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Artificial intelligence in the diagnosis of speech disorders in preschool and primary school children

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Abstract

The research aims to analyze the effectiveness of diagnosing speech disorders in preschool children using computer methods. At the first stage, the sample consisted of 395 children without speech impairments and 120 children with speech impairments. They were tested for understanding complex logical and grammatical structures. For 44 children with phonetic and speech disorders, an innovative method of computer animation was used to correct speech disorders. The results of an analysis using a computer program shoved a positive impact on the development of children. It was found that there were significant changes in three parameters. Firstly, the children showed an improvement in phonemic hearing, significant changes were identified in the sound analysis parameter. Finally, significant changes occurred in pronunciation: children began to cope better with the pronunciation of words with a complex syllable structure. The development of such programs can facilitate the process of teaching children with speech impairments.

Keywords: children, cognitive functions, pronunciation computer animation, speech impairments.

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1. Introduction

Global deterioration of the ecological and social situation in many developing countries has negative consequences. One of the most important is an increase in the number of children diagnosed with maladjustment (Kharbat et al., 2020). The consequence of maladaptive behavior is the educational problems in knowledge acquisition. The challenges cannot be compensated by standard teaching and corrections. According to different sources, the number of children with maladaptive behaviors is large. It ranges from 15 to 40% of the total population (Tang & Chu, 2021). Most children with maladaptive behaviors are children diagnosed with mental retardation. This diagnosis has the following manifestations: a slower rate of the main mental functions compared to the normal psychological development or weak development of certain functions of the cognitive sphere (Bernthal et al., 2017). In many developing and developed countries in Europe and Asia (Kazakhstan, Russia, Ukraine, China), after special psychological examination, the child was referred to a special class for correction and development of children with disabilities. In such classes, special education teachers, defectologists, psychologists, speech therapists work with children (Drigas & Ioannidou, 2012). In the developed Western countries (European Union, USA), children with mental retardation study in inclusive classrooms, if they do not have severe physical or mental disabilities (Grigorova & Ristovska, 2021).

Nevertheless, some children with mental disorders attend the traditional classrooms in secondary schools. The scholars admit that speech impairments do not influence the quality of learning, but such children learn successfully for a long period (Pratt et al., 2015). Thus, for some children with minor speech impairments, it is difficult to learn and acquire new knowledge because of cognitive and physical and mental dysfunctions (Bernthal et al., 2017). Therefore, during the first years at school, such children may not attract the attention of teachers and parents. In the future, the lack of learning progress will become more apparent. The main manifestation of mental disorders will include the low average score and the low level of mental development in comparison with their peers (Spencer & Petersen, 2020). Without assistance and prior diagnosis, such disorders can lead to serious developmental disorders. The result will be a low quality of life in adulthood.

The specialists may record speech disorders and mental retardation. They will introduce the psychologist and correctional activities (Grigorova & Ristovska, 2021). The relevance of the diagnostic methods is the priority in special needs education, defectology and pedagogy. It is necessary to introduce methods that help to diagnose mental disorders in children from risk groups, who may develop learning difficulties due to speech disorders or mental retardation. The development of such methods poses difficulties since the causes and manifestations of developmental disorders of mental and speech disorders are variable and heterogeneous (Bellon-Harn et al., 2020).

1.1. Literature review

Speech disorders and mental retardation in children may lead to the development of higher mental dysfunctions and adverse social conditions (Bellon-Harn et al., 2020; Sugden et al., 2016). There are no standardized tests to identify the development of higher mental functions in children in the elementary grades (6-8 years) (Snodgrass et al., 2017). The neuropsychologists believe that the following factors may pose difficulties for teaching children with developmental disorders and speech disorders: a) the impossibility to develop cognitive activity for normal learning; b) poor psychological functions responsible for programming or control of actions; c) unclear visual and spatial representations, leading to a narrow linguistic space and difficulties in speech function (Morris & Bellon-Harn, 2021; Sugden et al., 2016). Spatial representations are responsible for the formation of

higher mental functions in a child. They are the basic components of these functions. Speech and writing skills are formed based on spatial representations (Andersson, 2018). Maladaptive development led to psychological disorders.

