25-30 cm distance from a baby's ear making energetic, clearly separate (staccato) sounds for approximately 1 second. In the first trial, the rattle is shaken 3 times for 1 second each time and then the reaction is observed. After that, there is a 5-second interval and the stimulus is repeated 9 more times [10].

Response decrement to bell

This test is performed in the same way as the previous one with the use of a bell making a sound for 1 second at a 25-30 cm distance from a baby's ear. Particular sounds should not differ from one another. In the first trial, the bell sound is made 3 times for 1 second each time and then the reaction is observed. After that, there is a 5-second interval and the stimulus is repeated 9 more times [10].

Assessment of response decrement to rattle and bell

An ability to decrease responses to repeated disturbing sounds is one of the mechanisms observed in newborns. The above-mentioned tests are aimed at assessing this ability.

The table below presents the scoring for the baby's reactions (Tab. 1)

Tab. 1. Scoring in the assessment of response decrement to rattle and bell [10]

Scoring	Newborn's reaction
1	No shutdown observed and item has to be discontinued because baby moves into a crying state or exhibits signs of physiological stress, e.g. apnea, startles, tremors or severe cyanosis.
2	No shutdown observed with a gradual increase in level of responsivity over the 10 trials. Startles may be present after the final trial.
3	No complete shutdown observed over 10 trials. Diminution in responses does occur at some time during the 10 trials but global responses return and are still present after the final trial.
4	No complete shutdown observed over 10 trials. Body movements are still present but there has been a decrease in the level of responsiveness over the 10 trials, with a gradual diminution from global to more minimal levels of responsiveness. Body movements may be delayed and an infant is able to shut out completely at least once during the sequence.
5	Shutdown of body movements; some diminution of blinks and respiratory changes after 9-10 presentations of the stimuli.
6	Shutdown of body movements; some diminution of blinks and respiratory changes after 7-8 presentations of the stimuli.
7	Shutdown of body movements; some diminution of blinks and respiratory changes after 5-6 presentations of the stimuli.
8	Shutdown of body movements; some diminution of blinks and respiratory changes after 3-4 presentations of the stimuli.
9	Shutdown of body movements; some diminution of blinks and respiratory changes after 1-2 presentations of the stimuli.

Social interaction - animate and inanimate auditory orientation

These tests should be performed when a newborn is awake (state 4 – minimal motor activity, state 5 – high motor activity). In order to perform the test of inanimate auditory lorientation, a rattle should be shaken at a distance of 15-23 cm from a newborn's ear out of his or her sight. A newborn's head is in the midline of the body. Constant, rhythmic and delicate sounds should be made. Contrary to the previous tests, in which the sound was unpleasant for a newborn, in this test the sound should be attractive and interesting. Therefore, it is best to start from a delicate sound and increase its intensity if a newborn does not react. Thus, the lowest level of response to the sound should be determined, as it differs depending on a baby. If a newborn starts grimacing, wincing or turning away, it means that the stimulus is too strong and should be decreased. If a newborn does not turn away and locates the sound, the test should be performed twice in turns on each side of the body [10].

The test of animate auditory orientation looks similar to the previous test; however, the examiner's voice is used as a stimulus. Soft and delicate voice should be used to talk to a newborn and to attract his or her attention but without causing distress. During the test, the volume, tone or sound made by the examiner should be changed so that the newborn does not get accustomed to the sound [10].

A detailed procedure of tests:

1. A baby's head is held in the midline of the body and is supported by an examiner.
2. Use a rattle or your voice, making delicate threshold sounds out of a newborn's sight – 15-23 cm from a baby's ear at a 90º angle.
3. Observe the baby's attempts at locating the sound.
4. Present the stimulus twice on each side in turns.
5. Differentiate the volume and pace of sounds to maintain the baby's attention so that he or she does not get used to the sound. Use delicate interesting sounds.
6. During the rattle test, do not talk to the baby and do not show your face; during the voice test, do not use any other sounds.
7. If a baby starts grimacing, wincing or turning away, change the volume of the sound so that it is not disturbing.

After the tests, the newborn's reactions are assessed according to the table below (Tab. 2)

Tab. 2. Scoring in the assessment of animate and inanimate auditory orientation [10]

Scoring	Newborn's reaction
1	No reaction
2	Respiratory change or blink only
3	General quieting as well as blinking and respiratory changes
4	Stills, brightens, no attempt to search for source
5	Shifting of eyes to sound; stills and brightens
6	Alerting and shifting of eyes, head turns to source
7	Alerting, head turns to source, searches for, finds and looks at stimulus (at least once)
8	Alerting, head turns, eyes search and find stimulus repeatedly (3 out of 4 times)
9	Alerting prolonged and consistent, head turns, eyes search for and find stimulus every time (4 times out of 4)

The aforementioned tests are only elements of the whole NBAS, while points given for these tests constitute only a part of the whole assessment of a newborn. However, applying the scale in a selective way may be useful in diagnosing auditory integration disorders. These tests are easy to perform and the described results help to classify a newborn to a group of low (7, 8 or 9 points), average (4, 5 or 6 points) or high (1, 2 or 3 points) risk of auditory processing disorders. If a newborn is given a low number of points in the aforementioned tests, the therapists who perform assessment with the use of the NBAS should refer the baby for further diagnosis in order to confirm auditory integration disorders and implement a proper therapy [10].

