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Quantitative Standards of Cognitive Activity in Healthy Russian Schoolchildren Aged 8-17 Years As Examined on the Computer Testing System "Psychomat"

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This article represents the results of a research on cognitive functions, the dynamics of their age and gender differences revealed by the KPFK-99 "Psychomat", a psycho-physiological computer complex, in healthy schoolchildren of various age groups. The study included 241 children aged 8 to 17 years (52% girls and 49% boys). The average age of the students observed was 11.8 years. Cognitive activity norms were calculated for healthy schoolchildren with an amplitude of one year, which makes it possible to evaluate its objective quantity. The impossibility of combining children into one-age group teams (such as a junior, middle and senior school age), according to the standards of cognitive functions, was proved. A model of cognitive functions assessment using the parameters of the computer psycho-physiological complex was developed. An even increase in performance as children grew older was also proved, thus indicating smooth improvement of a child's cognitive functions throughout the school-age. The absence of significant gender differences in cognitive performance of same-aged children (as used in the methodologies) indicates the possibility of co-education of boys and girls in a school.

Keywords: *cognitive functions, psychophysiological computer complex, healthy students.*

Today cognitive impairment in children and correlated difficulties in learning activity appear as a serious challenge to pediatricians, neurologists, psychologists and other professionals working with children. On one hand, this is due to high prevalence of such disorders among school children (7 to 30%) [1], on the other hand it is due to the progress in the field of cognitive brain function research [2, 3]. Recent activity demonstrated the rationale of cognitive impairment diagnostics in children having physical diseases, particularly allergic (for example, there was proved cognitive function impairment in children suffering from long-term perennial allergic rhinitis of moderate and severe course flow in 95.3%), and juvenile arthritis (a decrease in cognitive functions depending on the course severity and juvenile arthritis duration) [4-7].

For this reason, the general practitioners and pediatricians of non-neuropsychyatric specializations pose particular demand on the orientation in matters of cognitive status in children. The most difficult thing is to establish the interaction with representatives of related disciplines in the process of diagnosing [1]. In particular, there are certain difficulties in interpreting the results of psychological examinations by clinicians known for their subjective nature.

In addition to clinical complications, subjective nature of standard psychological examinations limits the visibility of demonstrating results to parents of patients, and complicates further research. Taking it into consideration, the methods, that can determine the status of cognitive functions non-invasively and in the accessible form to produce objective numerical results, gain special importance [2, 8, 9].

Diagnostics of cognitive functions using (KPFK) "Psychomat", a computer psychophysiological complex, is one of such methods. The method of diagnosis using KPFK "Psychomat" undermines the automatic presentation of test tasks to the child basing on a complex computerized mode, and keeping of subject’s responses, carried out by pressing the stylus on the touch-sensitive buttons on the remote; this device performs a computerized count and processes the results while storing them in a database. These processes provide the greatest possible standardization and objective examination of procedure with a maximum limit of the human factor in the person of the researcher [10-12].

Key advantages of this method:

1) the ability to record cognitive function parameters in numerical terms - milliseconds and

error rates;
2) to propose methods of testing, which can be effected only using computer technology: that is, simple and complex sensorimotor reactions, binatests, tapping test, etc.;
3) interest of the child in the research procedure itself, which can be explained with a game form, being contrary to the standard testing;
4) removal of possible impact of intermediary specialist on the results of research and their evaluation;
5) processing speed and ease of storage.

Computer methods in diagnostics have been used in this center for more than 15-years. The first studies of neurologists were led by O. Maslova, the professor, and held in 1995 at the Neuropsychiatry Department at Pediatrics Institute of RAMS (now it is one of the universities comprising Child Health Research Center of RAMS). As of today, in addition to academic achievements, specialists from various departments have held more than a dozen of scientific researches using computer test systems, which resulted in systematic improvement of computer-assisted diagnostic systems, with help of designers and manufacturers [2, 6, 7].

At the current stage of computer technology development, manufacturers of psychophysiological complex KPFK introduced a new model KPFK-99 "Psychomat," that differs from the previous set by convenience (number of touch panels reduced from three to one; increased sensitivity of touch buttons etc.), introduction of new parameters and tests. The new generation of computer systems makes the task fulfillment easier for the child at the level of motor execution procedures; therefore, it also contributes to further objectification of research results.

However, new technical features of this set automatically require for the corresponding standards. There are no standardized normative data for children of all age groups that could be available for research available using KPFK-99 "Psychomat". Until some time, this did not cause any particular problems, as every researcher had the opportunity to gain regulatory framework, which would be limited by the study objectives and use it as a control group [6, 7]. But due to the fact that recent KPFK turns from the purely scientific instrument into the subject of practical public health and psychology application, the lack of common standards on cognitive functions on children of all ages has become particularly noticeable.

In this regard, there have been planned and carried out a study represented in this publication.

Research objective: to establish quantitative standards for cognitive activity, that can be detected by KPFK-99 "Psychomat" on children of different age groups; and determining the cognitive function dynamics and gender differences in healthy schoolchildren.

Work performed at the Research Institute of Preventive Pediatrics and Rehabilitation (L.S. Namazova-Baranova, director, is a Corresponding Member of RAMS) in Child Health Research Center RAMS (A.A. Baranov, director, is an academician of RAS and RAMS) on the base of Department of Rehabilitation of children having allergic diseases and respiratory diseases (head office – Torshkhoeva R.M., Doctor of Medicine) and secondary school № 120, SWAD, Moscow (O.A. Shiryaeva, director).

Criteria for inclusion in the survey are the following: children aged 8 - 17 years, a satisfactory or above satisfactory assimilation of secondary school curriculum, physical health (I and II group of health according to Grombakh scale).

Exclusion criteria were: lack of motivation to perform tasks during the study, difficulties in learning activities and / or behavioral problems, impaired physical well-being at the time of the study, chronic diseases along with a history of neurological disease.