The current approach of neuropsychologists to disorders in children involves two main hypotheses. Both hypotheses include the hierarchy of the child's system of ideas about the world. Initially, multilevel visual and spatial functions are formed in children. Further, more complex constructions are developed associated with the child's understanding of logical and grammatical constructions using the language (Roberts et al., 2019). Local damage of the temporal, parietal, and occipital brain areas result in violation of spatial and speech functions (Wren et al., 2016).

Correctional methods for children with phonetics underdevelopment and phonemics problems include methods such as work with speech defects and literacy improvements in secondary schools (Pratt et al., 2015). Educators often use artificial intelligence and computer programs to meet the challenges of the educational system. In particular, game learning is used in the form of computer games (Owens, 2014). Some of the articles prove the effectiveness of the technique described above in children with severe speech and spatial impairments (O'Toole et al., 2018).

The literature review suggests that educators require new innovative methods to diagnose speech disorders in children. This issue is well developed and analyzed by scholars (Bellon-Harn et al., 2020; Snodgrass et al., 2017). Nevertheless, most articles describe one aspect of child development only such as logopedic, correctional, or investigate from the point of view of defectology or special education pedagogy (McGoron et al., 2019; Tang & Chu, 2021). Moreover, there is a lack of research with concrete experimental results based on the application of computer programs in the education of children with speech disorders, which determined the relevance of this study. The current research represents an integrated approach based on the standard methods of psychology and innovative methods of computerization.

The aim of the study is a comparative analysis on the effectiveness of speech disorders diagnosis in children (5-8 years old) using standard psychological and innovative computer methods. The research question was: Can the computer-assisted instruction method improve phonemic hearing, sound analysis, and pronunciation? Such research can contribute to the practice of teaching children with speech disorders (taking into account their cognitive features), as well as to psychology, as it becomes possible to study the cognitive process in such children and ways to improve it. The objectives included: a) the research on the effectiveness of screening of logical-grammatical constructions in 5-8 years children according to standard psychological methods (the Rey-Osterrieth complex Figure test); b) identification of the computer games opportunities to master the basics of literacy by children with phonetic and speech disorders. The second task is to design and identify the effectiveness of correction methods, speech therapy and computer games. The scholars expect that the post-test results will differ significantly from the pre-test results. At the end of the experiment, children in the control group will have more developed speech skills than in the control group.

2. Method

2.1. Sample

The research was carried out in the cities of Almaty, Semey, and Nur-Sultan (Kazakhstan). The results were analyzed by by Abai Kazakh National Pedagogical University. At different research stages, a different number of participants were involved. The total number of participants was 395 children

between 7-8 years from the first grades of public schools (average age 7.3 ± 0.3 years), and 120 children with speech impairments and mental retardation (average age 7.2 ± 0.2 years).

2.2. Research design and methods

Parents of all children signed written consent to participate in the research. The document contained information about the experiment, the methods used, and the expected results. All participants were guaranteed anonymity and confidentiality of information. The experiment aligned with the standard ethical norms and was approved at a meeting of the Ethics Committee of the Abai Kazakh National Pedagogical University (Protocol No. 227).

The research consists of two parts. First, the scholars introduced techniques to test the understanding of logical and grammatical constructions by children. Secondly, the Rey-Osterrieth complex Figure test was formed (ROCF) (Rey, 1941). The scholars have chosen these methods to establish the level of the child's spatial representations with high reliability. The method used to identify the understanding of logical and grammatical structures helps scholars to determine the level of quasi-spatial representations of children with speech disorders. The Rey-Osterrieth complex Figure test is used to detect dysfunctions in visual and spatial orientation, as well as to identify parameters that other tests cannot detect. Moreover, both methods make it possible to identify the child's cognitive development.

