

# ADHD in Children: Mechanisms and Remediation

Irina Shevchenko<sup>1,\*</sup> and Janna Gluzman<sup>2</sup>

<sup>1</sup>Luria Research Centre of Developmental Neuropsychology, Moscow, Russia

<sup>2</sup>Psychology Department Lomonosov Moscow State University, Moscow, Russia

**Abstract:** Executive functions study is one of the main topics in A.R. Luria works. Attention deficit and hyperactivity disorder (ADHD) syndrome presents a good model of executive disorders. An experimental study of them reveals a complex structure of the executive behavior, including sustaining of activity and attention, selectivity in decision making, shifting, planning and prognostic abilities. Cross-cultural (Russian/Italian) differences in executive functioning of ADHD children are discussed. A comparison of ADHD syndrome in preschool and primary school age is aimed to prevent an aggravation of defects and their early remediation.

**Keywords:** ADHD, A.R. Luria, executive functions, neuropsychology, preschool age.

## I. INTRODUCTION

An underdevelopment of executive functions lies at the core of most dysontogenesis syndromes, it greatly influences the child's behaviour and learning in school and pre-school [1]. "A disobedient child rarely deviates from the given instructions by unwillingness to follow them. He can't just yet and doesn't know how to keep himself from an action unapproved by adults. Too large is his dependence on direct influences of the outside world; still very difficult is to predict the results of own actions, to divide in own mind the desired "now" and the possible "after" [2, p. 32].

The long process of maturation of the unit of activity programming and monitoring has according to psychophysicologists several critical points and, above all, the period between 6-7 years, when, upon the EEG data a simple emotional brain activation system is replaced by the verbal voluntary control of the brain with the growing participation of the frontal lobes of the left hemisphere [3]. During this critical period, as we know, the child's schooling begins. It is not surprising that all executive functions: programming and monitoring of individual action, forming designs and purposes of activities and regulation of behaviour are deficient in children with learning problems.

**Attention deficit and hyperactivity disorder (ADHD)** is one of the most common behavioral and learning disorders among children and a frequent reason for asking a psychological help in childhood [4, 5]. According to criteria DSM-IV [6] the frequency of ADHD varies from 3 to 20% [7], the official indicator in the DSM-IV being 3-5% [8]. It means that at least every thirtieth child has ADHD, and it really means that each class of a primary school has at least one such student.

At the behavioral level, this disorder is manifested primarily by excessive and not justified physical activity, fussiness and impulsivity, exceeding the limits of age standards, as well as the difficulties of attention concentration due to frequent switches of attention. Neuropsychological assessment identifies in these children the immaturity of various cognitive functions: gnostic, orientation in space, problem solving and others [9-12].

The disorder typically occurs early in the development process, usually within the first 5 years of life. However, the peak of applications to specialists is by six or seven years of age, when excessive, poorly organized and poorly regulated activity of a child becomes an obstacle for the intensive training activities. Even with relatively high intellectual potential the children with ADHD are often unsuccessful at school and are experiencing difficulties in social adaptation to peers [13].

Unfortunately, despite the frequency of the syndrome, this disorder is often revealed late, incorrect or not detected *at al.*, the behavior of the child is explained by a lack of a due upbringing from the parents or by a bad character of the child, which cannot be changed. Accordingly, most children do not receive timely and necessary support. The variety of methods for ADHD assessment is very large and differ in Russia and Western countries, therefore it is very important to find converging points and a theoretical foundation of the most frequently used tests.

## 2. MATERIALS AND METHODOLOGY

### 2.1. Experimental Study

The first part of our experimental study was aimed to select sensitive methods for revealing mechanisms of executive disorders in children with ADHD through an international study [14] with the following tasks: 1) To compare the discriminative value for ADHD diagnostic of

\*Address correspondence to this author at the Moscow Research Center of Developmental Neuropsychology, Moscow, 127220, Russia; Tel: +74956144051; E-mail: [irinanebogatykh@yandex.ru](mailto:irinanebogatykh@yandex.ru)

**Table 1. Subjects of the international study of ADHD.**

Measures	Russian group (M = 14, F = 5)	Italian group (M = 16, F = 2)	t-test	p-value
Age	9.00 (1.00)	9.78 (1.70)	1.78	0.097
Conners ADHD-index	74.79 (10.57)	78.11 (7.67)	1.87	0.069

some Lurian and Western tests for executive functions in learning disabled primary school students; 2) To reveal the potential of these tests for describing the structure of executive behavior: sustaining and selectivity of attention, shifting in execution, planning, recalling of performance and errors correction; 3) To analyze cross-cultural differences in these tests performance.