Volumes and methods used in the survey

The study included 241 schoolchildren aged 8 to 17 years (52% girls and 49% of boys). The average age of the observed students was 11.8 years. The following methods were used:

1. General clinical methods: a) analysis of the annual medical examination of students according to their medical records, b) pediatric examination performed on the day of the study.
2. Specialized methods: Research of cognitive functions by means of KPFK-99 "Psychomat", a computerized psychophysiological complex developed by CJSC "VNIIIMP-Vita" of Medical Instrumentation of RAMS.

The use of KPFK-99 in the study

KPFK-99 "Psychomat" is designed for effecting complex multifunctional control of higher mental functions of the central nervous system (CNS) of man being healthy and having disease, basing on the dataset of psycho-physiological and psychological tests. The complex includes more than 40 methods of studying cognitive, emotional and personal spheres of children and adults.

The researcher may generate the necessary preliminary battery for a particular survey of methods. The complex also incorporates the ability to set individual parameters for each method (for example, the interval between stimulus presentations, the number of stimulus presentations, complexity levels etc.) that allows to adapt the parameters of the presented method to the age-and clinically-dependent features of people under survey.

There was formed a special battery for this research, considering age and research objectives to cover the widest possible range of cognitive functions. Basing on the pilot study group of 20 healthy children of different school ages, for each method there were selected optimal parameters. Below there are the main characteristics and parameters of the methods used.

1. **Simple sensorimotor reaction**. The subject is instructed: as soon as possible to respond to the light signal by pressing a button.
2. **Complex sensorimotor reaction**. The subject is instructed: as soon as possible to **correctly** respond to the light signal by pressing a button and return to the initial position.
3. **Static coordination**. The subject should place the metal tip into the highlighted test slot approximately for half of its length, without touching the bottom, and start the timer once touching the wall of the slot. Next to signal the subject is to keep the metal tip in the slot, trying not to touch sides and bottom of the hole.
4. **Dynamic coordination**. The subject should place the metal tip into the test slot approximately for half of its length, without touching the bottom, then start the timer by touching the top of this slot. Next, the subject must as soon as possible move a tip along the slot, not touching the walls and bottom of the slot, and finally touch the nose of the metal tip.
5. **Correction test**. Task is to find a ring under presented stimulus among a number of rings with different labels.
6. **Mnemotest**. Illuminated images, which look like a table with some colored fields, are presented to the subject. The task is to reproduce the exact light image (LI). The light image is a square matrix of a certain number of cells (3 x 3), some of which are colored green.
7. **Binatest** (under mode selection). Two buttons on the remote control are randomly lighted up. The task for a child is to follow the sequence of signals and each time push the button, which has been lighted up **the previous time**.

8. **Rhythmotest**. This method provides for measure of rhythmic stimuli performance. Set undermines two steps: first, light or sound signals that follow a specified frequency, are shown to the subject. The subject must respond to each stimulus. In the second phase the subject is not presented with a rhythmic stimulus, but a sound or light signal occurs in response to subject’s reactions so they get the feeling they continue to monitor expected rhythmic stimuli. The first stage is called "Rhythm" and the second one is called "Tapping."

The specified parameters are shown in Table 1.
For the purpose of leveling age differences related to diagnostics process by psychological techniques, that could affect the objectivity of the results, the conditions to mind during the survey of children aged from 8 to 11 years were the following:

— game form of material presentation;

— mandatory preliminary demonstration of each task;

— interruption of testing at the first signs of tiredness occur;

— reduced screening program in comparison with elder children

— adjustment of regulations and presentation forms of some tasks in case of the individual perception patterns of the child

The study was conducted at the beginning of the studyyear: it is known that at the end of each quarter and in the spring, pace and mobility of the mental processes slow down [13]. Survey on KPFK-99 "Psychomat" was performed in the morning, while patients had good health and positive attitude along with no assessive premonitions.. All respondents were given standard instructions.

Statistical analysis of results

Average value ± confidence interval at the normal trait distribution were used to describe the quantitative indicators used.
The following formula was used for calculating the average value of the array of numbers xi (i = 1, 2, 3 ... N):

$$\langle x \rangle = \sum_{i=1}^{N} x_i /N.$$

This formula gives reliable values if the number of elements in an array of N tends to ∞. In case of a small number N, a Student formula is used for calculation. Using this formula, the average real value of numbers array is found:

$X_{average}$ = <x>± ξ, где ξ - confidence interval.

The value of this interval is calculated as follows:

$\xi = \frac{t_{p,N}\sigma}{\sqrt{N}}$, где σ — standard deviation of numbers array

$t_{p,N}$ — Student coefficient.

Results of the study

The age variability as child grows up poses the certain specificity on normative cognitive performance in healthy children [14]. That is why in clinical practice, it is appropriate to compare obtained results with the specific standards for the same age. In this regard, it was appropriate to define standards for each age group with an annual interval.

Derived norms of cognitive activity are presented in Tables 2 and 3.

It should be emphasized that these rules apply to set of parameters only for the methods listed in the Table. 1. Obtained standards can determine deviations in cognitive activity state during the examination of children on KPFK-99 "Psychomat". However, the qualitative nature of cognitive impairment in the individual child is not fully reflected by comparing with the norm and stating the deviations in the performance of certain procedure. It is very special that usually more than one cognitive function (rather several) is involved into selected methods. Therefore, occurred difficulties, if any, do not automatically give the answer which of the cognitive functions has been impaired. This makes it impossible to form functional part of the topical diagnosis.

