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On the Supportive Role of the Warnke Method in Improving the Phonological Competence of a Bilingual Girl

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Abstract: It is known that bilingualism may cause some specific problems with the articulation of sounds and errors in reading and writing when acquiring linguistic skills. The paper presents the results and conclusions related to the use of the Warnke method in improving the phonological competence of a bilingual girl aged seven, which learned two languages simultaneously (Polish and Italian) in her family environment. The case study method was used. The main objective was to assess the effectiveness of the first stage of the Warnke method in improving reading and writing skills in a bilingual child. The Warnke method focuses primarily on the diagnosis and training of the phonological competence and was based on the following assumptions: (a) the automation of hearing, vision, and motor functions can be improved at the level of brain activity; (b) the development and automation of phonological analysis and synthesis are based on the cooperation of the brain hemispheres. The preliminary and final results of the diagnosis obtained for basic brain functions (visual, motor, and auditory) and the level of literacy skills were analyzed and compared. The reading and writing abilities, before and after training with the Warnke method, were assessed using the symptomatic tests. The obtained results showed that during and after training with the method, there was noticeable progress in eight basic functions (visual, motor and auditory). Improvement was also seen in the following areas: knowledge of letters; pairing phonemes with letters; technique, speed, and fluency of reading and writing. The quality of reading and writing was verified and confirmed by symptomatic tests. The conducted study suggests that the observed learning disabilities were caused by deficits in the central processing functions, which resulted in a lower level of phonological skills.

Keywords: bilingualism; the Warnke method; automation of hearing; vision and motor functions; reading and writing skills

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1. Introduction

The research presented in this paper aims to show the potential possibilities of the Warnke method in the diagnosis and treatment of mild deficits in the processing skills of auditory, visual, and motor stimuli, which may occur in bilingual children and limit their possibilities of learning to read and write. The training of this method consists of selected simple exercises for the central processing functions with the use of simple electronic devices. The obtained results were verified with appropriate symptomatic tests.

According to the authors' knowledge, no results have been published so far on the use of the method in multilingual children. We hope that this work will inspire wider research in larger groups of people and/or for languages other than Indo-European.

1.1. Background

Terms such as *bilingualism*, *multilingualism*, *polyglotism*, and related *multiculturalism* became very popular in the 21st century. Numerous linguistic and cultural contacts, mainly

related to globalization and migratory movements, mean that the percentage of children growing up in a bilingual or multilingual environment is now increasing [1,2].

Sometimes bilingualism, multilingualism, and polyglotism are used as synonyms in the scientific literature. However, multilingualism (polyglotism) means using (speaking and understanding) two or more languages, while the term bilingualism refers to the use of only two languages. There are also individual multilingualism/bilingualism (relating to individuals) and social multilingualism/bilingualism (relating to groups of people) [3,4].

Bilingualism (and therefore also multilingualism) is a very complex phenomenon that can temporarily cause some particular difficulties in the development of speech and education of children. Many issues related to these topics have recently been researched and described in scientific publications in the fields of linguistics, psycholinguistics, and sociolinguistics (see, e.g., the work of [1–5]). However, since this article deals with the case of a bilingual girl, so in the following, only the issue of bilingualism is discussed in more detail.

The situation of bilingual people is very complex. Their development and life are influenced by various environmental, political, educational, and family conditions [3,4]. Therefore, a strict and homogeneous classification of the types of bilingualism is not possible. However, some attempts have been made to do so, and the most commonly used and most important criteria are linguistic competence and proficiency in the language [6].

In the process of linguistic development, the following ways of learning the second language can be distinguished [7]:

- Natural acquisition, which means learning an additional language without formal instructions, mimicking the way adults and possibly other children speak;
- Guided acquisition, meaning that knowledge of an additional language was acquired through teaching (e.g., school lessons).

A specific bilingual human being is not necessarily "completely" good or bad in all parts of the language system (syntax, semantics, and phonology); can have a strong second language accent while having impeccable syntax and rich vocabulary. Moreover, the organization of the language system, and thus the state of bilingualism, depends on personal life experiences and can therefore change over time [4,8]. Some topics related to bilingualism in children will be discussed in more detail in the next section.

There is now a fairly common opinion, supported by relevant investigations that bilingualism generally does not have to interfere with the educational process and create any particular obstacles to education. On the contrary, research shows that using more than one language stimulates the child's development [9–12] and brings many benefits in the later stages of education and in working life [13–15]. Bilingualism in particular promotes: intellectual development, emotional contact with other people, conversation skills, logical thinking, and mental flexibility and creativity. It improves learning opportunities through knowing two languages and being in touch with two cultures [10,11,14].

But of course, bilingual children may have deficits in speech, reading, and writing, similar to monolingual children. They may also have their own (perhaps only temporary) specific difficulties related to, for example, mixing the codes of the languages used [10,12]. Moreover, bilinguals operate in a complex linguistic and/or cultural environment and are influenced by many different factors. Therefore, it is worth remembering that not only the individual abilities of children but also the social context contribute to differences in children's linguistic development. Socioeconomic status, as well as the level of education and the profession of parents, has a direct impact on it.

According to Hoff [16], children from privileged social backgrounds are characterized by greater and faster lexical development than children from poorer socioeconomic classes. Moreover, the mother's level of education significantly determines educational practices and the type of linguistic interactions between the mother and her children. Therefore, in certain school periods, some bilingual children may have learning difficulties due to the lower knowledge of one of the languages used for a longer or shorter period of time [17].

