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The role of visual load in the process of children's and teenagers' visual system formation

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*The **aim** of the research is the analysis of text visual load influence on the structural and functional state of children's and teenagers' visual system. 97 children and teenagers as well as 88 young adults took part in the research.*
***Materials and methods.** The research has been carried out with the participation of 97 children and teenagers and 88 young adults. The texts with different typographic parameters on the paper carrier were used as a visual load. The typestyle of 10 typographical points was used for normal texts and 7 typographic points typestyle was used for the texts with undersized parameters. The positive reserve of accommodation for distance, the near point of clear vision and convergence were used for estimation of visual system state in the dynamics of visual work.*
***Results.** The factor analysis allowed establishing that the special mechanisms of visual perception of close objects were not formed in children and teenagers. It was proved by the fact that the visual work at close distance had led to obvious visual system stress. This stress was manifested by the increase in significant connections in the visual system and by presence of random components. Several different types of system organization have been determined at the same time. The configuration and number of connections in the visual system of young adults was preserved after the visual load. This is evidence that the visual system formation is completed in adult persons.*

Introduction

During the growth and the development of a child, the success of formation of visual system depends on a number of factors, which include special characteristics of structural and functional organization, genetic predisposition to a visual pathology, living conditions, visual environment as well as the quality and the quantity of visual information to be processed. Therefore, the visual surrounding of a child, a kind of "visual living environment", is of great importance [5, 6, 8, 13, 17, 18, 20].

Each stage of visual system formation has its own type of optimal visual load, determined by the dimensions of objects of recognition, their contrast ratio, and color range [4, 8-11, 13, 16]. When the visual load quality is low or when interacting with it for a long time, child's visual system will be put in difficult conditions of functioning, under which the visual perception will require a mobilization of all its resources. In addition, it should be noted that the human body elements are not perfect; all paired organs have differences that are compensated by an establishment of specific system of connections between them. In a visual system having two monocular subsystems, quite complex relations are set to provide a high-quality visual perception during the growth of the child [1, 7]. In case when the system has some "defects" caused by different structural organization or functional capabilities,

as binocular system with high visual functions, as a simple – the monocular, challenged one, can be formed [1, 7, 16, 19, 20].

The visual surrounding of modern children and teenagers has changed greatly over the last two decades; therefore, its role in the formation of the visual system has changed too. The complication of visual environment is caused by the emergence of new visual information media and by the quality change of the existing ones. Visually effective factors can include both traditional (games, toys, books, fiction, television) and quite new (computers, tablets, game consoles, electronic gaming devices such as Tetris, games on mobile phone). An assessment of the duration and frequency of the mentioned factors effect allows designating them as the primary ones influencing the visual system state [5, 6, 8, 9]. Some visual load characteristics can influence the functional state of the visual system. This is, first of all, the size of the object of perception that is hygienically regulated for each age [10, 13]. In addition, a significant role is played by objects` contrast ratio, as the selection and the contour emphasizing of the perceived image is one of the visual perception mechanisms. A method of forming image (continuous, discrete) affects the visual system too, as the perception of a discrete image from a computer monitor, a screen of a mobile phone or a tablet requires more tension of central visual perception mechanisms in comparison with a continuous perception of an image from paper.

Another characteristic is the color composition of the perceived information, including not only the color of targeted object of recognition but also the color ratio of its parts and external environment. The effect of' color is associated not only with its significant psycho-emotional impact on the human body that can negatively affect the child's general state, but also with the particularities of the perception of particular colors.

Despite a considerable popularity of new visual information media, reading is still the main way of acquiring knowledge in learning and leisure. Unfortunately, the quality of printed materials for children does not always meet modern hygiene requirements that may cause visual impairment.

The purpose of this work is to analyze the impact of the text visual load on the structural and functional state of the visual system of children and teenagers.

Research object and methods

To confirm the impact of format parameters of text load on paper carrier on the visual system formation process as well as on the development of donozology and pathology, a research has been conducted with participation of 97 children and teenagers. The inclusion criteria were as follows: distance and near visual acuity equal to 1, at least; positive accommodation reserves for distance and nearness equal to 3D, at least; the nearest point of clear vision and convergence within the range from 3 to 7 cm.

