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Auditory Gnosis Dysfunctions in Preschool Children with Severe Speech Disorders

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Abstract

The aim of this study was to determine how nonverbal and verbal dysfunctions in preschool children are associated with severe speech disorders. In order to achieve the objectives of the research a special method was developed, which consisted of two modules - "Nonverbal" and "Verbal". At the first stage, the study was conducted for each module, which allowed us to determine that children with speech disorders have significant deviations in auditory gnosis development, which causes speech disorders. However, at the second stage of the study a controversial issue arose: how do existing nonverbal auditory gnosis disorders stipulate the dysfunctions of verbal auditory gnosis development? The results of the correlation analysis show that there is a strong relationship between non-verbal and verbal auditory gnosis. Yet, if the development occurs spontaneously, without considering the "from simple-to-complex" principle, there is a significant imbalance in the formation of complex syntagmatic constructions. Therefore, during the corrective work, it is necessary to differentiate corrective tasks depending on the level of auditory gnosis development. A promising direction for further studies is the application of the developed diagnostic range of tools for creating special correction programs aimed at auditory gnosis development in children with severe speech disorders.

Keywords: *auditory processing, nonverbal gnosis, verbal gnosis, speech disorders, children with severe speech disorders, dysfunctions*

Introduction

In modern information-oriented environment, a child perceives and processes a large amount of information every day, which depends on the ability to perceive and distinguish it with the help of various analyzers, including auditory (Nuttall et al., 2017). The amount of information perceived by auditory analyzer is significantly less than by a visual one. At the same time, the level of child's speech development depends on normal functioning of a peripheral part of auditory analyzer (Attoni et al., 2010). Based on the sensations provided by analyzers, specific functions termed 'representations' in general psychology (Hillyard et al., 1998; Kaya et al., 2020), and 'gnosis' (Luriiia, 1956; Ulrich, 1977) or 'recognition' (Itti & Koch, 2001) in neuropsychology are developed.

At preschool age, the formation of all types of gnosis is observed in children, which corresponds to humans' receptors – peripheral parts of analyzers. One of these types of gnosis is auditory.

Auditory gnosis is one of basic neuropsychological mechanisms of verbal and nonverbal speech development, which functions subject to the formation of successive perception of stimuli (sounds) sequence realized in time and space (Beyn, 1979; Homskaya, 1973; Luriiia, 1956). This is the chief distinction between auditory and other types of gnosis, which are perceived not sequentially but holistically (Beyn, 1979; Kaya et al., 2020; Kayser et al., 2005). Successive mastery of auditory gnosis requires the ability to separately (discretely) "keep track" of the elements from the row (Beyn, 1979). Perception of any auditory information fragments does not provide its general understanding (Buchsbaum & D'Esposito, 2019; Surprenant & Watson, 2001). Due to this, it is important that in the early period of ontogenesis, a child acquires the ability to keep track of different sequential chains of auditory stimuli, such as melodies, words, etc. (Bailey & Snowling, 2002).

Through auditory gnosis, people perceive and differentiate speech and non-speech sounds, determine sound source direction and remoteness, perform auditory orientation in space, analyze sounds by frequency, intensity, duration and timbre, directly analyze various physical qualities of a sound stimulus (Kidd et al., 2007; Price et al., 2005). Depending on these characteristics, nonverbal and verbal auditory gnosis are distinguished, which are localized in the temporal lobes of the cerebral cortex (Beyn, 1979; Luriiia, 1956). Nonverbal auditory gnosis provides the ability to perceive and differentiate (Rees, 2012), and verbal – to distinguish and recognize speech sounds (Zaehle et al., 2004).

Dysfunctions of both nonverbal and verbal acoustic-gnostic processes are typical for children with severe speech disorders (Bailey & Snowling, 2002). It

is important to note that the scientists (Glogowska et al., 2000; Homskaya, 1973) consider reduced ability to perceive non-speech sounds with saved hearing and intelligence as non-verbal auditory gnosis dysfunctions. This category of children demonstrates difficulties with rhythmic analysis, differentiation of domestic noises, and distinction of various intonation components (Stark & Tallal, 1981; Tallal & Piercy, 1973). Concurrently, for children with severe speech disorders, such processes as perception of intonation components and matching of people's voices with their sex and age are disrupted (Crosbie et al., 2005).

Dysfunctions of verbal auditory gnosis in children with severe speech disorders are described in neuropsychological (Homskaya, 1973) and psycholinguistic studies of speech mechanisms (Marangoni & Gil, 2014). The scientists define a decreased ability to perceive speech sounds with preserved ability to hear other acoustic stimuli; difficulties in differentiating of oppositional sounds in paronyms (Attoni et al., 2010; Bishop et al., 1999; Leonard, 2014). This category of children has a disordered sound-producing speech component, they insufficiently distinguish acoustic features of phonemes, which is a sign of dysfunction of phonemic processes (Polivara & Karabulatova, 2018).

