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The Warnke Method for the Diagnosis and Improvement of Phonological Competence in Special Needs Children

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Abstract: Speech, reading, and writing are the basic forms of linguistic communication. Therefore, it is very important to diagnose any problems with them as early and completely as possible, particularly in children with special needs. One of the methods that focuses primarily on the diagnosis and therapy of such learning difficulties is the one developed by Fred Warnke. The diagnostic solutions of the method were motivated by the following assumptions: (a) Automation of hearing, vision, and motor functions can be improved based on the level of brain activity; (b) the development and automation of phonological analysis and synthesis are based on cooperation between the two brain hemispheres. The main purpose of this paper is to present and discuss some research results that show the usefulness of diagnosis of the first stage of the Warnke method, as well as the training determined by it, in improving the phonological memory, language, and reading and writing skills of a group of four Polish children with special needs. The range of automation of each function was estimated on the basis of the values obtained in the diagnoses (initial and final). The final diagnosis showed an improvement in the levels of speech, reading, and writing. Thus, the research has confirmed that the Warnke method diagnosis may help to broaden and complement the standard evaluation methods of phonological competence for Polish children with special needs. The outcomes were so encouraging that we decided to present them to a wider audience.

Keywords: special needs education; the Warnke method; phonological competence; diagnosis of basic functions; visual, auditory, and motor processing; central nervous system level

1. Introduction

It is well known that speech, reading, and writing are the basic forms of linguistic communication. During the process of development, a child learns reading and writing skills, having already substantially acquired speech skills, but it should be mentioned that the quality of speech, reading, and writing depends on a proper applications of the following abilities [1]:

- Linguistics skills in the areas of the phonological, morphological, lexical, syntactic, stylistic, and semantic subsystems of a language;
- Cognitive capabilities including the proper visual, auditory, kinesthetic, and memory perceptions.

In the early stages, the acquisition of reading and writing abilities requires a conscious analysis of the relation between a phoneme, which is a sound model of a phone (an individual sound unit of speech), and a grapheme (a graphic equivalent of a phone). Furthermore, the mental operations must reach the level of conceptual thinking.

If the progress in acquisition of these capabilities is sufficient, then an automation mechanism activates in the central nervous system, which enables the fluent reading, proper writing, and understanding of the meaning of a text. This automation in the language process means an involuntary and quick registering, analysis, and synthesis of the visual, auditory, and motor stimuli that take place in some specific areas of the brain [2,3]. As the functional integration theory states, some difficulties in learning are caused by poor (or the lack of) cooperation between the perception functions: Visual, auditory, tactile-kinesthetic, and sense of balance.

It is well known that disorders of the central nervous system, in the area of perception and data processing of hearing, seeing, and movement, can be a serious cause of difficulties in learning to read and, consequently, to write. For instance, according to A.R. Luria [4], speech, reading, and writing are complex actions in the human brain that have their own localizations and dynamics. A simple dysfunction of a specific brain area disturbs the formation and cooperation of some simple actions composing such complex activity. Moreover, research in psychophysiology shows that there is a connection between disorders in language development and in the acquisition of reading abilities, with some impairments of the cerebellum and disturbances in the vestibular brain system [5,6], which is connected with performances of the motor and automation functions.

On the other hand, in view of the many years of investigation in neurology, psychophysiology, and neuropsychology, scientists can now state that the actions of the human mind are somehow based on the perception of time and a proper processing of information in time [3,7–9], and that specific time dynamics occur in the mechanisms of cognition operations, such as eye–hand coordination, speech, language, memory, acquisition of new information, concentration of attention, and decision-making, among others.

Three time ranges have been distinguished in brain activity that are important for the reception and expression of speech. Phones take several dozen milliseconds (e.g., the production time of a plosive phone is around 30–40 ms) and several hundred milliseconds are necessary for the elementary particles of speech (syllables and words consisting of one syllable), while phrases are on the level of a few seconds.