One of the EU-funded projects [18] aimed to assess such difficulties. The influence of particular features of Basque and Spanish on reading skills in Spanish-Basque children was investigated. The results showed that bilingual children had a noticeable reading deficit compared to the control group.

Also, R. Kormi-Nouri et al. [19] studied the differences in learning to read and write in Persian among monolingual and bilingual Iranian children. The children were between 7 and 12 years old, and bilinguals spoke Arabic or Turkish at home. The results indicated that the relationship between age and school performance spoke in favor of monolinguals as the age of the children increased. The researchers explain that this is probably related to the fact that children in Iran do not receive school education in their mother tongue and the imbalance between the languages creates a negative impact on the overall development of these children.

It should also be mentioned that the studies that contribute to understanding how bilingual children acquire literacy skills do not specifically highlight the impact of bilingualism alone on their acquisition. However, E. Bialystok [20] identifies three areas of research important for the acquisition of reading and writing skills in bilingual people, explains the contribution of each, and associates them with the skills required of monolingual children to acquire literacy. The relationship between bilingualism and the development of each of those skills is different, sometimes indicating benefits and sometimes emphasizing deficits in bilingual children.

1.2. Purpose of the Study

As has already been mentioned, the main aim of the article is to present the results and conclusions related to the use of the Warnke method in improving the reading and writing skills of a bilingual girl aged seven. The initial diagnosis showed that the girl had deficits in the automation of the central processing functions, and it was very natural to assume that their training should result in improved phonological awareness and thus in better reading and writing skills. The purpose was to confirm these expectations. It should be added here that before the training, the girl did not show any particularly serious deficits in reading and writing and was included in the research at the request of the parents concerned about the increasing mixing of two language systems by her.

1.3. Significance of the Study

A natural question arises which of the many methods of compensating for difficulties in learning to read and write are effective and to what extent in correcting analogous problems in the education of bilingual children (cf. [4,21,22]). The authors evaluated the effectiveness of the first stage of the Warnke method in improving the automation of the central processing functions and the literacy skills of a bilingual girl.

As expected, after the first stage of training with this method in a relatively short time of 20 weeks, the automation of the central processing functions was significantly improved, and the problem of mixing language systems was reduced. It should be added that no other therapeutic intervention was used during that period of time, and our outcomes were consistent with the previous results of research on the effectiveness of this method carried out at the University of Hannover in a group of nearly 400 dyslexic children between the ages of 5 and 12 [23,24].

Of course, our study was very limited as it involved only one person, but the results seem encouraging enough to be presented to a wider audience. The authors believe that they can be an impulse to undertake similar research on a larger scale, also in relation to other languages, including those not belonging to the Indo-European group and/or historically not related to the same extent as Polish and Italian.

1.4. Research Questions

Research on the effectiveness of the Warnke method, especially in the area of improving phonological awareness, which is the basis for correct speech and proper reading and

writing, proves that influencing perception and central auditory processing with the use of the Warnke method devices effectively improves reading skills and writing in children with dyslexia [25]. Therefore, it was reasonable to expect that the Warnke method would be effective as a supporting tool in improving reading and writing also in bilingual children who had difficulties closely related to their bilingualism and coexisting with lower phonological awareness. The research questions were established on the basis of theoretical publications, scientific studies, and observation of the method's application in therapeutic practice. They are following.

1. Which central processing functions will improve, deteriorate or remain the same after training? How will change visual and auditory order threshold, spatial hearing ability, pitch discrimination, auditory motor coordination, choice reaction time? What will be the results of the frequency pattern test (low–high tones) and duration pattern test (short–long tones) after the training?
2. To what extent will the girl's reading and writing skills improve after training with the Warnke method?

1.5. Theoretical Framework

The speech development of bilingual children is the same as the speech development of monolingual children. However, the formation of the two language systems may differ in some aspects due to the different structures of these languages. Bilingual children with neurotypical (normal) speech development, regardless of whether they acquire languages simultaneously or sequentially, are able to reach particular stages of speech development in at least one language. What makes the group of bilingual children heterogeneous is the different degrees of acquiring linguistic competences. One can speak of language disorders in bilingual children when there are deficits in both of the learned languages. Language difficulties in acquiring a second code may result from problems with acquiring the first language. Therefore, if in a situation of bilingualism, at least one language system in a child is not formed correctly, the therapeutic action should be initiated as soon as possible [8,12].

Some studies [26–29] suggest that difficulties in acquiring reading and writing skills may be mainly due to lower phonological awareness, as it is known that there is a strong positive correlation between the development of children's phonological awareness and their reading progress [30]. Children usually show a fully developed phonological awareness by the age of seven [31]. Phonemic awareness, the final stage of emerging phonological awareness, is the most important determinant of rapid progress in learning to read and write.

The research on the assessment of phonemic hearing in monolingual and bilingual preschool children shows that bilingual children in whom the acquisition of both languages was carried out simultaneously achieved weaker results in some tests of linguistic proficiency and phonemic hearing. Deficits in the synthesis and auditory analysis in school learning lead most often to difficulties in reading and writing by listening. This means that in the case of children brought up in bilingual families, i.e., in the case of simultaneous bilingualism, particular attention should be paid during preschool and school education to the development of certain elements of phonemic hearing (auditory synthesis) in order to help the child avoid problems with learning [32,33].