There has been developed a model for determining violations of particular cognitive functions blocks. Basing on neuropsychological diagnostic methods according to A.R. Luria [15] there were identified the major functional blocks and the individual parameters of the different methods from KPFK-99 "Psychomat," which measure these parameters (that is being specific to them). This selection allows to conduct topical diagnosis as well, as each of the blocks is localized on a certain cerebral cortex area. The analysis of these parameters on their correlation to the function blocks makes it possible to judge on the state of cognitive functions. The scheme of correlating methods' parameters in KPFK to blocks of cognitive functions is presented below in Fig. 1.

A special function of visuospatial memory assessment, performed in accordance with Mnemotest method using the KPFK-99 "Psychomat", cause some certain difficulties. On the one hand, Mnemotest is the only memory-specified function method, on the other hand - the process of assignment is carried out not only through the function of visuospatial memory, but also using visuospatial perception. That is why the impact of the implementation techniques cannot unambiguously reflect the state of visuospatial memory. In this regard, there was developed a special visuospatial memory index, where the numerator is represented by successful implementation of correction tasks, and the denominator is represented by the average number of correct answers in Mnemotest.

This index eliminates the contribution of visuospatial perception into the effectiveness of Mnemotest performance, as it also takes into account the successful implementation of the correcting task, which depends solely on visuospatial perception state. The index should be considered only in case of deviations from normal performance at Mnemotest. Violation of visuospatial memory function is detected if values reach above the standard. The calculated rates of visuospatial memory index are shown separate from the other parameters (see Tables 2, 3), as they are calculated by the researcher and not automatically by KPFK-99 "Psychomat". The index values are listed in Tables 4 and 5.

Analysis of age dynamics of cognitive performance standards showed that along with the increase of age, of methods performance effectiveness improves: the average execution time of tests is reduced and the number of correct answers increases. In this case significant differences were obtained between age pLInts in several intervals from each other (for example, between 9 and 12 years), but not between adjacent (eg, between 9 and 10 years).

On this basis, it can be assumes that as a child grows older the improvement of cognitive activity proceeds smoothly, without significant jumps within 1-2 years. In addition, the nature of the age distribution of cognitive activity results proves the hypothesis on binding standards to age intervals of 1 year.

Otherwise, if there will be matched rates for age groups at intervals of 3-4 years (primary school age, senior school age, etc.), children in the boundary age groups with normal cognitive activity may automatically fall into the category of children with impaired activities.

In order to present detailed dynamics of age-specific cognitive functions there was carried out further analysis of methodology for assessing the results on the functional blocks. For clarity and comparability of dynamic parameter curves presentation in different units, the results of each of the parameters have been translated into percents in different age pLInts with respect to maximum results, taken as 100% (Fig. 2-4)

Graphical analysis of age dynamics of cognitive function demonstrated relative uniformity, while the parameters of cognitive function improve evenly as children grow older. Abrupt changes were recorded only in two positions.

In the first case there was recorded an abrupt increase in performance on the static coordination tests between the groups 13-14 and 15-17 years (see Fig. 2B). However, in our opinion, this does not prove a sharp improvement of static coordination in the boundary age groups, but it rather proves that testing samples were not performed adequately enough by children aged 13-14 years. This can be explained by the fact that static tests are extremely sensitive to emotional stress factor, which can be often faced by neuroscientists, who observe the so-called voltage tremor. The evidence of anxiety and emotional tension during the motor tests is mostly evident among teenagers aged 13-14 years, which has likely caused by impact insufficient performance of static samples in this study.

In the second case there could be seen a significant reduction in run-time tests of visuospatial perception in children aged 8-12 years (see Fig. 4A), which can be explained by the known fact of intense maturation of tertiary association fields of cerebral cortex, that are responsible for complex perception forms and regulation of voluntary activity [14, 15]. A smooth improvement of temporal parameters of visuospatial perception of children aged 11-12 years indicates that school subjects, requiring the development of the cognitive functions (geometry, drawing), would be untimely taught before reaching a specified age period (12 years).

Analysis of the dependence of the tasks results according to sex showed that there are no significant differences in performance between boys and girls. This fact can be regarded as one of the scientific arguments justifying the inadvisability of separate education for boys and girls in schools, because proponents of the separate education for boys and girls usually argue on gender differences in cognitive activities of children.

The results of cognitive performance standards, obtained in this research, are of great scientific and practical value, as they maintain extensive and detailed age-dependent and provide an opportunity to evaluate cognitive activity in objective quantity. In addition, the existence of such regulations relieves clinicians and researchers from comparing their own groups of cognitively healthy children, while applying KPFK-99 "Psychomat", in order to diagnose cognitive function state. In order to settle the status of individual cognitive functions on the basis of the obtained standards, there is recommended analysis of methods' parameters by relating them to the topical clusters of cognitive functions. The results may be used to justify the neurophysiological bases of school tutoring. High standard of methodological and technical performance is supported by age dynamics data that demonstrate an even increase in children's performance as they grow older.

Conclusion

1. **C**ognitive performance norms for healthy schoolchildren with an interval of one year were received, which allows to estimate cognitive activity in objective quantity.
2. An even increase in performance had place, as children grew older, thus indicating a smooth improvement of cognitive functions of the child throughout the school-age.
3. According to the collected data, it is not appropriate to unite children into expanded age groups (such as junior, middle and senior school age) for the regulatory assessment of cognitive activity is inappropriate.
4. The absence of gender differences in cognitive performance of children (as used in the methods) was proved, which beats one of the arguments for separate education of girls and boys in mass schools.