It seems that the theory stating that a temporal processing disorder can be an underlying cause of language disability affecting speech, reading, and writing has not been embraced by many in the field [10]. However, the results of experimental investigations in the Neuropsychological Laboratory of the Institute of Experimental Biology of the Polish Academy of Sciences confirm the opinion that a slowness in time perception and in the processing of information can be responsible for speech disorders, such as aphasia and some others [8,11] (p. 35), because it may cause poor performance of the motor and automation functions.

There are various approaches suggesting how to either compensate for or decrease disabilities occurring in the area of linguistic communication [10]. One such method is that of Warnke (the Warnke method), which was inspired by the assumption that temporal processing abilities and motor functions are related to the phonological skills needed for reading and writing development. The method was developed in Germany by Fred Warnke [12,13] and was designed equally for children, youths, and adults. It focuses primarily on the diagnosis and therapy of various difficulties in the process of learning, especially on problems occurring in speech, reading, and writing. The method also helps to develop and improve memory and concentration of attention. The methodological and technological solutions employed when it is used for diagnosis and therapy have been patterned to achieve the following three basic aims [14–16]:

- An automation of the processing of perceptions in hearing, seeing, and motor skills, along with a sufficient speed (the basic pre-conditions for learning the processing of perceptions must be well developed);
- An automation of coordination of the brain hemispheres (during the process of learning how to read and write, the two hemispheres of the human brain must work closely together);

- A development and automation of the visual dictionary (a development and automation of the analysis and synthesis in phonological skills on the basis of an integration of visual, auditory, and motor functions).

The tools and procedures of the method were standardized and refined by U. Tewes (Medical University of Hanover) [14–16], who started a suitable project in 2001 and obtained data of the seven low-level functions from 382 children (with normal intelligence) of the age of 5–12 years.

The aim of our research was to make a preliminary verification of if the method is effective for Polish children with special needs (the method was designed for German children with normal intelligence). Each of the children that took part in the research had somewhat different disorders, probably because of different problems in the brain activities. However, after the training, we noticed progress in each case. For each child, we applied a quite detailed method of a case study; however, we do not present here the detailed results of those studies, but only a concise evaluation of the effectiveness of the diagnosis and training applied.

2. Diagnosis in the Warnke Method as an Extension of the Assessment of Phonological Competence

In general, the methods of diagnosis for people with speech disabilities and difficulties in learning, reading, and writing focus on the evaluations of:

- Intellectual skills (to identify specific difficulties in learning);
- Level of psycho-motor development—especially of the socio-emotional (i.e., motivation) functions—and the quality of reading and writing.

The estimation of psycho-motor development (i.e., the evaluation of both the strengths and the disorders) concerns the integration of perception with motor skills and cognitive functions; this includes, in particular, the concentration of attention, memory, and connections of visual and auditory observations with spatial imagination (i.e., sense of direction) and level of language development [17].

The evaluation of phonological competence in terms of reception and transmission of the speech signs is especially interesting as a method of diagnosis of language skills. The phonological competence means skills (on the automatic as well as on the conscious level) of reception, analysis, synthesis, and manipulation of speech sounds. It consists of the following complementary elements:

- Skill of the auditory differentiation of phonemes—Phonemic hearing;
- Capability to perform the syllable transformations—Analysis, synthesis, removal;
- Capability to perform the phoneme transformations—Analysis, synthesis, removal;
- Capability to perform suitable transformations of the prosodic elements (recognition, localization of rhyme, alliteration, intonation, rhythm).

The phonemic hearing seems to be a primary ability of phonological competence. The deficits in it cause disorders in speech reception and, consequently, lack of or an insufficient automation of reading and writing. The reason for such deficits lies in incorrect central processing—Especially auditory processing. The abnormalities in central auditory processing are connected with disorders in the following functions: Sound source localization, differentiation of sounds, sound pattern recognition, analysis of temporal aspects of sound signal, capability to process very short sound signals, capability to deal with sound masking situations and with temporal organization of sounds, temporal integration of sounds, understanding of distorted speech, understanding of speech in presence of jamming signals, auditory lateralization, and capability to receive contemporaneous signals [2,18,19].