The visual and spatial representations with the logical-grammatical structures relate to the perceptions and impressive speech. In case of difficulties performing these tests, the results can collect data on the intellectual abilities of 7-8 years children. The technique is used by pediatric neuropsychologists for about 20 years. To test children with speech impairments, it becomes possible to identify the weak cognitive abilities causing difficulties in speech and general development. As soon as the problem was identified, the scholars conducted more effective psychological interventions in children with speech disorders.

The research consisted of three stages. In the first stage, the understanding of the logical and grammatical structures was assessed by children with and without speech impairments. The first stage assessed the abilities of all children from the sample. The tests were performed to research children's understanding of passive reversible constructions with 6 sentences and prepositional constructions with 4 sentences. The positive answer was accepted when the child unambiguously pointed to the card corresponding to the question. One point out of ten points was assigned one point. If the child had less than 5 points, it is considered as the difficulties in understanding the logical and grammatical constructions.

Using the results of the first stage, the scholars divided children into three groups for further research related to testing the effectiveness of correctional techniques. The first group consisted of children with a high understanding of logical and grammatical constructions. Children scored from 9 to 10 points. They answered correctly almost all of the questions. The second group consisted of children who had an average level of understanding of logical and grammatical constructions. The group consisted of 187 children. These children scored from 6 to 8 points. They answered most questions correctly. Finally, the third group consisted of children who had a low level of understanding of logical and grammatical constructions. The group included 121 children. These children had learning problems caused by speech impairments and mental retardation. The research suggests that children in Group 3 had more learning difficulties than children in Group 1. The results were confirmed by the school teachers who worked with these children.

The second stage included an assessment of the visual and spatial functions of children based on the Ray-Osterlitz method. According to the results of stage one, the sample of this stage included 20 children who had speech disorders and mental retardation (control group-1). The experimental group included 44 children with learning difficulties (Group 3 identified on the first stage). The participants were selected according to the following criteria: a) parental consent; b) the absence of general developmental disorders, c) all children are right-handed; d) all children from families that speak the same language (Kazakh). The second control group included 41 children with a high level of understanding of logical and grammatical constructions. The children were asked to copy the drawing onto another sheet of paper (A4) given to them. The results were evaluated using the following characteristics: a) the precision of the line. This indicator includes a scale from 1 to 13 points formed based on 24 criteria that evaluate how neatly the lines are connected or how much they intersect with each other. b) accuracy. The number of lines in the initial drawing and copy. c) the number of four types of errors made when copying an image. These errors included: the accuracy of rotation or the degree of rotation of the copied image (45 degrees or more); unnecessary elements of an image or a separate line in it; the wrong place of some parts in the copy. It is reflected in individual elements of the drawing; repeated parts using a single line to copy one or more elements from the drawing. d) The use of copying strategies, which included continuous repetition of lines of eighteen components.

The copying strategies included the following: 1) a whole image should be drawn, then a child should add individual elements (holistic strategy); 2) an analytical approach, when an image is drawn, step by step, with a transition from one component to another; 3) the lack of any consistency, a chaotic drawing.

Cognitive functions and their level were assessed using 18 different trials and tests. The methods include the speech test developed by Head (Russian adaptation) (Khomakaya, 1987), a graphic test, a test to determine a constructive praxis, the analysis of the fingers while drawing, the perception of information through the visual analyzer, the visual memory when non-verbal and verbal symbols are presented, reproduction of different vocal rhythms, memory associated with auditory and speech abilities and perception. Moreover, the analysis includes phonemic hearing, associative thinking, understanding of verbs meaning, coordination of the reciprocal type, dynamic indicators of praxis, analysis of the table image, analysis of the choice, understanding of different types of events on the drawings.