The aim of this study was to determine the interdependence of nonverbal and verbal auditory gnosis dysfunctions in preschool children with severe speech disorders.

Methodology of Research

The study involved 40 children who are currently attending mainstream nursery-schools in Ukraine. Among the participants, there were 20 children with severe speech disorders and 20 children with normal speech development. The average age of children was 4.5–5 years. The study was conducted with each child individually. For the normative sample, children were invited to participate via a nursery-school. It is important to notice that all the subjects had preserved physiological hearing and initially preserved intelligence.

In order to determine the level of formedness of auditory gnosis (nonverbal and verbal) in preschool children with severe speech disorders in comparison with children with normal speech development and achieve the purpose of the study, an experimental method consisting of two modules was developed. The research was conducted from October 2018 to March 2020.

The first module (“Nonverbal”) is aimed at achieving the following goals:

- studying the formedness of nonverbal auditory gnosis level in preschool children with severe speech disorders;
- detecting the ability to aurally differentiate and recognize non-speech sounds, to identify domestic noises and to determine the direction of a sound source in this group of children;
- studying the ability to acoustically analyze rhythmic structures, to perceive rhythms, memorize and reproduce them by auditory pattern, by speech instruction and during counting;
- identifying children's ability to perceive intonation components, determine voice affiliation, perceive and reproduce the voice pitch, strength and timbre.

The results of the "Nonverbal" module were grouped according to the following criteria:

- children's ability to navigate in space with the help of hearing, to determine the direction of a sound source;
- children's ability to aurally differentiate and recognize non-speech sounds (sounds of nature, domestic noises, etc.);
- ability to reproduce rhythms according to the auditory sample, speech instruction, during counting;
- ability to perceive intonation components, to determine voice affiliation;
- ability to reproduce the voice pitch, strength and timbre;
- number and nature of imitable units;
- self-control during tasks performance.

The second "Verbal" module is aimed at the following goals:

- studying the level of formedness of verbal auditory gnosis in preschool children with severe speech disorders;
- identifying children's ability to distinguish oppositional sounds in paronyms;
- determining the level of development of phonemic perception;
- determining the features of independent and reflected pronunciation of words with different structural complexity;
- determining the nature and features of word distortion by preschool children;
- determining features of pronunciation of simple syntagmatic constructions with and without support on a verbal / visual sample;
- determining child's ability to maintain a program of action (sense of rhythm) in the process of pronouncing a set of these constructions.

The results of the "Verbal" module were grouped according to the following criteria:

- the level of complexity of the constituent structure of the word, which is available for pronunciation;
- nature and number of pronunciation distortions;
- state of the rhythmic pattern of the word during reproduction (chanting, use of emphasis);
- tempo characteristics of reproduced words (speed, pauses);
- presence / absence of a certain type of distortion;
- strategy of a lexical unit structure analysis;
- self-control during words reproduction.

According to the evaluation criteria of “Nonverbal” and “Verbal” modules, each answer was scored from 0 to 3 points, depending on the errors during tasks performance. After counting the total number of points, the level of task performance was determined: high, average or low.

The study used quantitative and qualitative data analysis by the aid of statistical processing methods: descriptive statistics (measures of central data, measures of variability), Pearson correlation analysis.

Results and Discussion

Based on the results of the experimental study, we can summarize the diagnostic data for module I “Nonverbal” and determine the average performance of the levels of formedness of nonverbal auditory gnosis in preschool children with severe speech disorders compared with children of the same age with normotypic speech development (Fig. 1).

The results on “Nonverbal” module indicate that preschool children with severe speech disorders have immature nonverbal auditory gnosis, which is confirmed by the presence of a low level - 20% and average level - 35%. In contrast, children with normotypic development do not demonstrate low level and have almost twice as high rate of high level of nonverbal auditory gnosis formedness - 80%. The results presented confirm readiness of children with normotypic development to perceive verbal units.