One of the reasons for the impairment in phonemic hearing can be an incorrect functioning of the "brain clock" [8], i.e., of the information processing over time. The perception of speech sounds, as well as articulation, is inextricably linked with time. A statement addressed to us must have a very specific temporal structure to be understood.

The analysis and synthesis of a sequence of phonemic elements of sounds (phonemic hearing) occur in time ranges (in the brain activities) of around 30–40 ms (milliseconds). The time ranges of several hundred milliseconds, or even of a few seconds, are necessary in the normal process of learning reading.

Roughly speaking, the diagnosis of disorders in phonemic hearing concerns three levels: Syllables, elements of syllables (rhyme, alliteration), and phones. Usually, the estimation of effectiveness of analysis and synthesis of the word pieces and syllables is determined by tests, which contain lists of specific words and pseudowords (i.e., words without meaning). Evaluating the phonological skills, we also have to take into account the phonological memory and automation mechanisms that process the phonological information in time. We can use for this purpose, e.g., the tests that recognize verbal fluency (fast rhyming) and rapid naming tests [1,20].

The diagnosis of the Warnke method provides tools that expand and complement the classical methods of estimation of phonological competence (phonological analysis and synthesis). It uses tests that focus on:

(a) Causes of disorders in complex functions in the area of central auditory, visual, and motor processing;
(b) Symptoms of difficulties in complex functions.

The causes can be recognized by tests that evaluate the following functions concerning the analysis and synthesis of auditory, visual, and motor mechanism:

1. Perception Order Thresholds (visual and auditory);
2. Spatial Hearing (recognition of direction);
3. Pitch Discrimination;
4. Auditory–Motor Coordination;
5. Choice Reaction Time;
6. Pattern Recognition (in sequences of low–high and short–long sounds)—Frequency Pattern Test and Duration Pattern Test.

Visual Order Threshold evaluates the time resolution of visual stimuli, i.e., the distance between two stimuli, estimated in milliseconds. The capability to organize visual stimuli (i.e., to separate various perceptions and point out the correct order of them) is necessary to determine a proper alignment of a sequence of them. This is very important in the process of reading. If the value of Visual Order Threshold obtained in a test is too low, i.e., the time period between recognizable stimuli is too long, then the reading activity is slow, laborious, and exhausting.

Auditory Order Threshold describes the time resolution of auditory stimuli, i.e., the time distance (also estimated in milliseconds) that is necessary to perceive different auditory stimuli as separated sounds. If we measure the capability to organize rapid succession of several auditory stimuli and the value of Auditory Order Threshold test is too low, i.e., the time period between recognizable stimuli is too long, then some difficulties must occur in perception (discrimination) of plosive sounds (for example: b/d, g/k, p/t); consequently, there appear difficulties in speech understanding.

Spatial Hearing concerns localization of a sound source (up to a few angular degrees). That capability is necessary to select a particular sound from among other (disturbing) sounds. In this case, a very important skill is, for example, the space orientation and ability to follow the voice of a speaker or a teacher in a classroom (where many disturbing auditory stimuli may occur).

Pitch Discrimination is the skill of rapid perception of differences in the pitch of sounds. We can measure it by the capability to notice a rapid succession of two auditory stimuli. It is necessary to recognize the vowels and the intonation of speech.

Auditory-Motor Coordination is measured by the ability to fluently tap the rhythm of sounds, which a patient hears in headphones (once to the right and next to the left-hand side). This also reflects the level of coordination of the hemispheres.

Choice Reaction Time describes the skill of quick selection of the lower sound (heard once from the right and once from the left-hand side in headphones). It is connected with the capability to recognize phonemes and graphemes automatically, which is very important for acquisition of reading and writing in a fluent way.

The Frequency Pattern Test concerns the ability to distinguish tones of different heights. This automated capability is very important for the perception and interpretation of prosodic elements of speech, especially of intonation.

The Duration Pattern Test evaluates the ability to distinguish various durations of tones. This is also an automated capability, which is responsible for a division of speech into prosodic elements that can be recognized and interpreted, especially rhythm.