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Table 1. Parameters of examination methods

№	Parameter	Dimension	Value
Simple sensorimotor reaction			
1	Stimulus modality	-	light
2	Number of training reactions	piece	1
3	Number of main reactions	piece	5
4	The lower limit of time	ms	450
5	The upper limit of time	ms	1350
6	Self-assessment of success	-	none
Complex sensorimotor reaction			
1	Stimulus modality	-	light
2	Number of training reactions	piece	1
3	Number of main reactions	piece	7
4	Consequence type	-	random
5	Test version	-	1
6	The lower limit of time	ms	450
7	The upper limit of time	ms	1350
8	Self-assessment of success	-	none
Static coordination			
1	Hole version	-	3 (4,8 mm)
2	Feedback	-	exists
3	Initial time	c	1
4	Main time	c	5

№	Parameter	Dimension	Value
5	Self-assessment of success	-	none
Dynamic coordination			
1	Feedback	exists	1
2	Self-assessment of success	none	2
Correction test			
1	Number of training reactions	piece	2
2	Number of main reactions	piece	8
3	Consequence type	-	random
4	Test version	-	1
5	Feedback	-	exists
6	Self-assessment of success	-	none
Mnemotest			
1	Exposition time	ms	2000
2	Pre-exposition time	ms	0
3	Post-exposition time	ms	0
4	Set of light images (LI)	Proportion of shaded cells	2/16
5	Consequence of LI	-	random
6	Playback mode pf LI	-	Direct positive
7	Rotation angle	grad	0
8	Size of LI	-	3*3
9	Number of LI in test	piece	5
10	Number of test repertitions	piece	1
11	Opportunity to correct the answer	-	none
12	Self-assessment of success	-	none
Binatest			
1	Stimulus modality	-	light
2	Number of training reactions	piece	5
3	Number of main reactions	piece	10
4	Test	-	1
5	Test version	-	1

№	Parameter	Dimension	Value
6	Shift (deposition depth)	-	1
7	Self-assessment of success	-	none
Rhythmotest			
1	Stimulus modality	-	light
2	Length of the stage "Rhythm"	piece	20
3	Initial rate of response phase of the "Rhythm"	piece	1
4	Rhythm period	ms	500
5	Length of "Tapping" stage	piece	20
6	Initial rate of "Tapping" response phase	piece	1
7	Self-assessment of success	-	none

Table 2. Performance standards for children aged 8 - 11 years.

Method	Method parameters	8 years (n=25)	9 years (n=24)	10 years (n=22)	11 years (n=26)
Simple sensorimotor reaction	Average motor time	298,7±32,57[1]	238,7±38,3[1]	224,2±50,8	212±25
		295/301*	225/243	203/267	210/213
	Average latency time	287,65±17,5[1]	288,06±22,3	287,8±52,92	279±21[1]
		282/289	287/292	273/296	251/288
Complex sensorimotor reaction	Average motor time	331,76±31,9[1]	300±41,12	265±47,51[1]	266±39
		328/335	290/314	246/279	276/345*
	Average latency time	347,65±33,14[2]	337,46±48,33	311±72,87	308±32[3]
		341/350	329/342	301/328	277/345*

Static coordination	Touch frequency	0,68±0,17[3]	0,64±0,35	0,62±0,95	0,50±0,20[3]
		0,7/0,67	0,63/0,64	0,61/0,64	0,37/0,76*
	Average time on touch	72,45±43,33	66,66±23,5	66,4±30,46	63±29
		71/73,2	65,1/67,4	66,1/67,7	61,2/70
	Integral value (the total duration of touches to the time of performance in%)	4,36±3,75	5,00±2,94	4,49±3,2	5,05±2,81
		4,06/4,7	5,1/4,95	4,38/4,51	4,12/6,97
Dynamic coordination	Time of fulfillment	36078±7851[1]	28728±4849	27511±2656	28501±5372
		36051/37014	28680/28793	27402/27632	28318 /29169
	Touch frequency	1,68±0,35	2,12±0,36[1]	1,53±0,5	1,76±0,37
		1,67/1,70	2,1/2,3	1,48/1,55	1,66/1,79
	Average time on touch	188,25±34,4[1]	184,53±22,4	184,2±43,7	183±48
		188/187	183/188	176/198	197/178
	Integral value	30,174±6,14	30,14±4,67	29,58±13,16	30,18±7,49
		30/30,2	30,05/30,2	29,12/30,1	27,49/35,12
Rhythmotest	The average interval reaction on "Rhythm" stage	494±29,26	564±117,9	550±123,12	548±34
		503/489	589/500	576/514	560/521
	Trend of "Rhythm" stage	9,155±4,45[2]	3,96±3,60	3,8±6,52	2,2±1,9[2]
		9,12/9,2	4/3,8	3,72/3,97	2,2/2,1
	Average interval of reactions, "Tapping"	453±27,68	479,9±28,9	498,8±62,78	539±35

		447/460	469/487	474/512	552/517
	Trend of "Tapping" stage	0,575±3,53	-3,14±2,17	-0,42±5,71	-0,95±1,23
		0,573/0,578	-3,10/-3,21	-0,4/-0,47	-0,97/-0,93
Correction test	Number of mistakes	0,3±0,25[3]	0,33±0,25	0,2±0,55[3,2]	0,17±0,24[2,3]
		0,3/0,3	0,33/0,34	0,2/0,2	0,17/0,16
	Average answer pace	6374±558,8[3]	5977±612,9	4409±782,7[3,1]	3486±288[1,3]
		6403/6331	6058/5942	4498/4351	3526/3412
	Successful answers	95,55±3,78	95±3,80	97±8,37	97±3
		95,6/95,53	94,9/95,1	97,1/96,9	97/97
Binatest	Average rate of mistakes	-	-	-	13±8
					13,4/13,2
Mnemotest	The average number of correct responses to one light image (LI) (%)	90,5±8[1]	88,5±8,5	89±5[1,3]	94,6±2,0
		90,5/90,5	88,4/88,7	89/89,2	93,8/94,9
	Average time for LI playback	7856,35±1340,9	6217,73±915,9	5911±982,55	4652±988
		7813/7887	6198/6245	5840/5973	4128/4265

Note [1] — Significant differences p <0,05 between these age groups, [2]- Significant differences p <0,01 between these age groups, [3]- significant differences p <0,001 between these age groups.