The sample was assessed using one or several parameters at once, according to a system that provides a scoring. The total number of parameters was about forty. Due to the fact that each of the analyzed parameters used different scales, the scholars introduced a general assessment scale for a particular test. The received score was divided by the highest possible score. The coefficient varied from zero to one. One point means the highest results contained by the test. In addition, neuropsychological coefficients were calculated for children, which displayed the total sum of all coefficients of the tests for all forty tests. This neuropsychological coefficient reflected the total level of the child's cognitive abilities. The results obtained were analyzed using the control group 2 and the experimental group.

In the second part of the research, the scholars identified the dynamics of phonetic and speech disorders. It was important to identify children able to learn within the traditional classrooms and use computer animation. The research selected 24 children, between 7-8 years diagnosed with speech and phonetic disorders. Initially, innovative computer technology was used to display flash animation. Further programming and graphic processing of the elements of the future program were carried out. Animated characters in 2D were created to support the interactive material presented to children. The

interactive character (Bear) is voiced, and the main purpose of the character is to communicate with children. The final version of the program had 5 different menus. The selection of the menu provides tools for selecting and controlling other options (Figures 1 and 2).

Figure 1. The main menu of the proposed program.

*Note: The head of the menu written in uppercase is the name of the program —***BUKVACHUTAIKA (THE LITTLE BOOK OF LETTERS).** *The following list contains training steps with active links. The list reads from top to down as follows: Letters and Sounds; Development of Letters Knowledge (Gnosis); Analysis of Words and Sentences; Reading; Sound Analysis; Project.*

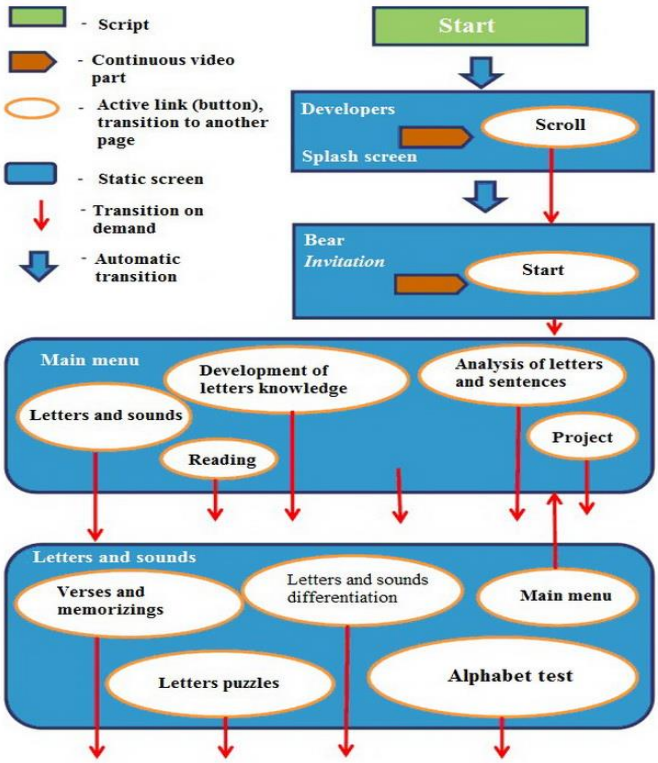

Figure 2. The detailed menu of the proposed program.

The classrooms lasted 1 hour and were held twice a week at the same time. The training section lasted for 6 months in the first half of 2021. After the end of the lessons, tests were carried out to compare their speech abilities before and after the experiment.

2.3. Statistical analysis

For each analytical test, the selected elements were tested for normality. Due to the fact that in all cases the distribution of features differed from normal, nonparametric statistical methods were used in statistical analysis. The research used a univariate analysis of variance. The difficulties in mastering and understanding logical and grammatical constructions were experienced by children. It is considered that differences are significant at $p \leq 0.05$. To check the differences, the Wilcoxon T-test was used. It helped to examine the change in cognitive activities. In this case, the shifts were calculated for each children group separately.