The symptomatic diagnosis of phonological processing (taking place in the area of language realization) is to complement and clarify the reasons (that have already been recognized to a certain degree) of malfunctioning of the complex functions in the area of the central auditory, visual, and motor processing system. In the Warnke method, this can be achieved by the following evaluation tasks:

- Reading of some special texts composed of pseudowords (words that are meaningless);
- Short-term remembering (memorization) of syllables;
- Selective perception of differing vowels and consonants;
- Dynamic vision and angular amentropia;
- Visual spelling.

3. The Essential Diagnosis Procedure in the Warnke Method

At the beginning of the diagnosis, we collected important information on the patient, his/her biography, parents and siblings, types of past therapies, the present reasons for testing, the results of audiometric tests, the results of visual tests, and information on past illnesses (especially in the nervous areas that are connected with hearing and seeing).

A very important part of the Warnke method is that of tests. A large number of qualified experts have validated them for several years. In this way, a basis was created for further training. The testing procedure consists of fourteen stages, which were designed as a kind of fun activity. The aim is to determine possibilities and chances for further training (and not to find out things that a person is not capable of). The stages are listed below, and they guide through the test procedure; of course, special test devices are necessary [13]. We describe these devices in the forms that were used in our research. At present, somewhat modified versions of them are available.

One of these devices, named Brain-Boy Universal Professional (BUP), can be used for testing and training of the following low-level functions: Visual and auditory order threshold, spatial hearing, pitch discrimination, visual and auditory motor-timing, choice reaction time, frequency pattern recognition, and duration of tone recognition. Another available device, named Brain-Boy Universal (BBU), with its seven different game programs, offers an easy and effective way to enhance the functions of central hearing. Actually, it is similar to BUP, but without the testing possibilities.

Each program of BUP (and also of BBU) can be started at different levels to make it suitable for either beginners or advanced users. A simple menu system guides through all of the functions; it is only necessary to use two of the three buttons of BUP for navigation. Moreover, there are two manuals provided: One for children and one for adults. There is yet another special feature in the BUP: In the case of a correct answer, BUP loudly praises the results and increases the difficulty. Thus, the user gets an immediate and motivating feedback. If it is disturbing for older children or adults, then the voice output can be switched off [12,16].

The whole diagnosis can be divided into two parts. The first part is based on the stages depicted below:

1. Visual Order Threshold. Two light flashes are produced. The examined person is asked to identify on which side he/she saw the first one (the level of difficulty increases steadily in the interval range of 5–800 ms).
2. Auditory Order Threshold. The user hears two clicks through headphones (one click from either side) and must determine which click was the first one (the level of difficulty is steadily increasing in the interval range of 5–800 ms).
3. Spatial Hearing. The direction of a click that seems to come from a point near the head center must be identified (range 20–800 ms).
4. Pitch Discrimination. Two sounds with different pitches are produced. The user must recognize the difference between them (which is lower and which is higher) and their order.
5. Auditory Motor Coordination—Finger-Tapping. In this step, the user must press two buttons alternately, in synchrony with the rhythm and speed of sounds that he/she hears in the headphones, coming from different sides. If it is done correctly, the speed increases over time (range 160–900 ms).
6. Choice Reaction Time. This step checks the ability to choose the correct sound as quickly as possible. The user must identify the difference between two tones by indicating which was, for instance, lower and show (as quickly as possible) the direction it came from.
7. Frequency Pattern Test. This program produces three sounds of which two are the same and one is different from them. The user has to recognize that different tone correctly in each sequence and indicate where it was: At the beginning, in the middle, or at the end of a sequence. In the case of success, the duration of tones and the intervals between them are shortened (range 10–800 ms).

7a. Duration Pattern Test. The program produces three sounds. One of them is longer than the other two. The user has to correctly recognize the longer tone in each sequence and indicate where it was located—at the beginning, in the middle, or at the end of the sequence. In the case of success, the durations of the sounds are shortened (range 10–800 ms).

The percentage rank that a child has reached in each of the eight functions is always available for a therapist.

The standardized percentage data for children aged 5–12 years are provided. They were established in cooperation with the Medical University of Hanover [14]. In this way, BUP became a professional device working on the basis of scientifically standardized data. Thus, it delivers valid information while testing the basic central functions.

