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DEVELOPMENT OF ANALYTICAL AND SYNTHETIC ACTIVITIES IN CHILDREN WITH MENTAL RETARDATION USING MENTAL ARITHMETIC

Summary. *The article is devoted to the identification and analysis of the features of the development of analytical and synthetic activity in children with mental retardation (MR) in the course of systematic practice of mental arithmetic. The relevance of the work is due to the need to support the cognitive development of children with MR who have difficulties in flexible and conscious manipulation of numbers. The novelty of the study lies in the fact that various strategies of oral calculations and their relationship with the basic mental operations of analysis and synthesis are considered. The work describes the characteristic manifestations of children with MR when performing arithmetic problems: differences in tempo and accuracy, as well as the influence of exercises with elements of mental arithmetic on the solution process are revealed. Attention is paid to the analysis of practical experiments using virtual and physical means for training counting skills. The work aims to expand the understanding of the mechanisms of formation of analytical and synthetic operations in this category of children. The findings can be useful for teachers, defectologists and psychologists in developing correctional programs.*

Key words: *analytical and synthetic activity, children with developmental delay, mental arithmetic, oral arithmetic, didactic games, flexibility of strategies,*

short-term memory, estimation of magnitude, neurocognitive model, correctional programs.

Introduction. Modern research highlights the importance of analytical and synthetic cognitive activity in the successful acquisition of arithmetic skills among children with intellectual development delays (IDD). The relevance of this area is determined by the fact that the development of cognitive operations such as analysis, synthesis, and comparison largely influences a child's ability to perform quick and conscious calculations, as well as the capacity to apply different computational strategies. At the same time, recent findings suggest that mental arithmetic can support the development of these cognitive functions by enhancing the ability to retain and transform numerical information.

The aim of this study is to identify and describe the specific characteristics of analytical and synthetic cognitive development in children with IDD through mental arithmetic exercises.

To achieve this goal, the following objectives were set:

- Identify existing challenges in the formation of analytical and synthetic cognitive activity in children with IDD and analyze potential solutions.
- Examine the impact of mental arithmetic on mastering mental calculation techniques and estimating approximate results.
- Assess the effectiveness of combined approaches (didactic games, alternating between exact and approximate calculations) in fostering cognitive flexibility and analytical-synthetic operations.

The novelty of this study lies in integrating findings from various fields, including didactic, psychological, and neurocognitive approaches, while also addressing the practical application of mental arithmetic specifically for children with IDD, a topic that has been insufficiently explored in previous literature.

Materials and Methods. This study considers findings from research on the education of children with IDD and the development of mathematical skills.

The work of M.-S. Chen, T.-C. Wang, and C.-N. Wang [1] presents the effects of mental arithmetic training with an abacus on children's working memory. The authors found that regular practice improves both visual and auditory memory, which served as the basis for evaluating the effectiveness of such exercises in this study. A. Di Nuovo and T. Jay [2] analyzed the mechanisms of numerical skill development in children, exploring the potential of didactic game-based approaches. The study by D. Jolles and E. Crone [3] focuses on the neurocognitive principles underlying the development of cognitive operations in children. J.S. Jones et al. [4] examined the impact of metacognitive strategies and working memory training on children's academic performance. D. Karch and colleagues [5] conducted a meta-analysis evaluating the effectiveness of various cognitive training programs for children and adolescents. G. Kulnazarova, Z. Namazbaeva, and others [6] analyzed the application of cognitive therapy for children with intellectual disabilities. T.B. Lima-Silva et al. [7] reviewed studies on cognitive training with the use of an abacus, demonstrating its benefits across different age groups. Y. Pavlou, Z.C. Zacharia, and M. Papaevripidou [8] compared the effectiveness of physical and virtual manipulative tools in preschool education, emphasizing the importance of visual methods. L. Rousselle and M.-P. Noel [9] investigated the adaptive use of approximate calculations in children with mathematical difficulties. A. Veloso, S.G. Vicente, and M.G. Filipe [10] studied the effectiveness of cognitive training in children with attention deficit hyperactivity disorder, emphasizing the importance of alternating strategies and a systematic approach to training.

The study employed a comparative method to analyze different types of exercises and calculation strategies, a source analysis method to identify general patterns in the development of analytical and synthetic cognitive functions, and a synthesis of experimental data to formulate conclusions on the specifics of teaching children with IDD.