* - here and further on with a sign «/»– parameter value in girls/boys

Table 3. Performance standards for children aged 12 - 17 years

Method	**Method parameters**	**12 years (n=27)**	**13 years (n=24)**	**14years (n=25)**	**15years (n=25)**	**16years (n=23)**	**17years (n=25)**

Simple sensorimotor reaction	Average motor time	186±21[1]	188±30	172±23	150±29[1]	151±33	140±20
		183/189	179/187	166/176	141/156	142/153	138/145
	Average latency time	259±19[1]	260±24	262±19	250±22	250±27	240±14[1]
		238/279*	227/269	224/265	219/255	219/257	214/251
Complex sensorimotor reaction	Average motor time	264±34	253±48	254±31	232±24	204±39[1]	208±61
		269/292	241/278	236/264	219/254	204/204	206/210
	Average latency time	296±23[2]	297±28	296±26	271±21	269±30	263±28[3]
		274/302	291/301	289/298	261/282	257/277	251/270
Static coordination	Touch frequency	0,54±0,23	0,6±0,3	0,6±0,3	0,4±0,3	0,2±0,15[3]	0,2±0,15
		0,48/0,55	0,6/0,6	0,6/0,6	0,4/0,42	0,2/0,21	0,2/0,2
	Average time on touch	63±29[3]	65±34	65±27	63±23	51±16	52±19
		59/68,7	58,8/67,4	57,9/66,1	57/64,8	50,7/52,2	51,5/52,7
	Integral value (the total duration of touches to the time of performance in%)	4,51±2,03	5,81±4,16	5,24±2,9	4,74±3,77	1,54±1,8	0,86±0,98
		4,03/5,96	3,91/5,9	3,8/5,84	3,62/5,1	1,07/2,3	0,73/ 0,98
Dynamic coordination	Time of fulfillment	28096 ±5196	25658 ±6169[1]	24974 ±6253	22835 ±5459	19924 ±3669	19414 ±4655
		23996 /27140	23240 /26721	18536 /22816	17596 /22032	17254 /20924	16970 /20423
	Frequency	1,86±0,35	1,96±0,52	2,09±0,43	2,0±0,47	1,99±0,64	1,75±0,27[1]
		1,78/1,94	1,91/1,98	2,07/2,13	2,0/2,1	1,99/1,98	1,75/1,75
	Average time on touch	148±21	141±24	142±16	137±19[1]	139±28	139±15
		162/146	157/139	149/137	141/134	140/132	138/129

	Integral value	27,27±5,8	27,15±6,64	26,50±4,9	24,73±5,2	24,63±8,76	23,95±3,1
		26,57/33,3	26,15/31,1	25,66/30,2	23,76/25,3	23,6/24,9	23,06/24,4
Rhythmotest	The average interval reaction on "Rhythm"	522±23	511±25	517±21	521±34	539±50	508±33
		549/512	545/506	543/503	535/503	529/492	517/488
	Trend of "Rhythm" stage	2,6±2,8	1,0±3,0	1,2±1,8	3,4±4,7	4,8±5,0	0,8±3,4
		2,5/2,6	1,0/1,0	1,2/1,2	3,4/3,3	4,7/4,9	0,8/0,8
	Average interval of reactions, "Tapping"	502±31	478±30	497±30	526±34	521±57	520±84
		512/485	468/495	523/470	510/532	534/498	531/501
	Trend of "Tapping" stage	-2,52±1,9	-1,72±1,84	-1,8±1,3	-2,0±1,45	0±2,1	-0,9±2,1
		-2,7/-2,03	-1,98 /-1,58	-1,9/-1,7	-2,21/-1,95	0/-0,4	-1,1/-0,75
Correction test	Number of mistakes	0,18±0,17	0,2±0,2	0±0[3]	0±0	0±0	0±0
		0,178/0,18	0,2/0,2	0	0	0	0
	Average answer pace	3383±240	3298 ±222	3086±365	2731±272[3]	2610±241[3]	2592±590
		3495/3245	3392/3109	3442/2894	3154/2601	2680/2312	2696/2480
	Successful answers	97±5,9	97±3	99±2	99±2	98±4	98±3
		97/97,2	97,1/97	99/99	99,8/100	98,1/98,4	98,5/98,6
Mnemotest	The average number of correct responses to one light image (LI) (%)	97,4±2	99±2[1]	98,6±2	100±2	100±2	100±2
		97,7/98,5	98/98	98,5/99	100/100	100/100	100/100

	Average time for LI playback	3779±458[3,1]	3427±368	3200±342[1]	3239±382	2884±471	2861±509
		3597/3780	3302/3560	3196/3295	3132/3050	2752/2987	2741/2874
Binatest	Average mistake rate	11,6±7	11±6	10±6	10±5	8±5	7±4
		11,7/11,4	11/11,3	9,8/10,3	10/10,1	8/8	6,8/7,1

Note [1] — Significant differences p <0,05 between these age groups, [2]- Significant differences p <0,01 between these age groups, [3]- significant differences p <0,001 between these age groups.