**Methods:** Shulte test from Luria battery [15] and test of figures matching. Both measure the *sustaining of activity and attention*. Hayling Sentence Completion Test [16] and analogy test from Luria battery measure *selectivity in decision making*. Dynamic praxis, test of conventional reactions (from Luria battery) and Numeric Stroop [17] test measure *shifting*. Problem solving test and Everyday Planning Test (Ibid) measure *planning* of steps and coherence between planning and execution. Iowa Junior Gambling test [18] measure ability to compare gains and losses and to recall the performance. Conners Scale determines the level of ADHD [19]. Let us give some details on some tests from Italian battery for executive functions.

**Hayling Sentence Completion Test** In this test children had to finish the presented orally sentences with a missing last word by semantically related (part A) or completely unrelated to the sentence (Part B). The missing words were matched for frequency and age of acquisition. Each type of answer (meeting or not meeting the instruction) was scored. Big scores in the part B revealed a lack of selectivity.

**Numeric Stroop** In this test children were required to count numbers. The trials were divided into two sessions: the baseline has 12 stimuli (stars) and the experimental sessions has 75 groups of identical numbers. The number of naming errors (the child named the numbers instead of counting them) was recorded as well as the difference in time to count stars and to count numbers (Interference Time) due to the Stroop effect.

**Everyday Planning Task** (EPT) is a semi-ecological task proposed in two versions, a version for children aged between 8 and 10 years and a version for children aged between 11 and 14 years. EPT includes three different tasks: Memory task, Time estimation task and Planning task. In the Memory task children had to recall the activities (like: to buy the bread for granny, to go to training, to do homework and so on), listed by examiner in any order. In the Time estimation task children had to estimate the duration of each activity. Finally in the Planning task children had to order 10 activities in accordance with logical and chronological constraints in a maximum of 30 minutes. Children can see the list of the 10 activities, they had an answer's sheet and a map of the city, where these activity are performed. The

dependent variables are: 1) the recall of activities in the Memory task; 2) the correct planning of activities (relationship between activities properly planned and number of moves required to complete them) in the Planning task; 3) number of rule violations; 4) coherence (consistency between estimation and effective use of time in the Planning task); 5) time to execute the task.

In the **Junior Iowa Gambling Task** the subjects are presented with 4 virtual decks of cards on a computer screen. They are told that each time they choose a card they can win some game money (a reward). However, the choosing some card often causes them to lose some money (a penalty). The goal of the game is to win as much money as possible. The decks differ from each other in the number of trials over which the losses are distributed. Thus, some decks are "bad decks", and other decks are "good decks", because some will lead to losses over the long run, and others will lead to gains. The dependent variable is the gain or loss of money at the end of the 100 cards. The Iowa Gambling Task copies daily, real-life, decisions [20] and has given a strong impetus to understanding the role of the emotional system in the organization of decision-making behavior [21-23].

**Subjects:** 37 learning disabled (inclusion criterion) public primary school students (19 Russian and 18 Italian) aged between 8 and 13 years old. Exclusion criteria were very low intellectual level (debility) and / or psychiatric pathology (depression, endogenic disease) interfering with learning in a public school. Both samples were diagnosed as ADHD according to the ICD-10 criteria using semi-structured interview with parents (K-SADS for the Italian sample). ADHD diagnosis were confirmed by the Conners Questionnaire for parents (upon T = 70 Conners score). The cut-off was established at T score = > 70. The parents gave written informed consent for assessment. Both groups were matched by age (Table 1).

**Results.** On the Italian Executive Function battery Italian children showed poorer performance than Russian children concerning the Coherence to use the time in EPT and they are faster (probably more impulsive) than the Russian children.

On the other hand Russian children produced more errors in the Numeric Stroop task. Italian children did not present comorbid learning disorders, therefore the absence of comorbidity could justify their better performance, compared to Russian children.

We did not find significant difference on the other measures of EPT, on the Interference time in the Numeric Stroop and in the Junior IOWA Gambling task (Table 2).