Phonemic hearing is the ability to hear precisely and differentiate between the sounds of speech. However, in the case of bilingualism, it is worth focusing on the distinctive features of individual sounds, which in the languages under consideration are different. Then, phonemic hearing should be understood as the ability to receive and properly interpret significant acoustic features of all sounds from the acquired languages. Until about six months of age, a child is able to differentiate all the phonemes of the world's languages. Later, phonemic hearing specializes in picking up and differentiating the phonemes of the mother tongue (or languages heard in parents' speech). In bilingual development, exposure to both languages does not always arise early in a child's life and is not always sufficiently intense. The end of the first year of life is a critical period for the

perception and differentiation of sounds. If a child at this age cannot differentiate certain features of phonemes in a given language, they become imperceptible to him/her. Then there may be difficulties in mastering the phonology of the second language [34].

Phonological awareness is the ability to recognize and manipulate the spoken parts of words and sentences. A study of the effectiveness of the Warnke method, especially in the field of improving phonemic hearing and general phonological awareness, which are the basis for correct speech and correct reading and writing, proves that influencing perception and central auditory processing with the use of the method devices effectively improves reading and writing skills in children with dyslexia [25]. Therefore, it was reasonable to expect that the method would be effective as a supporting tool in improving reading and writing also in bilingual children who had difficulties closely related to their bilingualism and coexisting with lower phonological awareness and/or worse phonemic hearing.

1.6. Ethical Issues

Bilingualism should be understood as a process that is constantly changing and whose relationship with a child's development is multifaceted, especially in the area of shaping intellectual abilities (including thinking and speech, reading, and writing). It is therefore important to see a bilingual child as a subject, a person with a certain life story, resources, opportunities, and difficulties. Therefore, each bilingual child should be treated very individually, taking into account the influence of various biological, social, environmental, educational, and cultural conditions.

According to current research, learning to use two languages at the same time should not lead to disturbances in the child's development. However, at various stages of this development, some gaps in language skills may arise, which may cause more or less temporary learning difficulties. Some of these difficulties may be due to developmental processes related or not to bilingualism, while others may be a consequence of language development deficits, e.g., in the sphere of phonological skills. Therefore, there is a need to very accurately determine the causes of the emerging problems, especially at the level of the central nervous system, which should make it possible to select the appropriate therapy. The intervention should then be planned in such a way as to focus on the identified deficits and at the same time not to disturb the entire acquisition process.

The results presented in this paper suggest that these expectations can be met by the Warnke method, which, using high-technology devices, allows to precisely detect and compensate for the sources of deficits (e.g., in phonological skills) resulting from disturbances in the central processing functions. These issues are discussed in detail in the next sections.

The girl was included in the Warnke training only after a detailed diagnosis (at the request of the parents concerned about the increasing mixing of language codes by her), which revealed the existence of deficits in the functions of central processing. The moderate difficulties she had learning to read and write could be attributed to the normal developmental processes related to bilingualism and did not require the use of additional developmental stimuli.

It should be added that very often, bilingual families face the stress of adapting to a different culture, which is why it is important to support these parents and children psychologically and pedagogically. The specialists must show great empathy and understanding of the family, emotional and personal situation of the child so that the interference does not cause damage to natural development. Such a cautious approach increases the chance of an accurate diagnosis and planning an adequate therapy. This approach was followed in this case of a bilingual girl, both in the planning and conducting of research, diagnosis, and training.

2. Selected Issues Concerning Children's Bilingualism

Proper development of the communicative competence (in particular linguistic communication) of a bilingual child depends largely on the upbringing conditions in the family

environment [6]. The following bilingualism classifications can be found in the Polish scientific literature [35].

1. Simultaneous bilingualism (when a child has assimilated a second language before the age of three) and successive bilingualism (when a second language was learned after the age of three).
2. Balanced bilingualism (when the level of competence of each language is the same) and complete bilingualism (when the linguistic and communicative competences of each language have been developed in both speech and writing).
3. Pure bilingualism (when the use of one language does not occur simultaneously with the other, in the same situational contexts, and language acquisitions have somehow been separated from each other) and mixed bilingualism (when the languages are in constant contact during use and both codes can be used alternately).

In the case of simultaneous bilingualism, as early as the age of two or three, children have the ability to differentiate between phonic signs and grammar rules while learning languages spontaneously. The research confirmed that in the process of learning both languages, there were two separate expansions of morphological and syntactic subcodes of each of them. That is why bilingual children are very creative and very easily change codes when forming statements. Moreover, they learn both phonological models very quickly and constantly expand their vocabulary. Thus, both language systems of such bilingual children develop naturally, at the same speed, but alternately in time [7].

Many parents, as well as some professionals, believe that a child born in a bilingual environment automatically becomes bilingual. However, bilingualism is not a permanent situation; it is a dynamic process that changes under the influence of many different factors [16].

By the age of two, bilingual children must constantly remember the two language systems and switch between them depending on whom they are talking to. At this stage, they mix and merge the codes because they are mainly interested in the speed and efficiency of communication and do not pay much attention to correctness. Therefore, children very often consciously join together words from both languages, for example, asking for 'aqua—water' [7,36].

In preschool and school-age, bilingualism can cause some problems in communication and the learning of language subsystems at the metalinguistic level, but also difficulties with acquiring pragmatic, social, and situational skills. The following symptoms of problems with communication and cognitive competences were distinguished in Polish scientific publications [37,38]:

- Difficulties in learning the articulation of some phonemes (some vowels and consonants);
- Difficulties in distinguishing the pitch of the sound, and hence the lack of understanding of certain statements (e.g., some questions, tags, and commands are mainly recognized by keywords and understood only by various contexts);
- Very frequent use of single words and/or nominal sentences;
- Too little vocabulary and difficulties in answering questions that are not closely related to the context and communicative situation;
- Difficulties in recounting past events;
- Lack of interest in listening to the texts read;
- Few or no questions formulated by the child;
- Problems with understanding and respecting social rules;
- Low dexterity in games with motor activities.