Concurrently, the existing nonverbal auditory gnosis dysfunctions of children with severe speech disorders are characterized by certain parameters. The majority has insufficiently formed ability to differentiate and recognize non-speech sounds aurally. For example, these children had difficulties while determining the location of a sound source and required more time and repetitions. Besides, children with severe speech disorders had significant difficulties in differentiating and

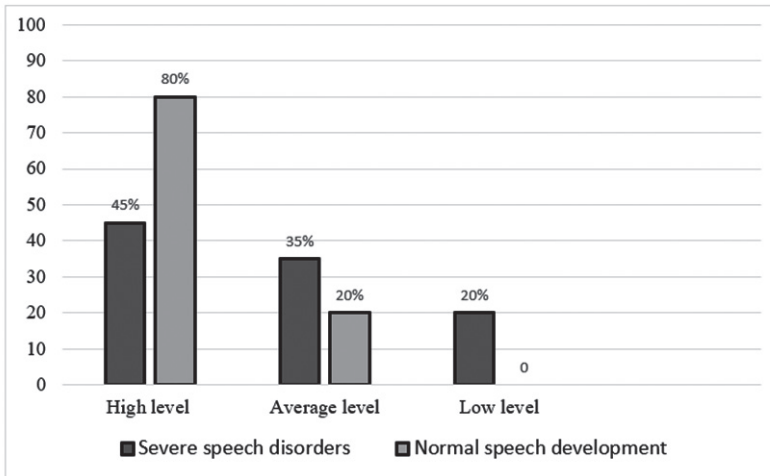


Figure 1. Average performance of nonverbal auditory gnosis in preschool children with severe speech disorders and normal speech development (in %)

recognizing nature sounds aurally. The following sounds were especially difficult to distinguish: rain noises, noises of forest on a windy day and sea surf sounds. The children experienced difficulties in identifying domestic noises, especially in distinguishing the sounds of such objects as matches, scissors, purse with money, et al.

The major part of children with severe speech disorders has an insufficiently formed ability to acoustically analyze rhythmic structures, aurally perceive and reproduce rhythms. Particular difficulties appeared during the reproduction of complex rhythms; most children could not cope with the task and correctly reproduce rhythms by the auditory sample. To perform the task correctly, they needed more time to perceive the rhythm and repeat it at a slower pace compared to the children with normotypic development.

The above results showed that the majority of children with severe speech disorders have underdeveloped ability to perceive intonation components, difficulties in determining voice affiliation of fairy tale characters. The voices of such characters as a mouse and a frog, wolf and bear were especially difficult to differentiate. Perception and reproduction of a voice pitch, strength and timbre are also insufficiently formed in children with severe speech disorders compared to children with normal speech development. The children with speech disorders

found it difficult to reproduce the voices of animal cubs, and special difficulties arose when pronouncing vowel sounds in low and high-pitched voices.

According to the results obtained the presence of nonverbal auditory gnosis dysfunctions in children with severe speech disorders may indicate the presence of speech command disorders since the developed non-verbal auditory gnosis, which ensures child's orientation in space, includes motor components, provides the perception of sound stimuli sequence and distinction of rhythmic and intonation components, as well as other non-verbal processes. The above-mentioned indicates that non-verbal auditory gnosis is a precondition for development of verbal auditory gnosis.

The results of diagnostics according to module II "Verbal" are presented in the diagram (Fig. 2). This made it possible to determine the average performance of levels of formedness of verbal auditory gnosis in preschool children with severe speech disorders compared to the children of the same age with normotypic speech development.

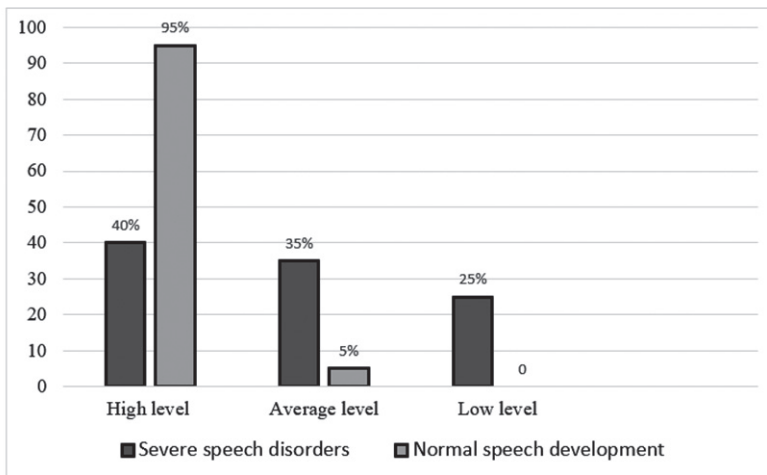


Figure 2. Average performance of levels of formedness of verbal auditory gnosis in preschool children with severe speech disorders and normal speech development (in %)

The results for "Verbal" module indicate that preschool children with severe speech disorders have underdeveloped verbal auditory gnosis, which is confirmed by the presence of a low level – 25% and average level – 35%. In contrast, children

with normotypic development do not demonstrate low level and have almost twice as high rate of high level of verbal auditory gnosis development - 95%. The results for the average level of verbal gnosis formedness are interesting: index of children with severe speech disorders (35%) is five times higher than the index of children with normal speech development (5%).