For making a comparison, a study has been performed with the aim of establishing the impact of texts with low readability parameters on visual system on 88 persons of young age (university students, the average age of which was (20 ± 1.5) years) with no ophthalmic pathology detected.

Before and after the work with a visual load that lasted 45 minutes and took place on different days, all subjects'` distance and near visual acuity positive accommodation reserves (AR) for distance and nearness, nearest point of clear vision (NP) and convergence (NPC) have been determined. Using correlation analysis (by removing highly correlated indexes) positive distance AR as well as the position of OU NP and NPC have been selected from all the investigated indexes to describe the visual information perception process.

In the course of research, the paper texts having different readability parameters were presented to the subjects as a visual load (the first load: normal font – 10 typographical points; the second load: undersized font – 7 typographical points). The visual task was to find and to strike out a given letter in the text. To process the results of the research, correlation and factor analysis, descriptive statistics, nonparametric tests of differences (Mann–Whitney–Wilcoxon), methods of alternative characteristics analysis have neeb used.

Results and their discussion

The subjects were divided into three age groups: junior, middle and senior school age. According to the research results of N. M. Maslova [11, 12] N. N. Vasilieva [2, 3], the younger group included 6-10 years old children, whose visual system is characterized by structural and functional immaturity, high mobility and function lability. 11-12 years old subjects composed the middle group. This age period is characterized by lower function lability, but a more expressed reaction to the visual load that is probably caused by significant structural and functional shifts throughout the body, and hormonal and metabolic imbalance. In the older age group (13-15 years old) the termination of the visual system formation occurs that is characterized by a higher stability of functional reactions to visual

load due to the formation of structural trace of adaptation to the reading as this type of the visual load is the main one for all the school years.

Table 1 shows the average values of the functional parameters of the visual system of children and teenagers of different age groups as well as of young people. According to the represented data, it is clear that the first age group (6-10 years old) has significantly lower functional indexes than the second one (11-12 years old). The children from the second age group have function indexes close to those of the adults, but in this age, high plasticity of the visual system still remains.

In the older age group the AR value is slightly lower than in the middle group but NP in this group are most closer to the indexes of the adults (the adults` ones are situated at 7-8 cm from the eyes).

Table 2 shows average values after the visual work with text load. The first load is a text with format parameters corresponding to age norms. The second load is an undersized text.

Analysis of the data presented in Table 2 and its comparison with the baseline values (Table 1) allow to make certain conclusions. It may be noted that in all age groups as a result of near-distance work there is a certain growth in AR approximation to the eyes of NP and NPC. However, we detected statistically significant changes in relation to AR only. This may be caused by opposite changes of indexes in investigated groups of children and teenagers. To detect patterns of index change in the course of visual work each of three possible options of index change (increase, decrease, no change) have been analyzed with two types of visual load (Table 3).

Through analyzing the presented data, it can be noted that after the first load in all the age groups the significant index changes are the increase of AR and the decrease of NP and NPC. Such index change indicates a formation of a state similar to transient myopia [14, 15]. The detected AR increase occurred, in fact, by the value of emergent transient myopia and stopped within 1-2 hours.

Table 1. Functional index values of visual system of children, teenagers and young people

Age, years	Indexes				
	AR OD (D)	AR OS (D)	NP OD (cm)	NP OS (cm)	NPC (cm)
6-10 (n=33)	3.9± 1.8*	4.4±1.9*	5.7 ±1.2	4.5± 1.5	5.0 ±1.3
11-12 (n=25)	8.4±1.3	8.1±1.4	5.2±1.7	5.4±1.8	4.2±1.6
13-15 (n=39)	7.3±1.4	7.2±1.6	6.0±1.2	6.0±1.5	4.8±1.5
18-22 (n=88)	5.4±2.7	5.2±2.8	6.6±1.9	6.7±1.8	6.0±1.8

Notes: *- differences in the values of accommodation reserves in the young children group and the children of the middle group are significant following Mann-Whitney test ($p < 0.05$); n - the number of children in a group

Table 2. The values of functional indexes of visual system of children and teenagers after a visual work with printed texts