3. Results

The research found that the understanding of logical and grammatical constructions in children with speech disorders and mental retardation was associated with great difficulties. Half of the children showed poor test results. They made mistakes that could be interpreted as a random choice of answers. Among 20 children who participated, 18 children received less than 5 points, and only two children received 6 points. Children who did not have speech disorders (308 children out of 395) made mistakes in logical and grammatical constructions. For many children with good academic performance, cognitive processes have not yet been developed (Figure 3). Among children with a high level of understanding of logical and grammatical constructions, one third had high rates of development, more than half of children had an average rate of development, and few children had a low level of development. In the group where children were at risk of mental disorders, the majority had a low success rate, the remaining third had an average one (Figure 3). There were no children with a high level of cognitive development. The results differ from the first group ($p \leq 0.05$-0.01 for each of the levels of academic success between groups).

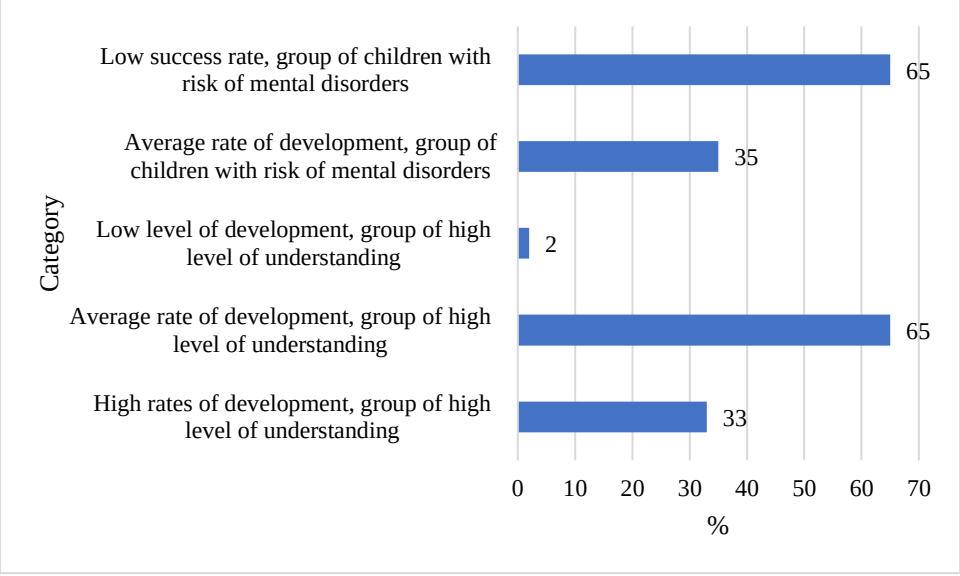

Figure 3. Development levels in groups of children with mental disorders and children with high level of understanding.

The analysis of the drawings copied by children revealed no significant differences between children in the experimental and control group 1 in any of the parameters. At the same time, significant differences were identified in other parameters in children development from these two groups, and children from control group 2. These parameters are as follows: a) structure ($F = 9.09$; $p \leq 0.05$); b) the number of bias errors ($F = 6.09$; $p \leq 0.05$); c) accuracy of the drawings ($F = 5.15$; $p \leq 0.05$). These indicators are structural and topological. The child can perceive and reproduce an image. In 6-7 years of children, such abilities have already been formed. For children from the experimental group and control group 1, the average score for the structure was less than 6 points (out of a maximum number of 13 points), the drawings of the majority of children (68%) lacked integrity and had topological errors. For children over 5 years, a combination of holistic and analytical strategies in the drawing is the norm. Moreover, the first strategy prevails over the second one. Almost half of the children from control group 2 used the first type of strategy, and less than half used the second type of strategy (Figure 4). At the same time, children from the control group 1 and the experimental group followed a chaotic strategy, and a small percentage of children followed analytical strategies (Figure 4).