Phonological disorders

The studies presented in foreign literature show how significant proper auditory processing is in the process of acquiring speech and language communication.

Phonological disorders are difficulties in speaking which are characterised by the use of words and sounds which are inadequate to age and regional differentiation. The disorders regard both sound production and its perception and organisation, i.e. sounds may be replaced, omitted, interjected, shuffled and/or distorted. The reasons for phonological disorders remain unclear; however, it seems that they correlate with such factors as gender, age, loss of hearing, family context, brain damage in the developmental age and auditory integration disorders [1,4].

In the research by Tiago Mendonça Attoni et al., a group of children with phonological disorders were given tasks engaging the auditory system and requiring skills of differentiating phonemes in order to find correlations between these features. The authors studied the way in which children dealt with auditory stimulation and examined whether auditory integration disorders affect speech acquisition. The research included children aged 5-7 years with diagnosed phonological disorders. To assess auditory processing, Pediatric Speech Intelligibility test, Speech-in-noise test, Staggered Spondaic Word test and Dichotic Digit Test were employed. The results of the tests of auditory processing and phonological abilities in the control group were positive and revealed nearly no mistakes, while in the study group, each test revealed mistakes. While analysing the results of the study, the authors concluded that there exists a correlation between auditory processing and distinguishing phonemes and that auditory integration disorders affect the process of assimilating speech sounds and their use. Difficulties in speaking may be caused by disorders of distinguishing phonemes, which, in turn, may be related to the lack of ability to decode and organise auditory stimuli [5].

Quintas et al. conducted similar research and revealed that auditory processing in children who developed correct speech differed from auditory processing in children who had phonological disorders. The largest differences were noted in Dichotic Digit Test and Staggered Spondaic Word (SSW) test. It seems that phonological disorders are mostly affected by the ability to understand information in the environment in which numerous noises and competitive sounds occur. The American Speech-Language-Hearing Associacion (ASHA) concluded that there exists a cause-and-effect correlation between language difficulties and auditory processing disorders, particularly in terms of understanding speech. The authors of the above study also concluded that children whose language competence acquisition is disturbed may have problems with completing selective attention tests [3].

In another study, Rocha-Muniz et al. sought to determine whether auditory processing disorders occur in children with specific language impairment (SLI). They examined 75 children aged 6-12 years. Group 1 included children without speech disorders, group 2 included children who were diagnosed with auditory processing disorders on the basis of at least two tests recommended by ASHA, while group 3 included children with SLI diagnosed on the basis of international criteria. The groups underwent 3 tests, i.e. 2 tests assessing sound lateralization (Speech-in-noise test and Dichotic Digit Test, in which both ears were assessed separately) and one test evaluating temporal aspects of auditory processing (the frequency pattern test – both ears were assessed simultaneously). Children from the groups 2 and 3 achieved lower results in all the tests than children from group 1. Both children with SLI and those with auditory processing disorders had difficulties understanding speech in loud environment and processing non-verbal sounds. These disorders may lead to difficulties in proper speech perception and disorders of speech integration and production [4].

Summary and conclusions

Numerous studies focusing on the correlation between auditory integration and speech and language communication acquisition processes examined the influence of these disorders on phonological abilities in children. In the majority of children, these abilities are acquired in a non-linear manner from birth till the 5th year of life. Speech acquisition mainly involves learning which sounds are used in what way, so this process also engages auditory system and auditory processing. The majority of children acquire phonological abilities without effort and at the age of 5 they can properly use sounds and sound sequences of the language used in the surrounding environment. However, as research shows, when auditory processing is disturbed, phonemes are not properly distinguished, which, in turn, may negatively affect the acquisition and organisation of speech sounds. If phonological disorders are diagnosed in a child, it seems indispensable to assess processes of auditory integration and distinguishing phonemes in order to make a more detailed diagnosis and implement more effective therapy.

Language communication develops on the basis of auditory perception, while disturbed mechanisms of auditory processing make this process more difficult. Such a situation disrupts phonological abilities acquisition and leads to phonological disorders which may later turn into speech impairments. Disturbed auditory integration may also lead to learning difficulties. Auditory processing disorders occur in one-third of children with developmental dyslexia, half of children with specific learning difficulties and in half of children with specific disorders of language development. Improper auditory processing may, inter alia, cause difficulties in understanding speech in difficult conditions and may result in confusing words which sound similar. It may also cause problems with focusing on a task which requires listening [6,7].

In case phonological disorders occur in older children, tests assessing auditory processing should be performed. However, if language communication difficulties already exist, it is relatively late for the procedure to be implemented. It seems that initial assessment of the processes of auditory integration in the first months of life is significant. The NBAS is one of the well-known and effective tools also applied in Poland by sensory integration therapists. It is a simple tool which is widely used to assess the developing brain of a child. However, it is indispensable to draw therapists' attention to the relationship between auditory integration disorders and the development of speech.

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