* - here and further on with a sign «/»– parameter value in girls/boys

Table 4. Norms of visuospatial memory index, calculated directly by the researcher

Method	Method parameters	8 years (n=25)	9 years (n=24)	10 years (n=22)	11 years (n=26)
Mnemotest	Answering success at correction test / Average number of correct answers to one LI	1,05	1,07	1,89	1,03
		1,05/1,05	1,07/1,071	1,89/1,9	1,04/1,022

Table 5. The norms of visuospatial memory index, calculated directly by the researcher

Method	Method parameters	12 лет (n=27)	13 лет (n=24)	14лет (n=25)	15лет (n=25)	16 лет (n=23)	17 лет (n=25)
Mnemotest	Answering success at correction test / Average number of correct answers to one LI	0,995	0,979	1,004	0,99	0,98	0,98
		0,99/0,98	0,99/0,99	1,01/1	0,998/1	0,98/0,98	0,98/0,98

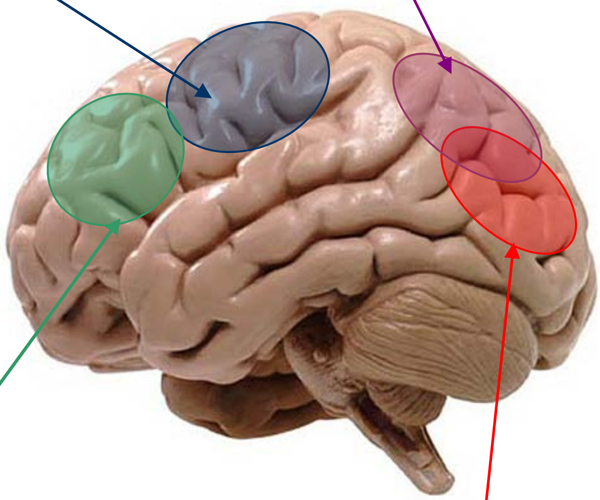
Fig. 1. The scheme of parameters correlation of KPFK techniques with cognitive functions blocks

Psychomotor activity

1. Simple sensorimotor reaction
   - Average motor time
2. Complex sensorimotor reaction
   - Average motor time
3. Static coordination:
   - Touch frequency
   - Average touching pace
   - Integral value*
4. Dynamic coordination:
   - Performance time
   - Touch frequency
   - Average touching pace
   - Integral value*
5. Rhythmotest:
   - The average interval of reaction "Rhythm"
   - Trend segment "Rhythm"
   - The average interval of the reaction

Visuospatial perception:

1. Correction test:
   - Answering success
   - Average anwering rate
2. Mnemotest:
   - Average number of correct answers



Voluntary attention

1. Simple sensorimotor reaction:
   - Average latency time
2. Complex sensorimotor reaction:
   - Average latency time
3. Correction test
   - Number of mistakes
   - Average answering rate
4. Mnemotest:
   - Average number of correct answers to one LI (%)
   - Average time of playback on LI
5. Binatest:
   - Average rate of mistakes

Visouspatial memory

1.Mnemotest:

- Average number of correct answers to one LI (%)
- Visouspatial memory index (VSMI)

Fig. 2A. Dynamics of motor reactions in children of different age groups (average run-time on tests)

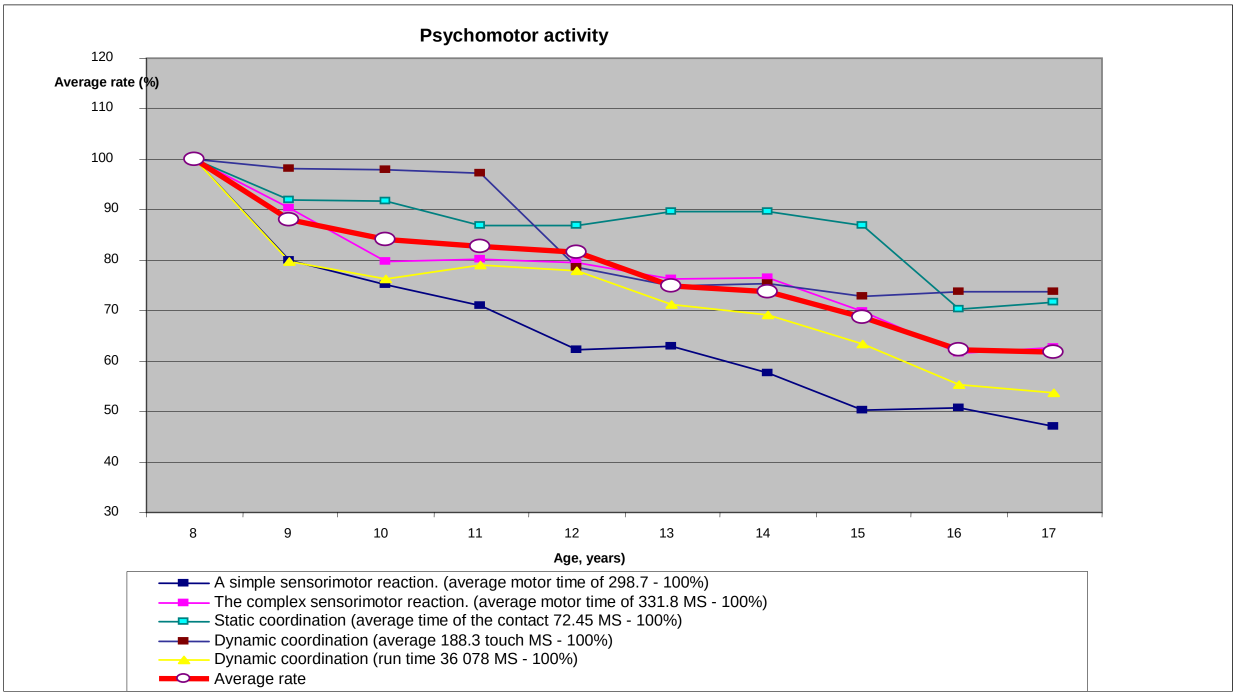


Fig. 2B. Dynamics of motor reactions in children of different age groups (number of contacts in tests)