Type of load	Age, years	Indexes				
		AR OD (D)	AR OS (D)	NP OD (cm)	NP OS (cm)	NPC (cm)
First	6-10	5.3± 1.7*	5.3± 1.8*	5.5 ±1.1	5.3± 1.3	3.8 ±1.1
	11-12	9.5±1.3	9.4±1.6	4.9±1.7	4.6±1.6	3.4±1.1
	13-15	7.7±1.5	7.9±1.5	5.6±1.2	5.4±1.4	4.3±1.7
Second	6-10	5.7±1.3* **	5.6±1.2* **	5.2±1.0	5.1±1.0	3.4±1.1
	11-12	8.8±1.2	8.7±1.1	6.2±2.1	6.3±2.5	3.9±1.7
	13-15	8.3±1.3	8.1±1.2	6.3±1.1	6.2±1.2	4.8±1.5
	18-22	5.4±2.9	5.3±2.8	6.5±1.9	6.6±1.9	6.1±1.8

Notes: *- differences in the values of accommodation reserves in the young children group and the children of middle group are significant by the Mann-Whitney test ($P<0.05$);** - differences in the values of accommodation reserves in the junior and older age group are significant by the Mann-Whitney test ($P<0.05$)

Table 3. Distribution of indexes into groups depending on pattern of frequency change