The existing verbal auditory gnosis dysfunctions in children with severe speech disorders are characterized by certain parameters. The children with severe speech disorders had difficulties in distinguishing acoustically close and articulatory distant sounds by ear, and vice versa. Accordingly, during the performance of the task children did not try to determine the sound, but to guess it. In addition, the majority of children with severe speech disorders have an insufficiently formed ability to perceive and distinguish phonemes by ear; there are difficulties in identification of oppositional sounds in paronyms and insufficiently high level of development of phonemic perception, in contrast to children with normal speech development. When determining the features of perception of rhythmic and structural word characteristics (syllables, words, minimal structural units, quasi-words), the results of the study showed that most children with severe speech disorders have an insufficiently formed ability to independently and reflectively reproduce words of complex component structure. Thus, the children had difficulties in pronouncing two- and three-syllable words with matching consonants, namely: sound skipping or extra vowel adding. They demonstrated an insufficiently formed ability to perceive rhythmic and structural characteristics of a word, as well as difficulties in maintaining a program of action in the process of pronouncing a row of words / constructions.

The results of the presence of verbal auditory gnosis dysfunctions explain severe speech disorders in this category of children. However, a debatable issue is whether the existing nonverbal auditory gnosis disorders cause dysfunctions in verbal gnosis development. In order to clarify this and identify the relationship between nonverbal and verbal auditory gnosis, Pearson correlation analysis between the characteristics studied was performed. The results are presented in Table 1.

In the process of correlation analysis, direct significant correlations were established between the reproduction of simple syntagmatic constructions and aural identification of non-speech sounds ($r = 0.78$, at the significance level of $p \leq 0.001$) and aural distinction of voice pitch, voice strength and timbre ($r = 0.93$, at the significance level of $p \leq 0.001$). These results indicate a certain interdependence, i.e. aural distinction of non-speech sounds, as well as voice pitch distinction, strength and timbre underlie the formation of reproduction of simple syntagmatic constructions, which subsequently will be a base for more complex ones.

Table 1. Correlation analysis of the relationship between nonverbal and verbal auditory gnosis

Verbal auditory gnosis \ Nonverbal auditory gnosis	Paronyms differentiation by ear with visual support	Paronyms differentiation by ear without visual support	Independent words pronunciation	Reflected words pronunciation	Simple syntagmatic constructions
Speech sounds distinction (by ear)	-0.72	-	-	-	0.78
Rhythms perception and reproduction (by ear)	-	-	-0.77	-0.9	-
Voice pitch, strength and timbre distinction (by ear)	-	-0.75	-	-	0.93

The above is confirmed by the significant inverse correlations found in this study. In particular, there are inverse correlations

- between aural distinction of non-speech sounds and aural differentiation of paronyms with visual support ($r = -0.72$, at the significance level of $p \leq 0.001$);
- between aural distinction of the voice pitch, strength and timbre and aural differentiation of paronyms without visual support ($r = -0.75$, at the significance level of $p \leq 0.01$);
- between aural perception and reproduction of rhythms with independent pronunciation ($r = -0.77$, at the significance level of $p \leq 0.001$) and reflected pronunciation ($r = -0.9$, at the significance level of $p \leq 0.01$).

Thus, if complex speech processes are formed on the basis of simple ones, but the ontogenetic principle of transition from nonverbal to verbal processes is not observed, there will be dysfunctions in the formation of complex speech phenomena. This proves that the process of forming verbal constructions should proceed gradually, considering "from simple to complex" principle, namely from nonverbal gnosis with gradual inclusion of simple verbal constructions at the level of phonemes, words, phrases, sentences, etc. This will allow a child to involve natural speech intuition; as a result, the speech will be developed successfully.

Conclusion

Auditory gnosis is defined as one of basic neuropsychological mechanisms of formation of verbal and nonverbal speech, which is essential to preschool children's development. It is established that nonverbal auditory gnosis is a basis for verbal gnosis formation which provides distinction of subtle differentiated features of phonemes, which has a positive effect on the formation of simple ones, and, as a result, complex syntagmatic constructions.

The results of nonverbal and verbal auditory gnosis correlation analysis proved the interdependence of their dysfunctions in preschool children with severe speech disorders. These results became the basis for further development of methods for auditory gnosis formation in this category of children.

In the context of this issue, the promising areas of further research are the development and experimental verification of the methods of formation of auditory gnosis in preschool children with severe speech disorders. Such an objective can be reached through formation of children's perception and differentiation of nonverbal (determination of a sound source direction and remoteness; auditory orientation in space; sound analysis by frequency, intensity, duration and timbre; analysis of various physical qualities of a sound stimulus) and speech sounds (from phoneme with gradual verbal material complication to complex syntagmatic constructions).

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