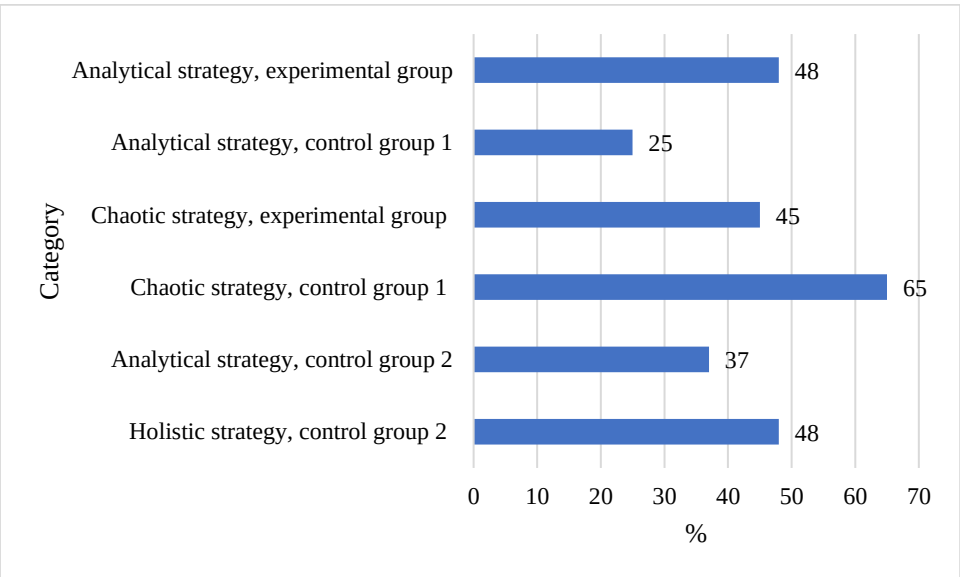

Figure 4. Copying strategies, used by children from the control and experimental groups

The research underlines that if the analytical or chaotic strategy prevails, then the development of the holistic strategy in such children is lower. The children included in control group 1 and in the experimental group processed visual and spatial information poorly. It was associated with a weak holistic strategy. In addition, it becomes obvious that a weak holistic strategy is the main feature for children with visual and spatial difficulties in perceiving information and speech difficulties. Children in the experimental group were similar in diagnostic parameters to children from control group 1 with speech impairments and speech retardation. It was considered that they might have difficulties since the early stages of learning. Such children could be classified as children from control group 1.

At the third stage of the first part of the research, the scholars examined the neuropsychological characteristics of children from experimental group 1 and the control group 2. This was necessary to compare the weak components of the higher mental activity of children and identify factors that can

cause learning difficulties. It was found that children from the experimental group showed low results on 11 out of the 18 tests. The tests included: a) the response associated with the choice ($F = 8.89$; $p \leq 0.0029$); b) drawing of a table ($F = 26.84$; $p \leq 0.0001$); c) praxis of a constructive type ($F = 24.89$; $p \leq 0.0001$); d) the results of the speech test developed by Head ($F = 52.57$; $p \leq 0.0001$); e) the analysis of the fingers while drawing ($F = 9.94$; $p \leq 0.0031$); f) the perception of information through the visual analyzer ($F = 12.81$; $p \leq 0.0009$); g) reproduction of different vocal rhythms ($F = 16.93$; $p \leq 0.0002$); h) memory associated with auditory and speech abilities and perception ($F = 8.71$; $p \leq 0.0041$); i) phonemic hearing ($F = 6.82$; $p \leq 0.001$); j) thinking related to action ($F = 9.44$; $p \leq 0.003$); k) the reciprocal type ($F = 9.41$; $p \leq 0.004$).