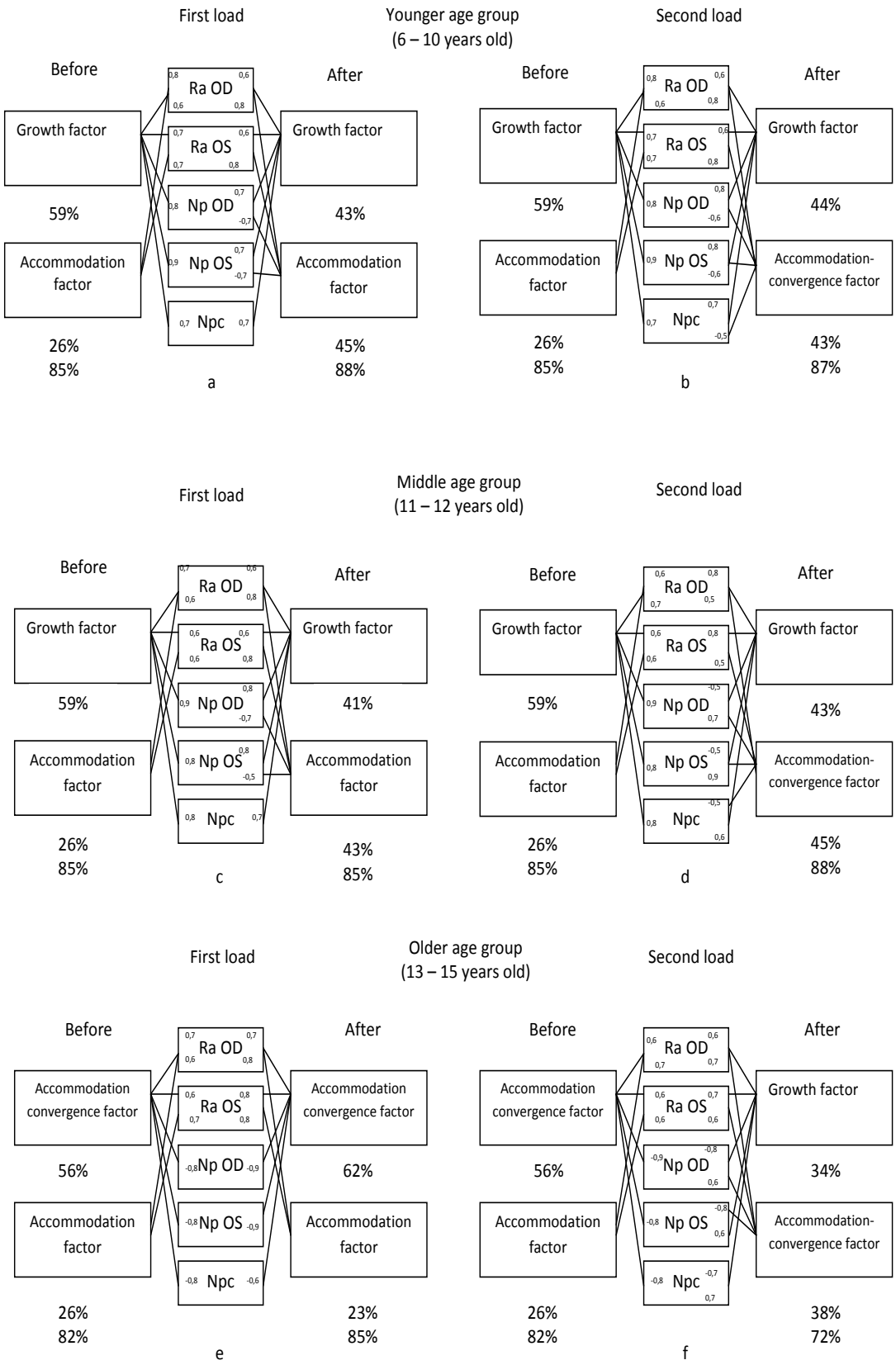
Type of load	Age, years	Index	Pattern of change (%)		
			Increase	Decrease	No change
First	6-10 (n=33)	AR	60±8.5	23±7.3[1]	17±6.5[2]
		NP	22±7.2[1]	65±8.3	13±5.9[3]
		NPC	25±7.5[1]	55±8.7	20±7.0[3]
	11-12 (n=25)	AR	60±9.8	20±8.0[1]	20±8.0[2]
		NP	19±8.0[1]	61±9.8	20±8.0[3]
		NPC	5.0±4.1[1]	85±7.1	10±6.0[3]
	13-15 (n=39)	AR	66±7.6	15±5.8[1]	19±6.3[2]
		NP	26±7.0[1]	57±7.9	17±6.0[3]
		NPC	18±6.0[1]	60±7.8	22±6.6[3]
Second	6-10 (n=33)	AR	55±8.7	25±7.8[1]	20±7.0[2]
		NP	30±8.0	55±8.7	15±6.2[3]
		NPC	20±7.0[1]	60±8.5	20±7.0[3]
	11-12(n=25)	AR	45±10.6	34±9.5	21±8.1
		NP	31±9.2	52±10.0	17±7.5[3]
		NPC	26±8.8[1]	63±9.7	11±6.3[3]
	13-15(n=39)	AR	51±8.0	35±7.6	14±5.6[2]
		NP	21±8.0[1]	66±7.6	13±5.5[3]
		NPC	37±7.7	41±7.9	22±6.6
	18-22 (n=88)	AR	24±4.5[2]	25±4.6 [3]	51±5.3
		NP	33±4.5	40±5.2	27±4.7
		NPC	42±5.2	29±4.8	29±4.8

Notes: [1]- differences in the frequency of index increase and decrease are significant (p<0,001); [2]- differences in the frequency of index increase and no change value are significant (p<0,001); [3] - differences in index the frequency of index decrease and no change value are significant (p<0,001); n - volume of the group

To evaluate the dynamics of functional indexes of children and teenagers under the influence of reading texts with different format parameters, a hypothesis has been formulated: the informativeness of the structure of these indexes correlation shall change in the process of visual work. To verify this hypothesis, factor analysis has been conducted and factor structures have been built (Fig. 1).

In the junior age group (Fig. 1, a and b) both before and after the two types of the load, the structures are flexible because they contain two factors each. Summary input of these factors in the total dispersion in all the cases is similar in value and makes up 85-88%. Before reading, the first factor unites all investigated parameters and forms fairly strong positive relations with them (correlation coefficients make 0.7-0.9). The input of this factor in the total dispersion makes up 59%. The visual system of children of this age group is in active formation process and its functional index values increase. The first factor impact leads to an increase of all investigated indexes and this factor can be named a "growth factor". After the first load (Fig. 1, a) the structure of relations of the first factor is preserved, although its internal relations slightly weaken, and the input in the total dispersion decreases to 43%. This factor – as before the load – leads to an increase of all the indexes and represents a "growth factor".