There may also be some difficulties in recognizing and interpreting sounds, especially those that make up speech. It seems that such difficulties may be caused by several disturbances in the organization of certain brain functions (e.g., central auditory processing) and may cause problems in [39,40]:

- Dealing with competing acoustic signals (e.g., selective attention);

- Sound localization and lateralization (which may cause problems with determining the direction of sounds);
- Dealing with degraded acoustic signals;
- Auditory discrimination and recognition of auditory patterns (resulting in, e.g., confusing similar sounds such as "hat" with "bat", "there" with "where", etc.);
- Temporal aspects of listening, including time integration, time discrimination (e.g., time-gap detection), time ordering, and time masking (occurring when a sudden sound makes other sounds that immediately follow or precede it inaudible) [41].

The dominance of one language can lead to an unconditional transfer of skills developed in the dominant language to the weaker language and cause negative consequences when differences between languages require different strategies or the development of different skills [20].

Therefore, it is especially important to support the development of phonemic skills in children who are learning to read in two languages, especially with very different orthographies, as it may be significant for learning to read (because of a greater number of possible phonological errors, which may hinder the correct decoding and recognition of words) [42].

The aim of the study in the work of [42] was to determine whether the simultaneous acquisition of two languages (Polish and English) by bilingual children with different degrees of spelling clarity significantly affects the pace and dynamics of their phonemic awareness development, compared to (Polish) monolingual ones.

The results indicated a delayed development of phonemic awareness in children from the bilingual group. Children from the English-speaking school obtained significantly lower results in phoneme segmentation than children from the monolingual group; they also had lower scores, at the level of statistical tendency, in the more difficult version of the phoneme removal attempt. They also achieved competence in this skill later than the children from the Polish-language school, as it was only in the second grade that they began to develop it. In the ability of phonemic segmentation of words, the lower results obtained by children from the bilingual group probably result from the interference of different patterns of pronunciation and naming phonemes in Polish and English. The level of development of phonemic awareness is even in the second and third grades, suggesting that the slowing down is a temporary effect (see the work of [42]).

Let us mention that learning to read is particularly important as reading helps to understand the relationship between letters and sounds and to spot phonemes that are not always visible in speech [42–44].

It seems that contact with two languages with different spelling clarity can stimulate children to discover the linguistic structure of words and thus improve their reading skills [20,40,45–47]. Moreover, practicing phonological skills in two languages can stimulate thinking about the linguistic form [20,45,47,48] and enable the inter-linguistic transfer of these skills [20,42,49,50].

According to Cummins [51], the condition for such a transfer is adequate exposure to each language and appropriate motivation to learn these languages. Research in the work of [50] showed that Polish children acquiring reading and writing skills as part of a bilingual English-Polish program had an advantage in terms of fluency in reading words in Polish (their first language) over children taught mainly in Polish. However, this advantage was noticed after an average of two and a half years of literacy training. After the first year of learning to read and write, children participating in the bilingual program achieved significantly worse results in terms of fluency in reading words in Polish than their peers from the group practicing monolingual reading and writing. The combination of two different literacy training systems can also result in the early learning of a mature reading strategy by children participating in bilingual literacy training, i.e., the use of both smaller and larger parts of words, visual analysis of whole words, and context of sentences. Language acquired skills tend to be transferred to the other language (bi-directional), making the reading process more effective [50].

A picture naming experiment [48] comparing the performance of monolinguals and highly proficient, L1-dominant bilinguals revealed that monolinguals name pictures faster than bilinguals, both when bilinguals perform picture naming in their first and dominant language and when they do so in their weaker second language. It is the co-activation of different languages and the resulting constant necessity to choose the right language that is most likely responsible for the longer processing time of linguistic information by bilinguals. It has been observed that extracting words from a given language from memory (lexical access) is slower in bilingual people compared to monolingual people [52,53].

Bilinguals also are worse in tests that belong to the classic battery of neuropsychological tests, consisting in enumerating words belonging to a specific semantic category (e.g., animals) or phonological category (e.g., a word beginning with a given sound) [54]. It may take a bilingual child a little more time to eliminate the error and learn the correct structure or sound, among other things, than for monolingual peers. For example, children learning English as L2 may need up to three years more to fully master the use of grammatical morphemes [55].

It seems that thanks to its influence on phonological awareness, the Warnke method can be used as a support tool in reducing this type of difficulty in some bilingual children, for example, shortening the time to become fluent in reading and writing.

Let us also mention that the phenomenon of bilingualism is associated not only with the acquisition of linguistic competences (speaking, reading, and writing) of two specific languages but also with having two types of tools for self-realization, i.e., the pursuit of self-awareness (becoming oneself) and creating individual identities in two communities. These processes depend on the quality of possible transfers from communication to cultural competences.

The term culturally and linguistically diverse (CLD) appears in the literature to refer to children with cultural and linguistic diversity. They usually belong to ethnic minorities for which the language of the country of residence is not the first language acquired.

Without a thorough understanding of the cultural, sociolinguistic, and psychological contexts of a child's family, it is easy to overlook the real source of the educational problem. The awareness and knowledge of the extent to which each of the above-mentioned factors determine the development of a child's communication is extremely important here. In the case of communication disorders in bilingual children, it is also important to assess the development of languages spoken within and outside the family and to adapt appropriate speech therapy procedures and methods.

Finally, let us add that bilingualism clearly influences children's literacy development, but as mentioned earlier, assessing this impact is neither simple nor uniform.