All results of the test procedure can be easily recorded with the PC software MediTOOLs. Moreover, the complete reports for parents, teachers, and therapists can be automatically generated in a similar way.

The second part of the diagnosis was not used by us. It requires tools of a different kind. For the convenience of readers, the stages of the second part are described below [12–14]:

8. Coordination Skills. The child is asked to balance a light wooden stick (1 m long) on the back of his/her hand for a few minutes.
9. Reading Meaningless Texts. The child is asked to read a meaningless text aloud (consisting of pseudowords) to determine which strategy he/she uses in reading. The number of mistakes and the time used show which method in reading the child applies.
10. Short Time Memory. The child hears 2–6 meaningless syllables and is asked to repeat these syllables.
11. Perception Discrimination. The child has to repeat meaningless words in some order to determine his/her ability to distinguish the (plosive) consonants (acoustic conditions of a classroom are simulated).
12. Dynamic Vision. The child must track, only with his/her eyes (without moving the head), a finger that is moving and drawing a horizontal figure-eight pattern.
13. Angular Ametropia. This stage tests if the child's eyes are able to focus on the same spot. If there is a deficit, it often leads to serious difficulties in reading from a blackboard in the classroom.

14. Visual Spelling. The child is asked to draw words "in the air", to find out if they have developed an inner representation of spelling. If necessary, the software *Orthofix* can be used to train the child in automatic visual spelling. Depending on the results achieved, a necessary amount of training can be estimated and combined with some other pedagogical activities.

4. Procedure of the Research

The main purpose of the research presented in this paper was to evaluate the effectiveness of diagnosis of the first stage of the Warnke method in the improvement of the language, memory, and reading and writing skills. The research hypotheses (formulated on the basis of some theoretical publications and observations of the method in practice) were the following:

1. The diagnosis of the Warnke method extends, complements, and clarifies estimations obtained in the classical symptomatic diagnosis of phonological competence.
2. It helps the trainer to estimate the level of difficulties (before and after a training) and definitely helps to improve the child's activity, which should be observed in each case.
3. The range of automation of each function of central processing will be estimated on the basis of values obtained in diagnoses. The results obtained should be in correlation with current levels of speaking, reading, and writing.

We used the method of case study. The applied tools were logopedic observation and analysis of the following tests: The language skills test by Z. Tarkowski [21], a Polish version of the Rey Memory Test (Rey 15 Item Test), a test for the exclusion or recognition of dyslexia [22,23], a test for evaluation of reading and writing skills [23], a test for pedagogical diagnosis of reading and writing skills in grammar schools [24], a test for evaluation of reading aloud technique [25], the "little house for dwarves" test [26], the pseudoword reading test (Kers a lig) [12], the short-term memory test [12], and the tests in the BUP. We also used the devices that were described in the previous section and the standardized percentage data, established for children at the age of 5–12 years, for the Warnke method.

The research was conducted in the Institute of Special Needs Education in the Pedagogical University of Cracow (Poland), with the support of a group of four Master students (as a part of their Master tasks on the case study method). It concerned the effectiveness of the Warnke method in testing and training of the eight low-level functions in a group of the following four children [27–31]:

1. Eight-year old boy (boy no. 1) with mild intellectual disabilities and speech disorder problems;
2. 13 year old boy (boy no. 2) with mild intellectual disabilities, FAS (fetal alcohol syndrome), and problems in short-term verbal memory (phonological memory);
3. Seven-year old bilingual girl (girl no. 1) with difficulties in reading and writing, and normal IQ;
4. Eight-year old girl (girl no. 2) with normal IQ and some early dyslexia problems.

The boys were selected from two different schools by their speech therapists. The girls were selected by the students (with the consent of their parents). The number of children was determined by the number of students, because each student trained and tested only one of these children (under suitable supervision). The students took only a very basic training in the Warnke method, but the tests on the language competence were done by professional speech therapists.