**Table 2. Scores of ADHD children in the Italian Battery of executive tests.**

Measures	Russian group (M = 14, F = 5)	Italian group (M = 16, F = 2)	t-test	p-value
Every Planning Task (EPT)				
EPT-Memory	8.00 (1.53)	8.50 (1.20)	1.103	0.278
EPT-Planning	0.96 (0.17)	1.05 (0.17)	1.735	0.092
EPT-Violations	1.89 (2.31)	1.33 (1.19)	0.923	0.363
EPT-Coherence	6.68 (1.42)	4.71 (2.63)	2.479	<b>0.021</b>
EPT-Time	14.99 (3.86)	12.47 (3.22)	2.148	<b>0.039</b>
Numeric Stroop				
Errors	3.47 (2.23)	1.72 (1.36)	2.825	<b>0.008</b>
Interference time	-0.001 (0.52)	0.27 (0.31)	1.883	0.068
Iowa Gambling				
Money Gain or Loss	-48.16 (77.45)	-49.17 (74.07)	0.040	.968

**Table 3. Scores of ADHD children in the Russian Battery of executive tests.**

Measures	Russian Group (M = 14, F = 5)	Italian Group (M = 16, F = 2)	t-test	p-value
Shulte Test	1.55 (0.78)	0.67 (0.71)	3.614	<b>0.001</b>
Test of Conventional Reactions	0.95 (0.43)	0.56 (0.51)	2.529	<b>0.016</b>
Analogies Test	0.40 (0.44)	0.17 (0.38)	1.701	0.098

In the Russian EF tasks the two groups did not show significant difference in the Analogies test, but they performed significantly different in the Shulte test and in the Test of Conventional Reactions (Table 3).

So, the results of this first part of the study prove that the difference between children with and without ADHD was both in worse scores for all tests in the first group and in qualitative differences: lack of steps planning and comparing own actions with previous results, impulsivity, and difficult recall of performance. The most discriminative for groups with and without ADHD were Numeric Stroop test and the test of conventional reactions. Cross - cultural differences were mostly seen in tasks including time planning. It should be mentioned, that the difference between the two groups (Russian and Italian) tends to be significant on the Conners scale that may impact the difference in executive functioning between the two groups.

## 2.2. The Second Part of the Experimental Study

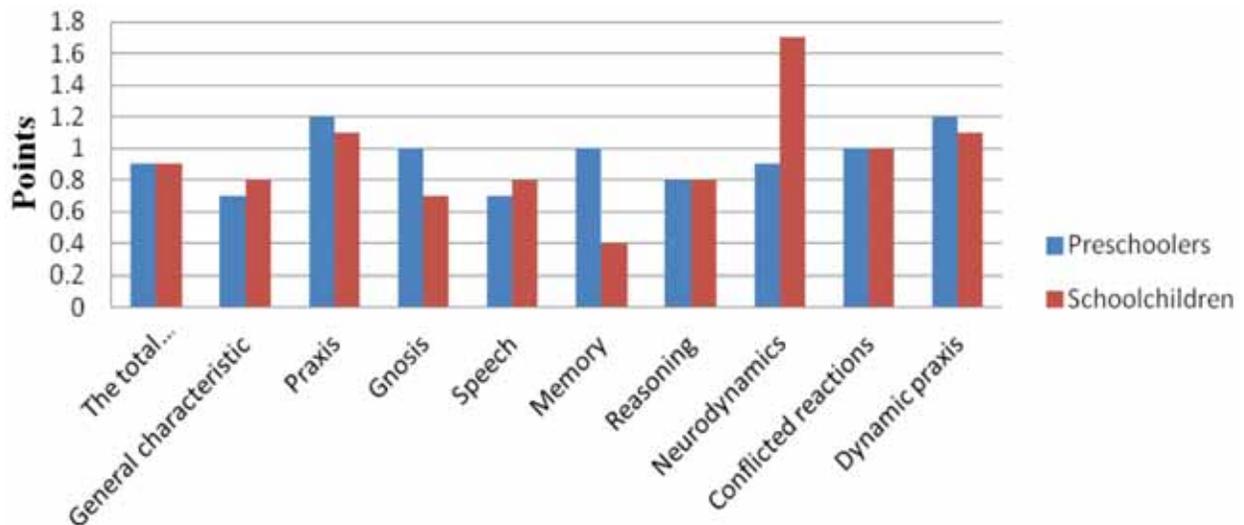
The analysis of the corresponding literature has shown that in most studies the observations were carried out for children of school age. It's a period when the signs are manifested more clearly. Mechanisms of development and manifestation of ADHD in early and pre-school age remain largely out of attention of psychologists.