3. The Warnke Method—Brief Description

In general, linguistic disorders in bilingual children can be talked about if deficits occur in both of the languages learned. Language difficulties in acquiring the second code result from problems with the acquisition of the first language [56,57]. A holistic approach is required in the treatment of a bilingual child with such disorders (e.g., difficulties with writing and reading). The main goal of therapy is to increase the skills and effectiveness of communication of the child with the environment. The therapist must determine the stages of development and the level of competence and skills of the child that will allow for the creation of an appropriate therapeutic program. Therefore, any method that allows simplifying this procedure is in great demand. One such method is the method developed by Fred Warnke, which is now called the Warnke method [24,25,58,59].

The Warnke method focuses on the coordination of the work of the cerebral hemispheres, the improvement of motor skills, and the automation of the processing (with sufficient speed) of auditory-visual perception. It is based on the assumption that the phonological skills necessary for efficient reading and writing are related to the development of temporal processing and motor functions.

The theory that temporal processing disorder may be the root cause of language disability affecting speech, reading, and writing has not been accepted by many in this field [26], but the results of experimental research at the Neuropsychological Laboratory of the Institute of Experimental Biology of the Polish Academy of Sciences confirms the opinion that the slowness of time perception and information processing may be responsible for speech disorders, such as aphasia and others, because it may cause poor motor functions and automation [6,60].

Moreover, taking into account many years of research in neurology, psychophysiology, and neuropsychology, it can now be concluded that the actions of the human mind are somewhat based on the perception of time and the correct processing of information over time [22,41,60–62] and that specific time dynamics occurs in the mechanisms of cognitive operations such as hand-eye coordination, speech, language, memory, gaining new information, concentration and decision making, etc.

Stimulation by therapists using the Warnke method is based on the mechanisms of brain neuroplasticity. Hence, the basic premise is achieving, thanks to this type of neurobiological therapy, the development of cognitive functions (including auditory and visual-motor functions). Therefore, the main goal of therapy is the implementation of tasks that improve the work of neurons and neural networks in the relevant brain centers [37]. Building the language system and reading and writing skills in the child's mind requires, inter alia, specific stimulation of the mechanisms of the left hemisphere. These include, for example, the skills of phonological analysis and synthesis, understanding relationships, and sequential action. Therefore, areas of the brain that are related to auditory, visual, motor, memory, and thought functions must be intensively stimulated. As the bilingual child's ability to do so increases, both language competences should improve.

Now, the three basic purposes of the Warnke method will be briefly described.

The first is the automation of perceptual processing in hearing, seeing, and motor skills. Therefore, the basic prerequisites for learning to process perceptions need to be well developed. Processing speed should also be improved and automated. A small electronic device called the Brain Boy Universal Professional (BUP) is helpful in the treatment of hearing, visual, and motor impairment. It includes seven game-like training programs that enhance the seven basic functions of perception and their processing. Only a few months of training is enough for a significant improvement.

The second is the automation of the coordination of the cerebral hemispheres. In the process of learning to read and write, the two "halves" (=hemispheres) of the human brain must work closely together. Coordination between the hemispheres is provided by the corpus callosum, the nerve cord that connects. In many cases of dyslexia, this nerve cord is suspected to be malfunctioning. In order to improve the function of the corpus callosum, Fred Warnke developed a special "lateral training".

For example, in one of the exercises in this training, an electronic device causes sound to travel between the two sides of the headphones, and the child always needs to know where the sound is coming from. In another exercise, the child listens to the reference voice (from the CD) traveling from one side of the headphones to the other and also hears his/her own voice reading the same text in sync with that reference voice. Regular lateral training results in better synchronization of both hemispheres by activating the existing but inactive nerve tracts in a relatively short time.

The third goal is the development and automation of a visual dictionary. In general, children who have reading and writing difficulties often have only a vague idea of the spelling of a word. This can be improved through a training called "visual spelling". This training helps the child find ways to remember all those words whose pronunciation is significantly different from the spelling. Orthofix computer software is a very effective help in this training [24].

One of the most important parts of the Warnke method is testing, and many qualified experts have validated it over several years to provide a basis for further training. The fun-designed test procedure consists of 14 steps (lasting about an hour), which are to find

skills and opportunities for further training. It is important that the procedure does not focus on things that the child is not capable of.

The 14 steps in the testing procedure are as follows: 1. visual order threshold; 2. auditory order threshold; 3. spatial hearing; 4. pitch discrimination; 5. auditory motor coordination (finger tapping); 6. choice reaction time; 7. frequency pattern test and duration pattern test; 8. coordinative skills; 9. reading meaningless texts; 10. short time memory; 11. perception discrimination; 12. dynamic vision; 13. angular ametropia; 14. visual spelling. For more information, please refer to the work of [27,28,30,55].

4. Methodology of the Study

The training was conducted with the support of a graduate student (as part of the research for the master's thesis on the case study method [63]). The main aim of the study was to evaluate the effectiveness of the first stage of the Warnke method in improving the reading and writing skills of a bilingual girl. The hypotheses were established on the basis of theoretical publications, scientific studies, and observation of the method's application in therapeutic practice. Namely, the following was assumed.

1. Training in eight basic (visual, auditory, and motor) central processing functions contributed to reducing their deficits and increasing phonological competences in the following areas:
   - Pitch discrimination (resulting in better articulation of vowels, consonants and whole words, and fewer substitutions and devocalizations);
   - Auditory motor coordination;
   - Speed of perception of phonemes (which consequently improved reading fluency and verbal expression);
   - Auditory differentiation of consonants and better perception speed (which improved speech understanding and reading speed);
   - Coding and decoding prosodic speech elements (intonation and rhythm);
   - Coding, understanding, and expressing words, sentences, questions, commands, and longer texts.
2. The extent of automation of each function, estimated on the basis of the values obtained in the tests, is correlated with the performed quality of reading and writing activities, which should be verified and confirmed by symptomatic tests. Central processing functions improve the following reading and writing skills: (a) knowledge of Polish letters; (b) associating phonemes with letters; (c) technique and speed of reading and writing; (d) quality of the graphic writing level.