The second factor after the work unites AR for distance of OU only, causing their unidirectional change. This factor can be named an "accommodation factor". The presence of this factor can be explained by the fact that a young child mostly perceives quite large objects at a remote distance. After the first load the input of the second



Ra = reserve of accommodation; Np = near points; Npc = Near points of convergence.

Figure 1. Factor structures of functional indexes of children and teenagers before and after reading of paper texts with different format parameters.

factor has increased nearly twice. The structure of relations in the second factor has changed.

Now, its impact leads not only to AR increase but to the approximation of NP to the eyes. After the work, this factor unites the indexes related to the distance and near accommodation that is why it is named an "accommodation factor". The structure of the relations of indexes with this factor is typical for a state similar to transient myopia. (AR increase and approximation of NP to eyes).

In addition, it is to note, that the work with text having normal format parameters has put visual system of children in tension that was evidenced by significant increase of number of relations in the structure from 7 – before the work to 9 – after the work.

After the second load (Fig. 1, b) the "increase" factor has been preserved and its input into the total dispersion was the same as after the first load. The second factor as well has a similar input into the total dispersion as in the case of the first load. The character of its internal relations is the same as after the first load. It forms strong positive relations with AR and negative ones with NP and NPC. Since NPC is included into its structure, this factor can be named an "accommodation-convergence" one. Such a configuration of relations is also typical to transient myopia. The number of relations after the second load is 10; it points to an ever greater visual system tension in comparison with the first load.

The results indicate that the texts - both with normal format parameters and with undersized font have an impact on the functioning of visual system of young children and cause a state similar to transient myopia. The study involved healthy children with no ophthalmic pathology detected. The presence of the factor causing myopic index changes in the factor structures points to the possibility of formation of myopia under the influence of text load, particularly with an undersized format. It can be assumed that the probability of pathology formation during the work of children having low functional reserves of visual system with the first and the second visual loads is higher.

The structures of correlations between the indexes of visual system of the middle age group children (11-12 years old) after two types of visual load are presented on the Figure 1 c-d. It may be noted that the configuration of relations in obtained factor structures, their transformation after two types of visual load, input in total dispersion are similar to those in the junior age group. There are only some differences in the values of factor loads.

The obtained result points out that in the age of 11-12 the visual system does not have any formed mechanism of optimal near object perception. The appearance of a "pre-image" of this mechanism similar to myopia is observed when presenting a visual load with undersized format to children.

The results of the evaluation of interconnections between the visual system indicators in children of the older age group (13-15 years) are shown in Figure 1, e-f. By comparing the obtained structure with the structures of the younger and the middle age groups one may note their difference. Both before and after the work there is a factor present within the structure, the connection configuration of which corresponds to the "myopic" type functional system, ensuring the operation in close proximity, i. e. by this age such system has already been formed. Usually, provided that there were contributory causes and conditions, children already have "school" myopia by the age of 14-15 years. In this case, since the participants of the research were healthy children and teenagers, the obtained results indicate the established system of small objects perception at close distance.

The "accommodation-convergence" factor can be named as the first factor, both before and after the work, since it combines the accommodation indicators (reserve of accommodation and near points), as well as the near point of convergence, which in addition to accommodation is connected with convergence. The second factor before the work affects only the distance accommodation; therefore, it is named the "accommodative" one. After the first load the first factor ("accommodation-convergence factor") differs from the initial one by insignificant growth in factor loads. The resulting factor structures, both before and after the first load, indicate that this load is adequate to the visual system capacity of teenagers in the senior group, since it does not cause its structural and functional changes.