That is why a neuropsychological assessment of children with specific needs and deficits of mental functions development in the pre-school age is of primordial importance for the psychological and pedagogical practice. An early diagnosis and remediation should be oriented at the pre-school age, when compensative abilities of the brain are greater, and still we are able to prevent the persistent abnormal manifestations [24-26].

This was the aim of our study.

*Methods:* In our study, we used the following methods:

- Conners Scale to determine the level of ADHD [19] – a questionnaire containing 10 (short variant) or 80 (full version) questions, which assesses behavior of the child. In this study, the parents of preschoolers were proposed the short version of the questionnaire, while parents of primary school students filled out the full version.
- Methods of Lurian neuropsychological examination, adapted to the children population, with quantitative and qualitative evaluation of results. These methods allows us to differentiate difficulties in learning and behavior, due to an underdevelopment or individual peculiarities of functioning of brain structures [12].



**Fig. (1).** A comparative pattern of neuropsychological assessment data in preschool and school children before remediation.

- Analysis of the early development of the child through a special questionnaire for parents.
- *Subjects:*

9 preschool children with ADHD, confirmed at a neurological assessment and by Conners Scale data (score exceeding 15 on Conners Scale-10) participated in the study. Between them there were 7 boys and 2 girls aged 3 to 6 years. All 9 preschoolers followed a course of neuropsychological remediation in the Moscow Research Centre of Developmental Neuropsychology, after which a control neuropsychological follow-up was done to reveal a dynamics of results after remediation.

Besides the sample included 13 schoolchildren with a diagnosis of ADHD, confirmed at a neurological assessment and by Conners Scale-80 data. There were 11 boys and 2 girls aged from 7 to 11 years.

### 2.3. Comparative Analysis of the Neuropsychological Data in Preschool and School Children Before Remediation

We compared preschoolers and schoolchildren on data of Lurian neuropsychological assessment before remediation.

It was revealed that schoolchildren without remediation at the pre-school period show minimal positive differences with preschoolers in gnostic and mnestic functions that can be associated with the growing up of children, while the average summarized scores of cognitive remain unchanged<sup>1</sup>.

At the same time in many mental spheres, like: the orientation of children in time and what about, their general knowledge, the control of own behavior, critical attitude to the mistakes made and adequacy during the assessment. Also there was revealed an underdevelopment of verbal functions - expressive speech, naming, understanding of logical and grammatical structures. However, the most negative changes were observed in neurodynamic functions of children. For various reasons in children the level of functional brain

activity is unstable, has poor resistance to loads, requires constant stimulation and periods of productive work are alternated by rest. So it is more than expected that the working capacity of pupils worsen with ever-increasing loads at school from year to year (Fig. 1).

In addition to the quantitative analysis of scores of neuropsychological assessment for both groups of children we did a comparative qualitative evaluation of defects of higher mental functions in preschoolers and schoolchildren. The results are presented on the (Fig. 2). One can see an increase in the number of defects in the areas of speech, memory and neurodynamics among pupils compared with preschool children.