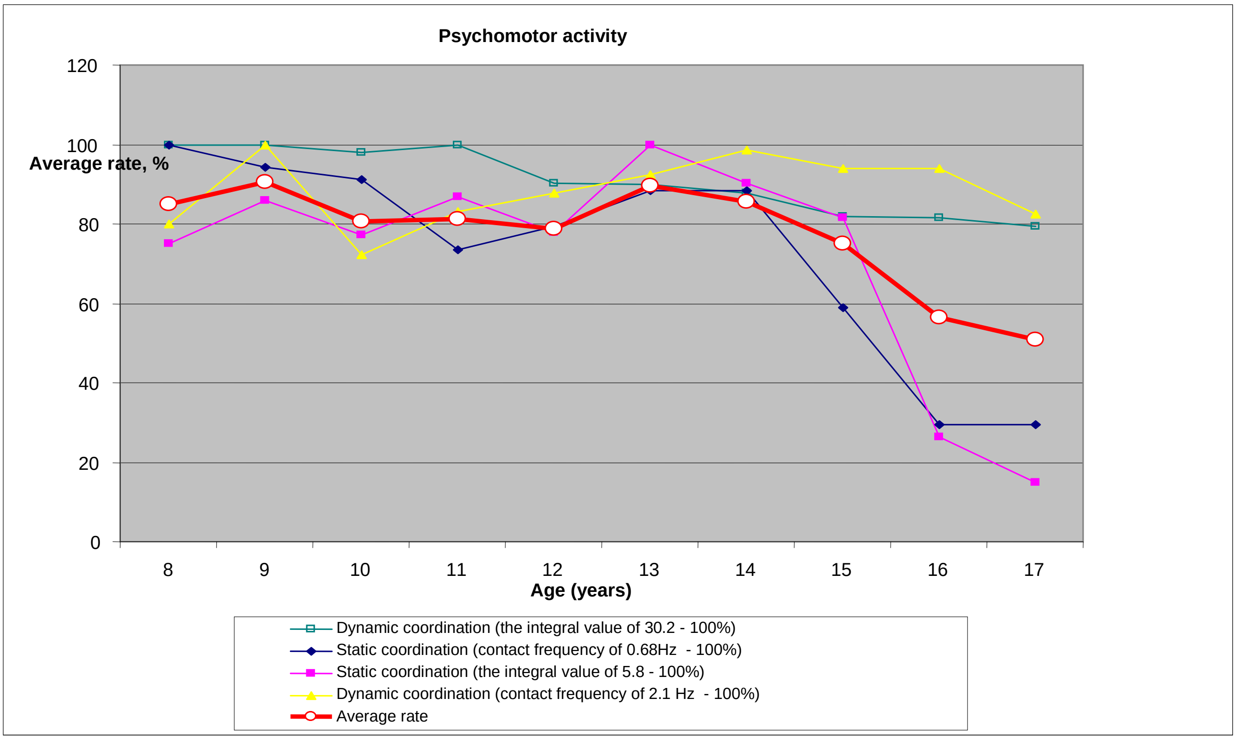


Fig. 3A. Dynamics of voluntary attention in children of different age groups (average run time on tests)

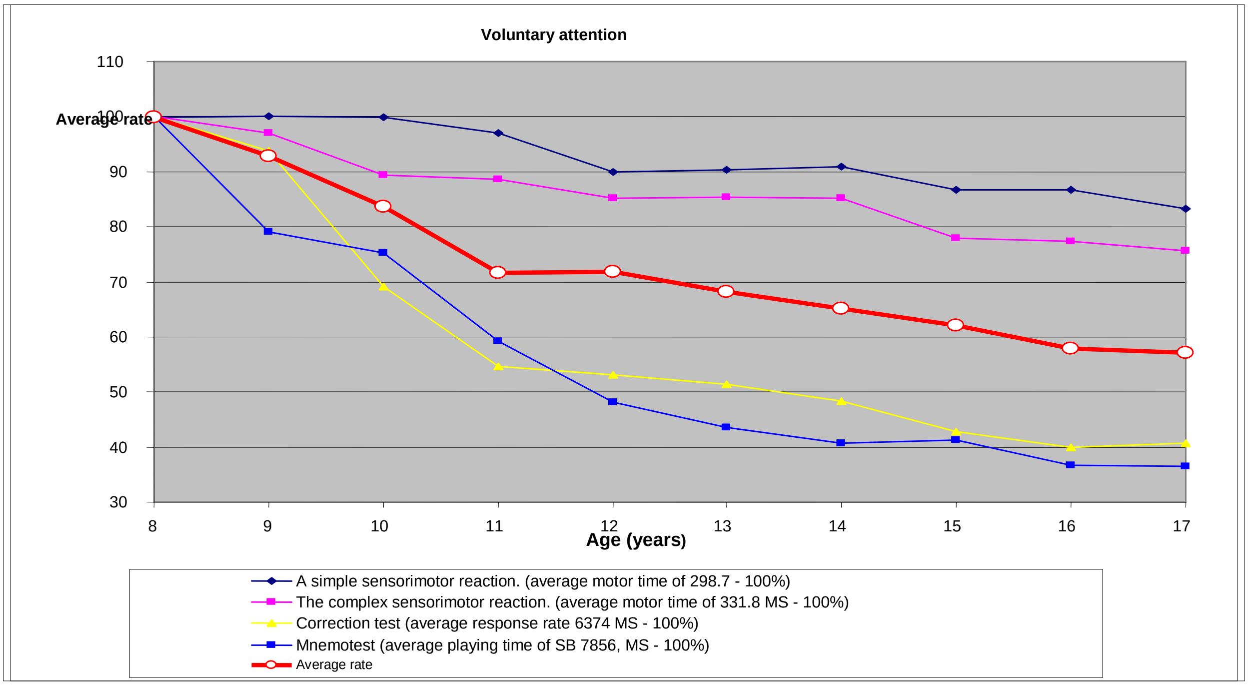


Fig. 3B. Dynamics of voluntary attention in different age groups (number of correct answers in the tests)