In the cases of boys and the first girl, the training of auditory, visual, and motor central functions was conducted for five months, with twenty meetings; one meeting every week and with each session lasting about 45 min. In the case of girl no. 2, the training of auditory, visual, and motor central functions was conducted for four months, with sixteen meetings; one meeting every week, and each session lasted about 45 min. In each case, the training during each meeting included the same activities, described in points 1–7a in Section 3 of this paper. There was no training in speaking, reading, or writing.

All procedures of the posttest were analogous to those of the pretest. The same communicational skills were checked (with the same tests). The initial and final results of the central function skills were measured with special standardized software provided by the Warnke method (the BUP device) [16].

In the case of boy no. 1, the main purpose of research was the effectiveness of the Warnke method in improvement and development of speech. During the pretest, we focused on the diagnosis of the level of language and communication skills and the level of the eight basic functions of central auditory, visual, and motor processes. We applied the following tools: Language skills test by Z. Tarkowski [21] and the Warnke functional test in BUP. The pretest and posttest on the language and communication skills were done by professional speech therapists.

In the case of boy no. 2, the main goal of research was to check the effectiveness of the Warnke method in improving phonological memory. During the pretest, we focused on the diagnosis of the receptiveness of his phonological memory and on the level of the eight basic functions of central auditory, visual, and motor processes. We applied the following tools: A Polish version of the Rey Memory Test (Rey 15 Item Test) and the Warnke functional test in the BUP.

In the case of girl no. 1, the main goal of research was: The effectiveness of the Warnke method in improving her abilities of reading and writing. During the pretest, we focused on:

- Exclusion of dyslexia;
- Diagnosis of the level of reading and writing skills;
- Level of the eight basic functions of central auditory, visual, and motor processes.

We applied the following tests: A test for the exclusion of dyslexia [22], for the evaluation of reading and writing skills [23], for the pedagogical diagnosis of reading and writing skills in the grammar school [24], and the Warnke functional test of the BUP.

In the case of girl no. 2, the main goal of research was: The effectiveness of the Warnke method in dealing with her dyslexia problems, i.e., in improving her automation of reading. During the pretest, we focused on:

- Recognition of the level of dyslexia;
- Diagnosis of the level of her reading skill;
- Phonemic reading test;
- Short-term memory test;
- Level of the eight basic functions of central auditory, visual, and motor processes.

We applied the following tests: A test for diagnosing the level of dyslexia [22], for evaluation of the reading aloud technique [25], the "little house for dwarves" test [26], the pseudoword reading test (Kers a lig) [12], the short-term memory test [12], and the Warnke functional test in the BUP.

5. Results of the Research

The eight basic functions of central processing were evaluated after each meeting, and the outcomes showed a constant small progress, with several fluctuations. Below, in Tables 1–5, we present the results of initial and final diagnoses (before the first and after the last meeting). The second and third columns contain the normative values (reference and target), which were established for children aged 7, 8, and 12 years. Let us recall that the reference values were obtained by 50% of the children tested from each age group; the target values were achieved by 80% of the children tested. The fourth and fifth columns contain the pretest and posttest values.

Table 1. The results of boy no. 1 [14].

Name of Function	Reference Values for Age of 8 Years	Target Values for Age of 8 Years	Pretest Values	Posttest Values
1. Visual order threshold	47 ms	24 ms	240 ms	80 ms
2. Auditory order threshold	99 ms	49 ms	550 ms	80 ms
3. Spatial hearing	74 µs	42 µs	600 µs	100 µs

Table 1. *Cont.*

Name of Function	Reference Values for Age of 8 Years	Target Values for Age of 8 Years	Pretest Values	Posttest Values
4. Pitch discrimination	24%	8%	68%	14%
5. Auditory–motor coordination	403 ms	322 ms	830 ms	692 ms
6. Choice reaction time	104 ms	616 ms	1040 ms	488 ms
7. Frequency pattern test for low–high tones	220 ms	90 ms	800 ms	200 ms
8. Duration pattern test for short–long tones	200 ms	127 ms	500 ms	140 ms

Table 2. The results of boy no. 2 [14].