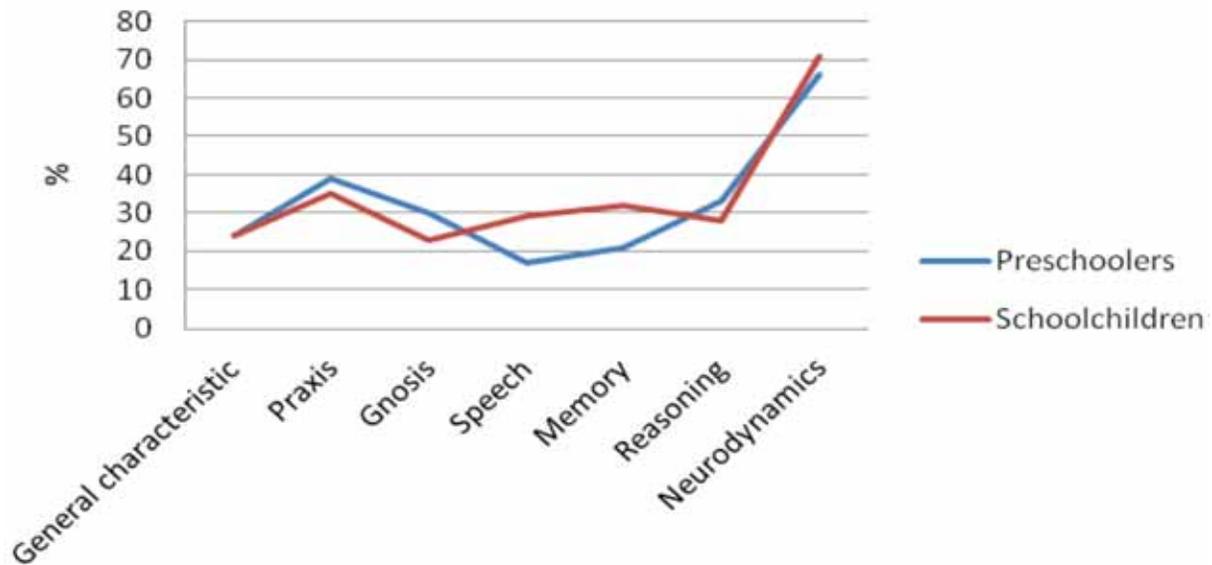
Spearman rank correlation showed that the age of the child has a significant correlation with neurodynamic indicators, impaired memory and the ability to solve problems. It means that more old is the child, worse (without remediation) are scores for neurodynamics, defects of memory and for solving problems.

Hyperactivity, or an excessive motor disinhibition, is a manifestation of fatigue. A tired child, not alike an adult, cannot control the condition and take time to rest. It is manifested in an overdrive (chaotic subcortical excitation). As a consequence, children have highlights of specific changes in the neurodynamic nervous processes.

The mental process in children also manifest apparent weakness in the formation of the unit of brain activation. The defects of neurodynamic bases of mental functions lead to the evidence that even with a sufficient ability of memorization the acquired information rests unstable, rapidly disappearing (inhibited) by interfering influences, especially homogeneous [12].

The solving of mathematic problems needs planning, execution procedures to achieve the results. An hyperactivity disorder includes, as was shown above an immaturity of planning and control even own movements (not to mention the higher levels), such a complex multi-level action, as a solving of mathematic problems causes great difficulties for children with ADHD.

<sup>1</sup> In Lurian system of scoring the greater score means worse abilities



**Fig. (2).** Number of defects (%).

Let us consider now the factors that aggravate cognitive underdevelopment in children with ADHD

The recent studies reveal many factors, which can lead to appearance of ADHD. That is why actually a multicausal theory of ADHD development is predominant. The biological factors, especially perinatal hypoxic lesions of central nervous system, are the most important in the first two years of life. In the later development the disorders also depend on psychological and social factors such as family situation, upbringing methods, financial and social situation [27].

The causes of observed symptoms were revealed in our study through the analysis of data of the checklist of early child development.

Significant correlations were found between children with *ambidexterity* and the severity of defects of reasoning, which indicates the need for a special approach to the formation of intellectual functions in children with incomplete dominance of the left hemisphere.

Significant correlations were found between *birth pathology* and quantitative scores for praxis. More noticeable was birth pathology (cord entanglement, asphyxia, hypoxia, hypotrophy and so on), significant were disorders of motor coordination, fine motor skills and praxis.

Significant correlations were found between *abnormal children's motor development* during the first year of life and quantitative scores of preschooler's speech development and speech defects.

Study of children with speech pathology shows that they had motor development problems since very early age. These children did not have any neurological motor symptoms (hyperkinesias, paresis) but they began to maintain head, to seat, to stand later than it was indicated by the age-related norms. They have formed later locomotor functions (climbing, walking, and jumps).

The psychomotor defects of the most children with speech pathology prove an *interrelation and interdependence between speech and motor development*. It also indicates a functional unity of speech (not only in its motor component) and of motor systems in the process of their formation in child's ontogenesis. It was revealed that a stimulation of fingers movements affects the central nervous system maturation [28]. A timely speech development is one of these means.

Defects of speech in children with motor underdevelopment, an importance of motor system in child's neuromental development prove the need for special complex neuropsychological remediation for all components of children's motor development.