The average neuropsychological scores by both groups were compared. They turned out to be higher in children from the control group 2 than in children from the experimental group (26.78 ± 0.71 and 23.69 ± 0.57, $p \leq 0.05$). The results showed that the level of cognitive development in children from the experimental group is low. In the experimental group, the neuropsychological indicator was high. Children belonged to the group with learning difficulties because their spatial representations have not yet been fully developed. Thus, the scholars admitted that they did not have cognitive development problems. The research highlighted that cognitive weakness in children were connected with the use of holistic strategies. To test this hypothesis, the research introduced the following steps: a) children from the second control group and children from the experimental group were joined into one group and had the same neuropsychological coefficient. Therefore, children with low indicators were removed from the experimental group. Children with high indicators were removed from the second control group. The same number of children was enrolled in each of the two groups (experiment - 1, control - 3) (25 children). The selection showed that there were no significant differences in the average value of the neuropsychological coefficient (25.24 ± 0.37 and 25.78 ± 0.51, $p \geq 0.05$). After that, the scholars conducted a comparative analysis on how successfully children from the two groups passed neuropsychological tests. Significant differences were identified according to the results of two tests the speech test developed by Head ($F = 18.72$; $p \leq 0.001$), the results of constructive praxis ($F = 8.84$; $p \leq 0.006$). These tests are used to analyze the unsatisfactory development of visual and spatial functions. Therefore, in children from the experimental group, the weakness of the chosen holistic strategy shows the weakness of spatial perception.

The computer program had a positive impact on the development of children. It was found that there were significant changes in three parameters. Firstly, the children showed an improvement in phonemic hearing ($T = 17.019.987$; $p \leq 0.002$), and secondly, significant changes were identified in the sound analysis parameter ($T = 10.834$; $p \leq 0.004$). Finally, significant changes occurred in pronunciation: children began to cope better with the pronunciation of words with a complex syllable structure ($T = 9.044$; $p \leq 0.003$). For the rest of the group, the use of standard speech therapy and special education techniques led to significant changes in phonemic hearing ($T = 15.557$; $p \leq 0.006$). The use of a computer program as an element of teaching helps to significantly improve pronunciation and auditory perception in children and can be used in speech therapy and special education practice.

4. Discussion

The results show that children with phonetic underdevelopment had significant changes in speech development and literacy. The teachers used standard correctional and speech therapy lessons to work with such children. The use of an innovative methodology of computer games as an element of speech therapy and correctional activities in children with speech impairments helped to distinguish individual sounds from a group of sounds. Children were able to analyze syllables, whole words, and sounds in words consisting of a large number of syllables 3-6. Children can tell the structure of words

and pronounced words that had a complex structure. While using computer technology, only one parameter did not change. Children did not improve the pronunciation of sounds. Similar problems were identified by other scholars on the use of speech therapy methods (Beukes et al., 2016; Rodgers et al., 2022; Vismara et al., 2018). The research found that to correct the pronunciation of sounds, it was important to introduce other techniques in computer programs and make use of standard speech therapy methods (Brown & Woods, 2015). The scholars have identified a positive impact of computer games on children literacy. The research found that the use of innovative computer technology in combination with standard teaching methods was effective.

The research has shown that visual difficulties, as well as difficulties in the perception of space, are associated with the inadequate implementation of the holistic strategy (Orlikoff et al., 2015; Thornton et al., 2016). It was one of the causes of a child's failure and speech disorders (Roberts & Kaiser, 2012). For 7-8 years children, the image of space and environment have already been developed included structural ideas, concepts about coordinates, topology, sizes and proportionality (Orlikoff et al., 2015). At the age of 8-9 years, children develop a visual and spatial understanding of the activity. At the age of 10-12 years, children use projection systems as the main domain of cognition (Richmond et al., 2017). Unfortunately, quasi-spatial representations for children aged 7-8 years are not researched. The available sources have not examined the age of children and their physiological peculiarities when they developed complex logical and grammatical constructions. Although some scholars indicated the age of 7-8 years as such (Olson et al., 2016). Logical and grammatical constructions are found in textbooks written for first-grade children. In particular, the research revealed that such constructions are typical for mathematics.