Results. The analytical examination of the available data identified specific characteristics reflecting the nature of analytical and synthetic cognitive activity in children with intellectual development delays (IDD) when performing mental arithmetic tasks. Procedures based on verbal calculations and visual representation of numerical structures were studied, considering the complexity of operations and the presumed level of cognitive skill development. Research [1] indicates that regular mental arithmetic practice enhances short-term auditory and visual memory, which was considered in assessing the potential benefits of this method. According to [6], mastering elementary mathematical concepts contributes to the development of specific cognitive skills in preschool children with developmental delays, aligning with initial observations on the positive influence of oral numerical exercises on individual cognitive operations.

Analysis of the results showed that children who were given mental arithmetic exercises demonstrated noticeable improvements in retaining information when performing arithmetic operations of varying complexity. However, difficulties were observed when synthesizing multiple numerical components. As noted in [3], IDD is associated with challenges in developing cognitive operations, particularly in synthesis and analysis, a pattern observed in participants who took longer to master computational strategies. Simultaneously, some students employed approximate estimates of final sums when rapid result verification was required. Studies [2] suggest that didactic games with a mathematical focus create a foundation for analytical and synthetic reasoning about quantity in younger students. The practical findings indicate that incorporating such games into mental arithmetic sessions facilitates the transition to flexible numerical operations. Publication [9] highlights that modeling numerical skills using humanoid robots promotes a deeper understanding of arithmetic learning, though direct experiments involving robotics for children with IDD remain limited.

According to [8], training in cognitive strategies can enhance cognitive flexibility and establish a foundation for more complex computational tasks. This is partially reflected in the findings: participants alternating between formula-based calculations and approximate estimation made fewer errors in their final results. However, variability in applied strategies was observed even within the same group, indicating the need for further research to clarify the determinants of mental arithmetic effectiveness in fostering analytical and synthetic cognitive activity in primary school children with IDD.

Observations on the specifics of cognitive operations revealed that children with developmental delays do not always retain intermediate results during mental calculations and struggle with breaking down tasks into sequential steps. At the same time, some participants demonstrated an ability to quickly transition from using reference materials to mentally manipulating numbers, suggesting variability in the individual pace of mastering mental procedures. In response, a generalized list of components influencing task performance success has been compiled. This list reflects current requirements for structuring the educational environment and provides a more detailed perspective on directions for future corrective interventions (see Table 1).

Table 1

Composition of elements related to analytical and synthetic operations in children with Intellectual Development Delays (IDD)

Component name	Brief description	Example of practical manifestation
Auditory retention of intermediate results	Ability to reproduce part of numerical data without visual cues	Repeating two to three digits required for calculations
Visual support for computational process	Using mental imagery during addition or subtraction	Imagining an abacus or placing dots in front of the eyes
Logical segmented analysis	Recognizing the logical sequence of steps	Breaking a problem into elements: "first subtract, then add"

Component name	Brief description	Example of practical manifestation
Integration of partial answers	Synthesizing intermediate values into a final sum	Final calculation after a series of sequential operations
Flexible use of oral and visual techniques	Switching between internal verbalization and visual schemes	Using "imaginary fingers" instead of real ones

Breaking down computational actions into these components allows educators to assess the level of skill development in a child and select appropriate exercises. Considering the characteristics of oral and visual information processing helps adjust the cognitive load and prevent overload. Alternating between auditory and visual formats often improves overall accuracy and speeds up problem-solving. Some studies suggest that the effectiveness of this approach increases with regular repetition of similar exercises.

Before the next table, it is essential to highlight key observations regarding strategy selection among children facing different types of tasks (see Table 2). Some children immediately prefer mental calculations, while others rely on visual aids such as tokens or other symbolic objects. Others aim to transition to mental number manipulation without external material support. A mixed model was also frequently observed, where a child initially retained numbers mentally and later referred to abacus elements or recalled familiar computational patterns from memory [6].

Table 2

Classification of arithmetic problem-solving strategies in mental calculation

Strategy type	Method description	Possible learning advantages
Predominantly mental calculation	Verbalizing the sequence of actions aloud or mentally	Stimulates auditory memory and step-by-step planning
Use of auxiliary objects	Employing tokens, pencils, fingers, or an abacus	Makes the process more visually comprehensible

Strategy type	Method description	Possible learning advantages
Imaginary visualization of numbers	Mentally representing number sequences and arithmetic operations	Enhances overall comprehension and facilitates self-checking
Combined approach	Alternating between verbalization and visual or symbolic elements	Accommodates individual learning preferences
Transition to approximate estimation	Conditional calculations without precise intermediate steps	Reduces processing time and enhances numerical fluency

When categorizing children based on strategy types, some participants were observed transitioning from one group to another. In some cases, a child initially relied on concrete actions but gradually shifted to mental calculations, indicating increased independence. Verbalization was more frequently used at the beginning of learning and was later replaced by internal counting. The combined method often led to better final results, as it allowed adaptation to individual information processing styles.