Name of Function	Reference Values for Age of 12 Years	Target Values for Age of 12 Years	Pretest Values	Posttest Values
1. Visual order threshold	35 ms	20 ms	120 ms	28 ms
2. Auditory order threshold	65 ms	42 ms	50 ms	55 ms
3. Spatial hearing	39 µs	22 µs	20 µs	18 µs
4. Pitch discrimination	21%	6%	1%	1%
5. Auditory-motor coordination	292 ms	223 ms	315 ms	321 ms
6. Choice reaction time	648 ms	324 ms	466 ms	557 ms
7. Frequency pattern test, recognizing low-high tones	116 ms	30 ms	180 ms	46 ms
8. Duration pattern test for recognizing short-long tones	107 ms	53 ms	110 ms	100 ms

Table 3. Test results of boy no. 2: Receptiveness of phonological memory [14].

Test Number	Pretest—Number of Remembered Words	Posttest—Number of Remembered Words	Normal Data for Age of 13 Years
I	0	5	6
II	2	8	9
III	4	9	11
IV	4	7	12
V	5	8	12
VI (a few hours after test V)	5	8	13

Table 4. The results of girl no. 1.

Name of Function	Reference Value for Age of 7 Years	Target Value for Age of 7 Years	Pretest Values	Posttest Values
1. Visual order threshold	63 ms	29 ms	90 ms	34 ms
2. Auditory order threshold	136 ms	65 ms	160 ms	70 ms
3. Spatial hearing	95 µs	53 µs	180 µs	74 µs

Table 4. *Cont.*

Name of Function	Reference Value for Age of 7 Years	Target Value for Age of 7 Years	Pretest Values	Posttest Values
4. Pitch discrimination	31%	12%	40%	8%
5. Auditory–motor coordination	444 ms	359 ms	409 ms	385 ms
6. Choice reaction time	1172 ms	720 ms	over 2984 ms	1092 ms
7. Frequency pattern test (low–high tones)	300 ms	145 ms	160 ms	118 ms
8. Duration pattern test (short–long tones)	240 ms	147 ms	160 ms	120 ms

Table 5. The results of girl no. 2.

Name of Function	Reference Value for Age of 8 Years	Target Value for Age of 8 Years	Pretest Values	Posttest Values
1. Visual order threshold	47 ms	24 ms	34 ms	12 ms
2. Auditory order threshold	99 ms	49 ms	100 ms	50 ms
3. Spatial hearing	74 µs	42 µs	120 µs	14 µs
4. Pitch discrimination	24%	8%	below 80%	16%
5. Auditory–motor coordination	403 ms	322 ms	546 ms	235 ms
6. Choice reaction time	1040 ms	616 ms	1397 ms	528 ms
7. Frequency pattern test (low–high tones)	220 ms	90 ms	below 1000 ms	80 ms
8. Duration pattern test (short–long tones)	200 ms	127 ms	550 ms	90 ms

In the case of boy no. 1, after the final diagnosis, we observed progress in development of speech. In particular, we noticed (see [21] for more details):

- Progress in the articulation of sounds and verbs, no metathesis, and a smaller number of substitutions and devocalizations;
- A better understanding of words, sentences, questions, commands, and longer statements;
- An improved use of syntactic rules, better sentence and question creation, and longer texts;
- An enlargement of vocabulary and semantic scope (only a small progress).

The results of boy no. 2 in the final test (on phonological memory) showed an improvement. The number of remembered words increased by 50% in all samples. In the test of delayed memory, the boy remembered eight words, which is 61% of the norm. The detailed outcomes are shown in Table 3.

In the final diagnosis of reading skills of girl no. 1, we noticed progress in:

- Knowledge of letters and digits (which was on a high level);
- Pace of reading (40 words in 1 min, and the whole text in 2 min and 15 sec);
- Technique of reading (syllabic and whole words);
- Number of mistakes (which was very low: Only three).

In the writing skills, we observed progress in:

- Graphical level of writing (letters were of proper shape, with correct proportions and inclination, and were legible),
- Pace of writing (which was fast);
- Number of various mistakes (which was very low).