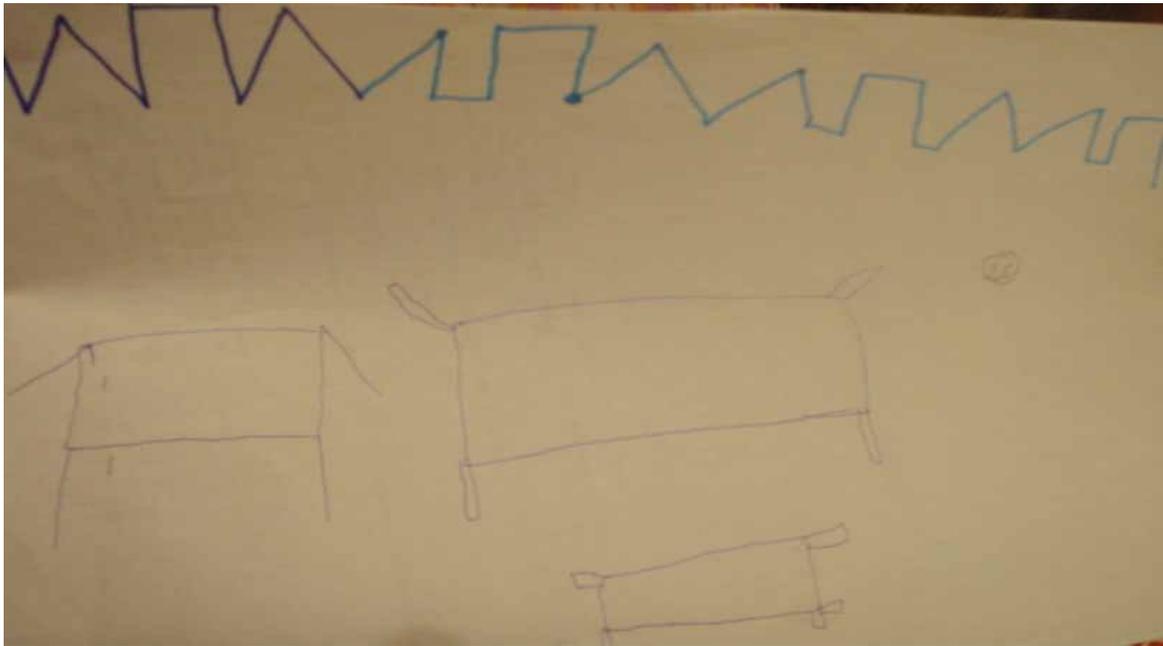
Significant correlations were found between child's motor retardation and *gnostic defects*, because active hands movements (crawl, toy's grip) stimulate the formation of constant objects images and of orientation in space. As was mentioned above the spatial defects are observed in most children with ADHD and are aggravated in school age (Fig. 3).

Perseverations and not coordinated movements can be seen, together with difficulties to follow program in the dynamic praxis and an immaturity of spatial functions in praxis and drawing.

#### 2.4. Remediation of ADHD.

Even psychiatrists say that the drugs do not solve the whole spectrum of problems of ADHD, because the problems of development of higher mental functions cannot be overcome with the medicines.

The follow-up of children with ADHD have proved the importance of a comprehensive program of motor and cognitive remediation of children with this syndrome (Fig. 4).



**Fig. (3).** Example of graphic test and drawings of table, made by 11-year-old schoolboy with ADHD.



Inhibition training in the task: "Achieve the last"



Training of control and attention in group remediation

**Fig. (4).** Remediation of children with ADHD.

Development of executive functions: voluntary regulation, orientation and control of own activities are the central focus of neuropsychological remediation of hyperactive children with attention deficit. Method of remediation is based on two main approaches: overcoming neurodynamic problems through a "saturation of the child by activity" and using of external supports for mediation of regulatory functions [10-12]. The limits of the article don't permit to describe these methods in details here.