The research subject was seven years old girl. Her parents spoke two different European languages; mother—Polish and father—Italian. The girl was bilingual and learned two languages (Polish and Italian) simultaneously in her familiar environment. She could automatically switch from one language to the other, but the consequence in her case was the mixing of codes, especially when reading and writing. Interview with the parents, observation of the girl, and assessment of her skills showed that the level of reading and writing in Polish was good, but with a few mistakes.

The case study method was used. The first step was an initial diagnosis. During the pretest, the authors focused first on excluding dyslexia and then on identifying literacy levels and the level of the eight basic functions of the central auditory, visual, and motor processes. The following tools (tests) were used: Dyslexia Risk Scale [64]; Questionnaire for Recognizing the Risks of Specific Difficulties in Reading and Writing of Students Starting Second Grade [65]; Materials for the Pedagogical Diagnosis of Writing and Reading Skills of Primary and Middle School Students [66]; and Warnke functional test with the Brain Boy Universal Professional (BUP) electronic device.

Based on the preliminary diagnosis, dyslexia was excluded. The authors also assessed the knowledge of Polish letters, the quality of associations of phonemes with letters, the quality of reading (technique, speed, and fluency), and the graphic level of writing.

We focused primarily on the qualitative analysis of the identification and interpretation of errors in verbal and graphic texts. The next step was to examine the value of eight basic visual, motor, and auditory functions. These values were compared with standardized data for a group of children aged seven.

The next stage of the study was a five-month training of central auditory, visual, and motor functions, consisting of twenty sessions, once a week for approximately 45 min.

The final diagnosis procedure was the same as for the pretest. The same communication skills and central functions were tested using the same tests and BUP device.

In this way, the authors compared the results regarding the level of automation of basic functions obtained in the initial and final diagnoses. The conclusion was that significant progress was observed in the areas studied (see next section). In addition, there was a noticeable improvement in reading and writing skills in a relatively short span of twenty weeks. This leads the authors to conclude that the first step of the Warnke method was effective in improving the literacy levels of this bilingual child, without any additional special training in reading and writing.

5. The Results of the Warnke Functional Test

Table 1 (below) shows the results of diagnostic tests (before and after the training) of eight basic central processing functions [58]. The second and third columns contain the normative values (reference and target) that have been established for the age of seven. Let us remind you that the reference values are those obtained by 50% of the surveyed children from each age group; target values are those that have been reached by 80% of the surveyed children. The fourth and fifth columns contain the pretest and posttest diagnosis values.

Table 1. Results for basic functions in initial and final diagnoses—reference and target values (ms stands for milliseconds and μs for microseconds).

Function Name	Reference Values for the Age of Seven	Target Values for the Age of Seven	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
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	-	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

Comparison of data in initial and final diagnosis provides sufficient grounds to conclude that significant progress has been made in all functions of visual, auditory, and motor processing.

In the first task (visual order threshold (the second line of Table 1)), a large difference can be observed between the values of the initial diagnosis (90 ms) and the final diagnosis (34 ms). The posttest value (34 ms) is close to the target value (29 ms), which means that there was progress in automating the perception of stimuli produced by the device in an unsynchronized manner.

In the second task (auditory order threshold (third line of Table 1)), the initial diagnosis value is 160 ms, but the final diagnosis value is 70 ms, which is much closer to the target value of 65 ms. These results show great progress in the automation of the perception and processing of auditory stimuli.

The advances in spatial hearing deserve special attention (fourth line of Table 1). During the initial diagnosis, the girl reached 180 μs. This result appears in the table of standardized data for children as young as five; it is too big. After the training, spatial

hearing improved to a very significant extent, as in the posttest, the girl obtained the value of 74 µs, which is between the reference value (95 µs) and the target value (53 µs).

In the fourth task (pitch discrimination (fifth line of Table 1)), the value of the initial diagnosis was 40% for all tasks in the game. During the training, the target value for all tasks was 12%. However, surprisingly, the girl's final posttest score was eight percent for all tasks, and this value corresponds to the average value for children over the age of 12. This is a huge advance that exceeded our expectations.

Another function stimulated was auditory motor coordination (sixth line in Table 1). The initial value was 409 ms, which is above the reference value (444 ms). Unfortunately, in this case, the target value (359 ms) was not reached. The final result was "only" 385 ms, but it is easy to see that this also indicates progress in the automation of the auditory motor coordination function.

The value of the choice reaction time function (seventh row of Table 1) was not specified due to technical problems. During the second training session, the girl reached 1472 ms, which is below the normal level for the group of seven-year-old children. The posttest value was 1092 ms, which indicates a great difficulty in quickly reacting and making decisions in the precise selection of a specific sound.

In the seventh task (frequency pattern test (distinguishing between low and high tones—eighth line of Table 1)), the initial diagnosis value was only 160 ms, while the final diagnosis was 118 ms. This result is better than the target for the group of children aged seven. These results again show a big advance in automating the distinction between low and high tones.

The value of the last function (duration pattern test (recognition of short and long tones—the ninth line of Table 1)) in the pretest was 160 ms, so it is actually better than the reference value. The final diagnosis value was 120 ms, which is better than the target for a group of seven-year-olds and shows that even in this case, there has been progress in the function automation.