In the case of girl no. 2, after the final diagnosis, we observed an improvement in:

- Reading pace (43 words in 1 min), fluency, and technique (syllabic and whole word);
- Understanding of the text read (without mistakes);
- Concentration of attention while reading;
- Understanding of questions and commands in the text (without mistakes);
- Recognition and differentiation of sounds (much faster);
- Perception of the opposition of sounds (i.e., voiced–voiceless, oral–nasal);
- Syllable analysis and synthesis (much faster).

6. Discussion and Conclusions

The treatment group consisted of four children with special needs, particularly with some difficulties in speech, reading, and writing. All children were subjected to logopedic examination, including an assessment of auditory analysis and synthesis, phonological memory, and distinguishing between phonemes.

After the final diagnosis, we found out that the first stage of the Warnke method was effective in the therapy of difficulties in speech, reading, and writing. We observed progress in all practiced functions of central auditory, visual, and motor processing. The levels of communication and reading and writing skills were much higher than before the training. The children made smaller numbers of mistakes in phonological areas of speaking (in expressing and understanding), reading, and writing. The values provided by the BUP device in the posttests proved this statement, because we could observe several improvements in the following skills:

- Auditory differentiation of plosive consonants and better speed of perception (which consequently improved the speech understanding and speed of reading);
- Coding, understanding, and expressing words, sentences, questions, commands, and longer texts;
- Recognition of pitch differences (consequently, there was a better articulation of vowels, consonants, and whole words, no metathesis, and a smaller number of substitutions and devocalizations);
- Auditory motor coordination;
- Speed of perception of phonemes (which consequently improved the fluency of reading and verbal expression);
- Coding and decoding of the prosodic elements of speech (intonation and rhythm).

Certainly, we cannot ignore here such issues as the regression to the mean, measurement error, and the lack of a control group. However, we must repeat here (see the previous section) that the evaluations of the eight central functions were done separately for each function and after each meeting (16 or more times), and the outcomes showed constant progress (consistent with the final results) with some small fluctuations (probably somehow due to the regression to the mean and measurement error). Moreover, the initial and final estimations of speaking, reading, and writing capabilities involved many aspects (also qualitative), and, in nearly all of them, we observed progress. This means that we can uphold our claims without considering these issues in detail. Moreover, the differences between initial and final estimations seem to be meaningful, and children with special needs are generally not capable of much progress in such short periods of time in the activities examined without any special support.

So, we can state that the results obtained point out that the recognition of causes in the Warnke diagnosis may complement and extend possibilities of the classical symptomatic diagnosis of phonological competence in Polish children with special needs, namely:

1. The diagnosis of the first stage of the Warnke method may extend, complement, and clarify estimations obtained by the general symptomatic diagnosis of phonological competence. During this diagnosis, we focused on the causes of disorders on the level of the central nervous system that are connected to deficits in the central processing of hearing, seeing, and motor skills. They may be caused by disorders in the following functions: Sound source localization, differentiation of sounds, sound pattern recognition, analysis of temporal aspects of sound signal, ability to process very short sound signals, temporal organization of sounds and temporal integration of sounds, understanding of distorted speech, understanding of speech in the presence of jamming signal, dealing with sound masking, auditory lateralization, and ability to receive signals contemporaneously and non-contemporaneously.
2. We found out that the Warnke diagnosis helps trainers to better determine the problems in each function, and, in the posttests, we noted progress in each clinical case.
3. The test values in each case were different because of differences between children in age, IQ, individual development (especially, the cognitive development), nature, and extents of disorders.
4. The results show a relationship between the values of the Warnke functional test and the improvement in learning ability. The ranges of automation of each function, estimated on the basis of test values, were correlated with the quality of speaking, reading, and writing. That statement was verified and confirmed by the symptomatic tests.
5. The values of each function and in each case of the diagnosis provided very relevant information, which contained detailed indications for development of further treatment.

Finally, let us mention that our research, like all research, had some limitations. They seem to be fairly obvious, but let us acknowledge some of them. These certainly included: A small group (only four children with different disorders), no control group, a short time of research (which suggests that the effects will not be long lasting), and application of only the first part of the Warnke method.

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