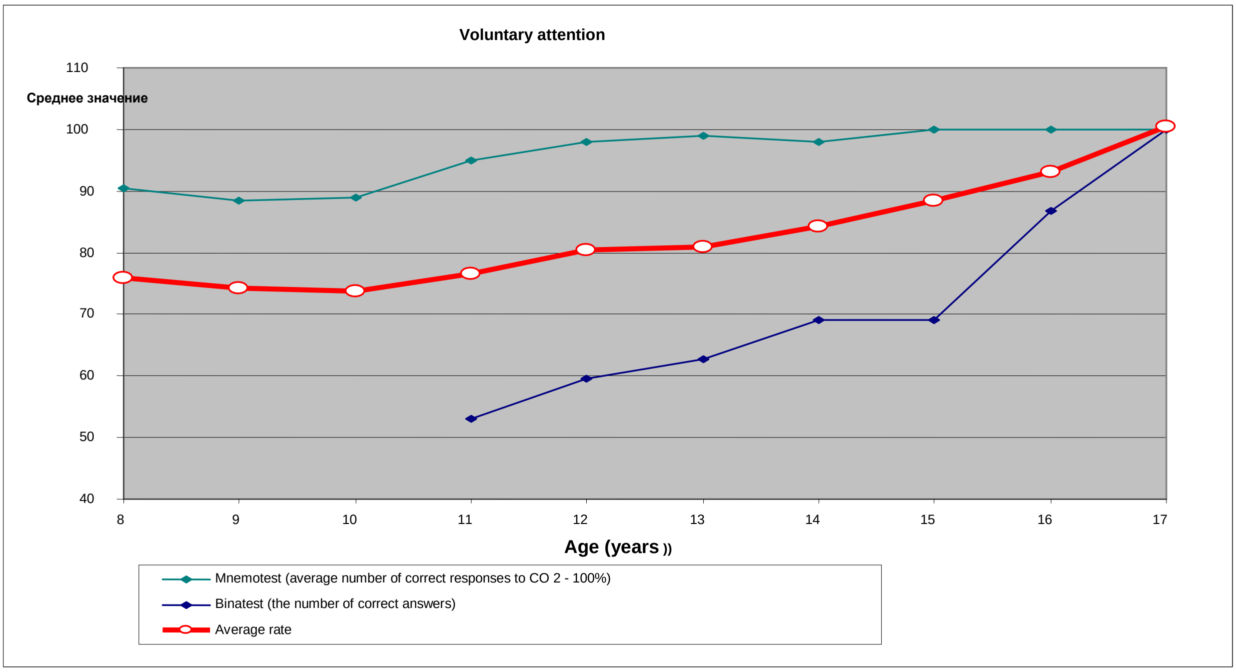


Fig. 4A. The dynamics of visuospatial perception in different age groups (average run time on tests)

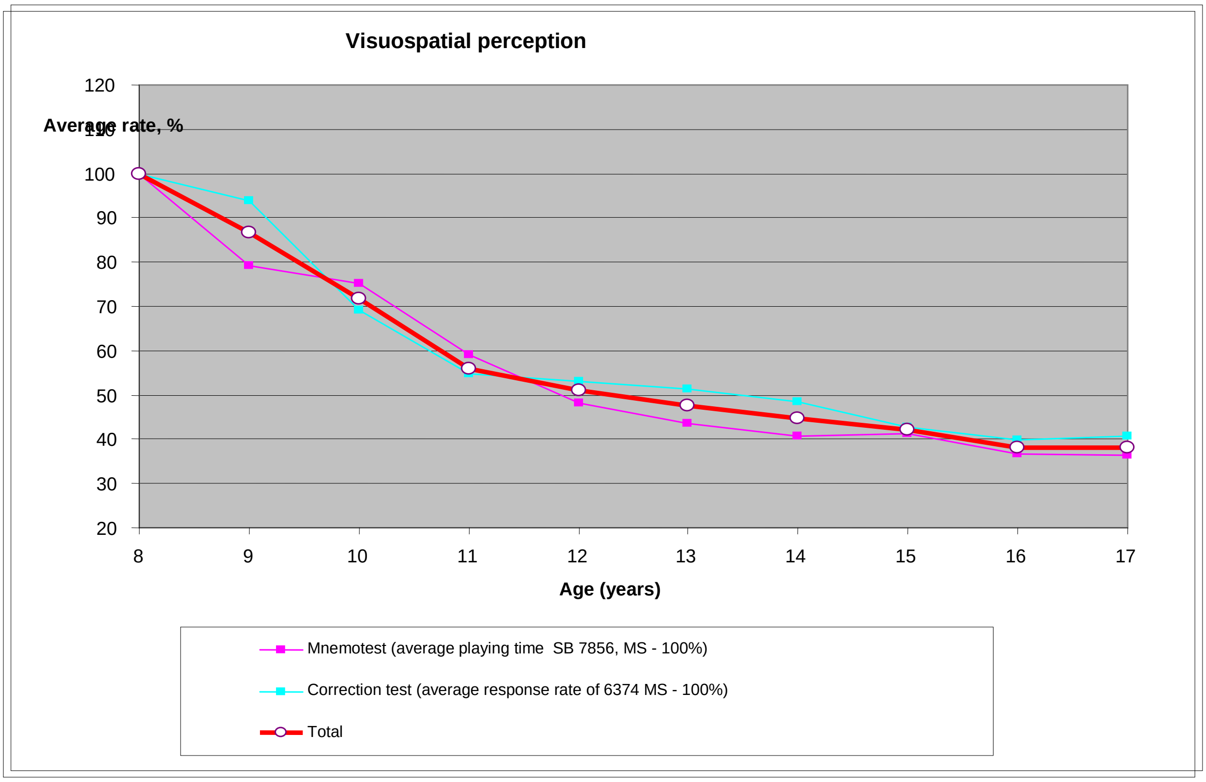


Fig. 4B. Dynamics of visuospatial perception in different age groups (number of correct answers in the tests)