6. Reading and Writing Skills Level

Below is an analysis and comparison of the initial and final diagnosis results obtained for literacy levels. The reading ability, before and after training with the Warnke method, was assessed using the following tools: Questionnaire for Recognizing the Risks of Specific Difficulties in Reading and Writing of Students Starting Second Grade [65]; Materials for the Pedagogical Diagnosis of Writing and Reading Skills of Primary and Middle School Students [66].

6.1. Initial Diagnosis Results

The knowledge of letters and numbers was at a high level. The girl made only one mistake, confusing the letter z with c.

The technique and speed of reading were also assessed, and the errors made were analyzed in terms of quantity and quality. Reading speed was measured in words per minute. The child read 19 words in 1 min and the entire text in 3 min and 42 s, which was above average. Reading style has been estimated as a mix of techniques based on words and syllables. Quantitative analysis showed that the girl made 11 mistakes when reading the full text, mostly by substituting and mixing up sounds with a similar place of articulation. She also made phonetic mistakes typical of mixing two codes, e.g., Polish letters articulated in Italian: z was pronounced as c, c was pronounced as cz or k, l was pronounced as ł, s was pronounced as z, g was pronounced as dż, sto was pronounced as zo (simplification of the consonant group).

For the diagnosis of writing skills (dictation), three texts were selected and adapted to the girl's abilities. She was right-handed, and the graphic level of the handwriting was acceptable. The child correctly drew the shape of the letters, combined them, and applied them in the right proportions. The letters had the correct slope and were legible. Typing speed was average. In the first text, the girl made three mistakes; in the second,

three mistakes; in the third, four mistakes. The errors were mainly caused by impaired perceptual motor skills and took the following forms:

- Confusing letters that are sonically or graphically similar (ę replaced by e, ł replaced by l, s replaced by z, cz replaced by dż, i replaced by j);
- Forgetting of some letters (letter z in cz);
- Adding unnecessary letters (letter k).

6.2. Final Diagnosis Results

In the final diagnosis, the analysis of the reading samples led to the conclusion that the knowledge of letters and digits was high. Only once the girl replaced ę by e.

The technique and speed of reading were also assessed in the second part of the diagnosis. The child read 40 words in 1 min and the entire text in 2 min and 15 s. This is a high-level result. Reading style was again assessed as a mix of techniques based on words and syllables. The quantitative analysis showed that the girl made only three mistakes: she mistook the letters twice (ł was pronounced as l, c was pronounced as k) and once cut the end of the word by reading the word *rowerek* (little bicycle) as *rower* (bicycle).

We can therefore conclude that after the Warnke training, the reading speed improved: it increased from "above average" to "high". The style remained the same.

In the final diagnosis of writing skills (using dictation with three texts), the graphic level of the writing was assessed as acceptable, similar to the initial diagnosis. The girl remained right-handed. The typing speed was fast (40 words per minute). In the second text, she made only one common spelling mistake. There were no errors due to sound or graphic similarity.

Tables 2 and 3 (below) compare the results of the initial and final diagnoses of the writing and reading skills before and after the training by the Warnke method.

Table 2. The results of the initial and final diagnoses of the writing skill.

	Initial Diagnosis Results	**Final Diagnosis Results**
Graphical handwriting level	acceptable, legible, the shapes of the letters are correct, the letters are combined, maintaining the appropriate proportions and slopes	acceptable, legible, the shapes of the letters are correct, the letters are combined, maintaining the appropriate proportions and slopes
Handwriting speed	average	fast
Number of mistakes	10	1
Qualitative analysis of mistakes	mixing letters that are similar in sound or graphics, omitting letters, adding unnecessary letters	typical spelling mistakes, no errors resulting from sound or graphic similarity, no omissions, and unnecessary letters

Table 3. The results of the initial and final diagnoses of the reading skill.

	Initial Diagnosis Results	**Final Diagnosis Results**
Knowledge of letters and digits	high level	high level
Reading speed	average result: 19 words in one minute and the entire text in three minutes and 42 s	high result: 40 words in one minute and the entire text in two minutes and 15 s
Reading technique	mixed: word-based and syllable-based	mixed: word-based and syllable-based
Number of mistakes	11	3
Qualitative analysis of mistakes	replacing and mixing sounds with a similar place of articulation, phonetic errors typical of mixing two codes	letters similar in sound or graphics mistaken twice, and the end of the word cut off once

Based on the analysis and interpretation of the test results, it can be unequivocally stated that after training from the first stage of the Warnke method, the writing and reading skills of this bilingual child have improved noticeably.

7. Conclusions and Discussion

In the early stages of development, acquiring literacy skills requires a deliberate analysis of the relationship between the phoneme (a sound model of a phone, which is an individual sound unit of speech) and the grapheme (a graphic equivalent of a phone). Moreover, mental operations must reach the level of conceptual thinking. Sufficient progress in acquiring these abilities activates an automation mechanism in the central nervous system that allows for fluent reading, correct writing, and understanding of the meaning of the text. Such automation means involuntary and fast registration, analysis, and synthesis of visual, auditory, and motor stimuli occurring in specific brain areas [27,30].

According to the functional integration theory [8], some learning disabilities may be caused by poor cooperation between the auditory, visual, tactile-kinesthetic, and sense of balance functions. In short, the diagnosis of phonemic hearing disorders is carried out at the levels of: syllables, syllable elements (rhyme, alliteration), and phons. Assessment of the effectiveness of the analysis and synthesis of syllables and word fragments is usually determined by tests that contain sets of specific words and pseudo-words (i.e., meaningless words) [30].