Most scholars underline that children with poor visual-spatial skills and understanding of space designations have some specific factors: a low level of understanding and wrong ideas about space (Rodgers et al., 2022). This leads to delays in speech development and affects the quality of learning (Law et al., 2019). The findings prove that there is a direct connection between the level of spatial representations in children of 7-8 years and the level of speech development. A low level of spatial representations is typical for children who may developmental retardation.

In education, speech defect correction practices help special education professionals to teach children with a low level of phonetic development. Literacy is also an important element of special education. Educators include computer games in the correction practices to tackle such problems (Kirby, 2022). The research proves the effectiveness of computer games for children with disabilities (Roberts & Kaiser, 2012). However, in speech therapy practice, the use of computer games has been poorly researched, especially in children with speech disorders. The majority of the articles examine the need to introduce computer programs in the education of preschool children paying no attention to other age groups (Orlikoff et al., 2015).

The data on neuropsychology indicate an earlier development of ontogenesis in children of mental functions such as praxis (kinesthetic type), understanding of the surrounding space, cognition of an auditory analyzer, memory associated with the use of speech abilities and hearing (Rinaldi et al., 2021). Therefore, the use of trials and tests intended to identify the functions of the psyche is possible by the age of 5. The spatial and visual functions are tested in later years, at about 6-7 years. The reciprocal coordination can be tested by 8 years. The last of the functions are programming, regulatory and control functions tested at 9 years. The current research proves that children from the experimental group experienced functional disorders related to cognition.

4.1. Limitations and future research

The research limitations include the age of children. The literature review reveals that at different age groups it is desirable to assess different mental functions in children. In addition, the results of using the computer program were tested on children with speech impairments and may not be appropriate for teaching children with other developmental disorders such as visual and coordination.

Future research is needed to identify to main functions of the computer programs that are used for children with speech impairments over a longer period, for example, for the school years. Age characteristics of children should be taken into account. Future research should compare the data collected for 7-8 years children with data on other ages, up to 7 years and older. The research provides recommendations on the positive experience of using a computer program as an innovative pedagogical method that can be included in complex speech therapy and special education methods when teaching children with speech impairments. The development of such programs, adapted for native speakers of a particular language and culture, can facilitate the process of teaching children with speech impairments.

5. Conclusions

The cognitive learning of children between 5-8 years suggests that there are differences at the individual level in understanding complex logical and grammatical constructions. Children with speech disorders and mental retardation make mistakes when copying the Figure of the complex images assessed using the Ray-Osterlitz test. Such children also experience problems with understanding complex logical and grammatical structures. The diagnostic method of screening among the group of 5-8 years children made it possible to define the main characteristics that place children at the risk group in academic performance since the early years of study. These characteristics include half of the mistakes made by the child in tests on the semantic load of complex logical and grammatical structures. The prevalence of the chaotic and analytical type of strategy while copying images can also be an indicator of certain disorders. The number of points up to 6 is also important for educators to determine the complexity of the copied drawing. It is associated with violations of the structure and topology of the drawing. The Rey-Osterrieth test is used to determine cognitive functions. The neuropsychological diagnostics of children in the risk group (children with speech impairments) identified the difficulties associated with two main factors. The first is the low level of cognitive functions. The second factor is the slow development of spatial representations associated with a seldom use of a holistic strategy when copying an image. The screening techniques used for the spatial representations in children with speech impairments help the scholars to collect practical results for special teachers, speech therapists, and school psychologists after two to three weeks of the learning process. The research examined the high mental functions in children. The results showed that these functions were insufficient or fragmented. Difficulties with understanding the logical and grammatical constructions were evident in the majority of children (78%).

6. Recommendations

The research recommends that the textbook authors should take into account the complexity of language. The innovative method based on the computer program and composition of speech therapists and special education made it possible to obtain better results in three areas under investigation (phonemic hearing, sound analysis, pronunciation) compared to the control group. In this group, the results improved in one parameter only (phonemic hearing). The research recommends developing similar computer programs for children with mental dysfunctions aimed at improving the speech abilities of children with language impairments.

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