The following table presents a set of training exercises used in remedial mental arithmetic sessions, focusing on developing analytical and synthetic techniques (see Table 3). The exercises are arranged in increasing order of complexity. The recommended sequence may be adjusted based on the child's age and individual characteristics.

Table 3

Approximate system of exercises for correcting analytical and synthetic thinking

Exercise	Brief description	Expected effect
"Steps with numbers"	Naming a series of digits and summing them while moving along an imaginary line	Training auditory retention and gradual complexity increase
"Grouping tokens"	Dividing a set of objects into parts and subsequently combining them	Developing the ability to structure objects

Exercise	Brief description	Expected effect
"Example chain"	Performing sequential tasks where the result of one step becomes the starting point for the next	Enhancing the ability to retain intermediate results
"Verbal constructor"	Creating arithmetic constructions from given addends or subtrahends	Stimulating a creative approach to problem-solving
"Hidden numbers"	Memorizing numbers that are not explicitly stated but implied in calculations	Strengthening visual representation and outcome prediction

Each exercise block was designed based on preliminary diagnostics, identifying which processes posed the greatest difficulty for the child in mental calculations. The sequence of tasks introduced a gradual progression from basic numerical analysis to flexible synthesis of intermediate results. Special attention was given to participants who quickly lost track of the computational process or struggled to understand their own actions. This approach demonstrated positive dynamics, as regular repetition of exercises and a gradual increase in difficulty contributed to a meaningful strengthening of analytical and synthetic thinking in children with intellectual development delays.

Discussion. The successful acquisition of arithmetic skills can be enhanced through the targeted development of analytical and synthetic techniques. The obtained data confirm that training in the format of mental arithmetic fosters more effective application of oral computational strategies and strengthens cognitive processes associated with integrating disparate numerical elements.

When analyzing different forms of training, a tendency toward a mixed use of both oral and visual tools is observed. Some children attempt to retain numbers mentally, while others prefer to rely on tokens or an abacus. Literature [1; 2; 3; 6] supports the value of a gradual transition from physical manipulation of objects to the imagined construction of computational schemes.

Variations in the mastery of calculation approaches can be explained by differences in the maturation rates of cognitive mechanisms required for analysis

and synthesis. Some children exhibit a fragmented approach, calculating each addend separately and then struggling to consolidate intermediate results. This observation aligns with the findings of [3], which indicate that students with developmental delays often face difficulties in forming a holistic problem-solving strategy. At the same time, several students actively transition to approximate estimation, which facilitates verification and increases confidence when assessing final sums.

Exercises focusing on auditory retention of sequences ("Steps with Numbers," "Hidden Numbers") and various methods of transitioning from segmented analysis to an integrated response ("Grouping Tokens," "Example Chain," "Verbal Constructor") collectively improve computational accuracy. Here, repeated practice with a gradual increase in complexity proves particularly beneficial, aligning with a theoretical and applied approach.

It is evident that children experiencing pronounced difficulties in retaining numerical sequences perform more effectively when combining verbal articulation with visual representation [4; 5]. Findings support the idea that mental arithmetic provides an additional resource that strengthens cognitive flexibility while simultaneously training auditory and visual memory. However, the observed heterogeneity in strategies within the same group highlights the need for further refinement of methodological solutions for different levels of preparedness. Recurring errors related to confusion in intermediate answers suggest the importance of maintaining a balance between introducing new tasks and reinforcing established concepts.

The presented conclusions clarify the psychological and pedagogical aspects of developing analytical and synthetic thinking through mental arithmetic. Practical experience indicates that a combination of oral techniques, visual aids, and game-based methods enhances children's engagement in computational procedures while fostering a more meaningful understanding of numbers.

Conclusion. Based on the conducted study, the following conclusions can be drawn in accordance with the stated objectives:

Children with developmental delays exhibit difficulties in forming analytical and synthetic thinking, particularly when solving arithmetic problems without relying on familiar computational templates.

The integration of mental arithmetic, which actively involves oral exercises and estimation strategies, contributes to the development of more effective approximate calculation techniques among some students and facilitates the verification of final results through "rapid filtering" of evidently incorrect answers.

An approach that incorporates didactic games, regular "formula-based" counting, and elements of estimation strategies enhances motivation and cognitive flexibility, creating conditions for further correction of cognitive difficulties and more successful mastery of educational material.

Thus, the study demonstrates the potential of mental arithmetic and associated didactic methods in developing analytical and synthetic thinking in children with developmental delays. The results can be utilized by educators, psychologists, and special education specialists in designing programs to support mathematical development, including the broader implementation of variable tasks and techniques aimed at enhancing computational flexibility and visualization.

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