When assessing phonological skills, one should also check phonological memory and automation mechanisms, which process phonological information over time. Verbal fluency tests (quick rhyming), as well as rapid naming tests, can be used for this purpose [21].

The Warnke method provides tools that complement and extend those classical methods of assessing phonological competence (phonological analysis and synthesis). These are tests focusing on: causes of disorders of complex functions in the areas of central visual, auditory, and motor processing.

During the diagnosis using the Warnke method, the focus was on the causes of disturbances at the level of the central nervous system, which is associated with deficits in the central processing of vision, hearing, and motor skills. Such deficits may be caused by disturbances in the functions of: locating the sound source, differentiation of sounds, recognizing sound patterns, analyzing the temporal aspects of the sound signal, processing very short sound signals, temporal organization and temporal integration of sounds, understanding distorted speech, understanding speech in the presence of a jamming signal, coping with sound masking, auditory lateralization, and the ability to receive signals simultaneously and non-simultaneously.

The obtained results are consistent with the earlier results obtained for children with dyslexia and some other disorders (see the work of [23–25,40] for more details) and indicate that the diagnosis of the causes of disorders by means of the Warnke method may complement and extend the possibilities of the classic symptomatic diagnosis of phonological competence in bilingual children. Therefore we can formulate the following conclusions:

(a) 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;
(b) The diagnosis may help trainers to better determine the problems in all central functions (in the post-tests, we noted progress in each of them).

Moreover, the study showed that the reading and writing skills of the bilingual girl improved after training with the first part of the Warnke method, which also is consistent with the earlier results obtained for children with dyslexia and some other difficulties (see the work of [23–25,40] for more details). The main hypotheses have been verified by the data analysis presented above, and the following conclusions can be drawn from them.

1. Much progress has been made in performing the eight basic functions (visual, motor and auditory): visual order threshold, auditory order threshold, spatial hearing, pitch

discrimination, auditory motor coordination (finger tapping), choice reaction time, frequency pattern test, and duration pattern test. Improvement was observed during and after training of these functions and was assessed in the final diagnosis using the functional activity test with the BUP device. Namely, there was improvement in the following areas of phonological competence:

- Pitch discrimination (resulting in better articulation of vowels, consonants and whole words, and fewer substitutions and devocalizations);
- Auditory motor coordination;
- Speed of perception of phonemes (which consequently improved reading fluency and verbal expression);
- Auditory differentiation of consonants and better perception speed (which improved speech understanding and reading speed);
- Coding and decoding prosodic speech elements (intonation and rhythm);
- Coding, understanding, and expressing words, sentences, questions, commands, and longer texts.

2. Posttest values for basic central processing functions were better than in the pretest. This means that training has resulted in advances in the automation of every function, which was correlated with the quality of reading and writing activities. The improvement in these results was verified and confirmed by symptomatic tests.
3. Symptomatic tests showed noticeable improvement in reading and writing skills in the following areas: knowledge of Polish letters; associating phonemes with letters; technique, speed, and fluency of reading and writing.

Of course, issues such as regression to the mean, measurement error, and the absence of a control group cannot be overlooked. However, it has to be reiterated here (see the previous section) that the assessments of the eight central functions were performed separately for each function at the end of each meeting, with results that showed steady progress (consistent with the final diagnosis) with little fluctuations (which might just be caused by regression to mean and measurement error). Additionally, both the initial and final assessments of reading and writing ability covered many aspects (including qualitative ones), and we saw progress in almost all of them. Moreover, the differences between the initial and final assessments seem significant. This means that the claims can be sustained without further detailed consideration of such issues.

Summing up, it can be concluded that the obtained results suggest that the observed learning difficulties were not directly caused by bilingualism but by deficits in the functions of central processing, which resulted in a lower level of phonological awareness (see the discussion below).

4. Based on the above statements, the authors proposed to continue training with the Warnke method to maintain the effects and prevent possible difficulties.

Moreover, the observations made in the course of the research lead to the following additional general suggestions:

5. It is recommended, as far as possible, to teach reading and writing separately in different languages and to clearly separate the different grammatical systems. This will enable the bilingual child to fully internalize the codes, thus reducing the risk of learning difficulties. It will also allow for a more precise definition of the child's own identity;
6. The following conditions seem to be helpful for the proper development of the systems of both languages: active contact with languages in everyday life situations; correct use of their languages by parents; consistent use of both languages (without mixing them); increasing communicative awareness (which language should be used to achieve the goal); awareness of own bilingualism (only a child fully aware of the fact that he or she uses two different language codes can speak, read and write correctly and without errors).

As it was written in the introduction, using more than one language has many advantages, but in certain specific circumstances, it can cause various specific learning problems [17,18]. Studies in the work of [26–29,42,50] suggest that reading and writing difficulties may be mainly due to lower phonological awareness, which may be related to deficits in central processing functions.

The Warnke method seems to be a promising tool in such situations, helping to reduce deficits of central functions and thus increase phonological awareness, which should result in improved literacy [25]. In fact, our observations show that even the first stage of the method appears to be effective in the treatment of reading and writing in bilingual children, and the main advantage, in this case, can be the speed with which results can be achieved.

However, due to the obvious limitations of the investigation presented in this paper, such as only one child, no control group, short study duration (suggesting the effects will not be long-term), and using only the first part of the Warnke method, more study is needed in this area. In addition, the research on checking the effectiveness of interhemispheric coordination training (from the second part of this method) in bilingual children with reading and writing difficulties seems to be promising.

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