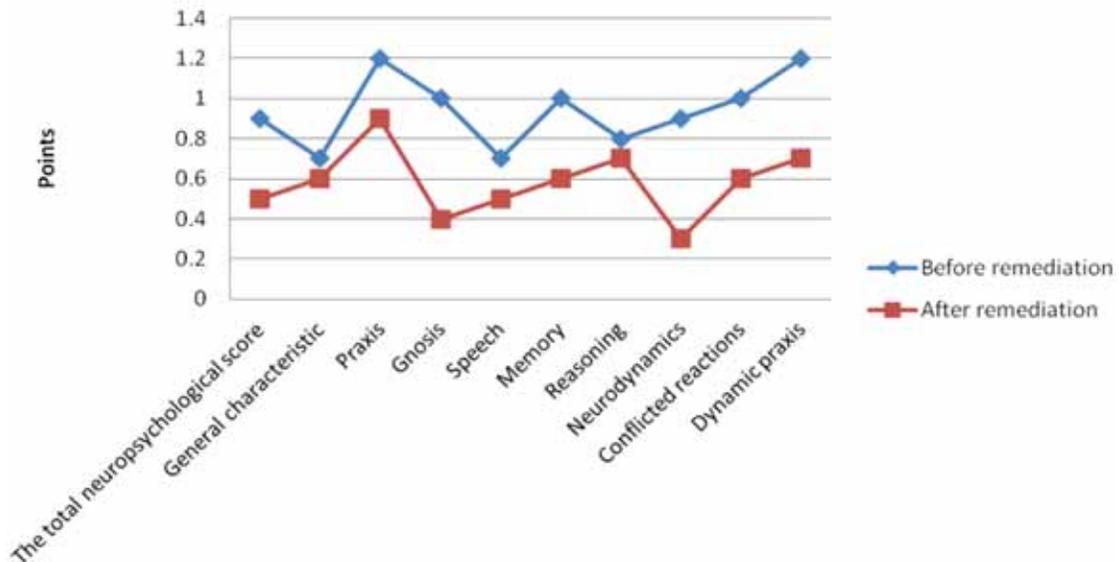
In our study, all preschoolers followed a course of neuropsychological remediation. At the end of the course, a control neuropsychological follow-up was done, which showed a positive dynamics (reduction of the penalty scores) in all spheres of the development of the child.

The most significant changes according to the T-test Wilcoxon were noted in the scores for praxis ( $p=0.008$ ), gnosis ( $p=0.018$ ), memory ( $p=0.012$ ) and reasoning

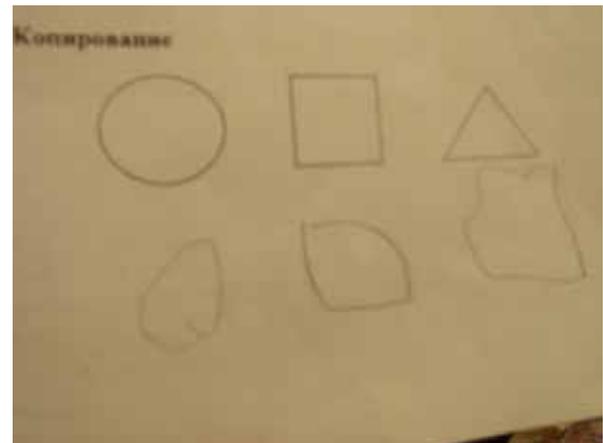
( $p=0.018$ ), as well as in conditioned reactions ( $p=0.043$ ) (Fig. 5).

Besides, statistically significant improvements was observed in the total neuropsychological score (the average of all spheres of the child assessment). It indicates, first the importance of a comprehensive approach for the neuropsychological remediation of children (instead of the development of a separate sphere), and, secondly, the importance of the remediation effectuated at the preschool age, when there is still time before scholarship and a comprehensive development of all higher mental functions in a preschooler will help him to be more successful in learning activities.

The following examples illustrate the development of spatial organization of movements and actions in a 4-year-old preschool child. Significant results appeared already after a course of 20 remediation sessions (Fig. 6).



**Fig. (5).** Dynamic of preschoolers scores after remediation.



**Fig. (6).** Copying of simple geometric shapes (circle, triangle and square) by 4-year-old child with ADHD before and after remediation.

Neuropsychological assessment of children after a remediation course shows that the used methods are effective both for overcoming the problems in learning, and for the reduction of the symptoms of ADHD [11].

## CONCLUSION

Our experimental study reveals the complex structure of executive functions disturbances in ADHD, including: neurodynamic deficit, providing difficulty in sustaining of activity and attention; bad selectivity in decision making, defects of shifting from one executed activity to another; of planning, prognostics, recalling of performance and errors correction. This is consistent with the published literature and complete it with important details.

The comparison of the syndrome of ADHD in preschool and primary school children, an estimation of the dynamics of child mental functioning after neuropsychological remediation in preschoolers prove the importance of assessment and remediation the syndrome of ADHD in the early preschool age. And the sooner a preschooler will

receive a comprehensive neuropsychological help, the easier will be the learning process at school.

## CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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