The second load for this age group also has led to an increase of the quantity of significant connections from 7 to 10, indicating the visual system tension. Moreover, it should be noted that the second load has reduced the dispersion percentage explained by means of the research indicators, which may indicate the presence of some other factors affecting the visual system, for example, associated with the significant subjects' nervous and emotional stress, caused by the low quality of the presented text. The second factor in

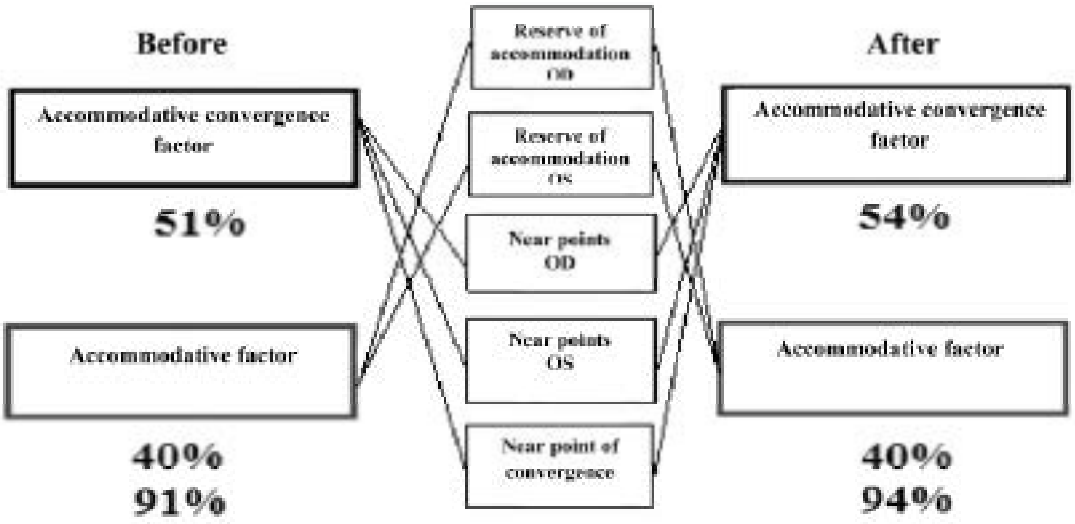


Figure 2. Factor structures of functional indicators of young adults before and after the reading of the text with reduced readability indicators on the paper carrier

the structure after the second load (Figure 1, f) is identical to the "growth factor" available in the younger and middle groups.

For comparison, we have defined the young adults' visual system parameters and a factor structure has been built before and after the text reading with reduced readability indicators (Figure 2). It may be noted that the initial factor structure of young adults (Figure 2) differs from such structure of teenagers (Figure 1, e, f). The young adults' structure describes the visual system almost entirely, since the factors' contribution to the overall dispersion amounts to 91% and the random component amounts to 9% only. In total, these two factors form a universal structure that ensures the objects' perception at different distances ("accommodation-convergence factor" – the near work, "accommodation factor" - distance perception).

After the work, the factors' contribution into the total dispersion has further increased and amounted to 94%, but the configuration of connections in the structure has not changed. Such a situation may indicate that the information perception system has formed at various distances, and visual work with the text in close proximity does not cause any significant tension, even with reduced readability indicators. This is confirmed by the preservation of the initial structure configuration and the quantity of connections. If we compare the structure in Figure 2 with the children' and teenagers' structures (Figure 1, a-f), we can note significant differences. "Growth factor" is not relevant for young adults and there is the same factors configuration and the same quantity of significant connections before and after the work. In addition, the selected factors make the greatest contribution into the total dispersion (90%) that also indicates a completion of the system formation, since the random component has a little effect on the connections structure. Children's and teenagers' work, even with the optimal visual load, appropriated for their age, causes an obvious tension of the visual system, manifested by an increase of the number of meaningful connections, big input of the random components and the presence of several variants of the indicators combination at the same time.

Conclusion

1. The evaluation of configuration of the connections in factor structures has demonstrated that in 6-10 and 11-12 years old children 12 years old children the visual system growth and formation continues, as evidenced by the presence of the "growth factor" causing unidirectional changes of all studied indicators, which remains in the system after various kinds of visual loads. The appearance of "accommodation-convergence factor" in the factor structure after the performance of the load confirms the formation of children's mechanism providing the reading of the texts at near distance.

2. Visual work at near distance in children and teenagers, even with optimal and age appropriate

visual load, causes obvious tension of the visual system, manifested by the growth in the number of meaningful connections, an increase of the input of random components and the presence of several options of the studied system organization, as evidenced by the existence of the "accommodation-convergence" factor along with the "growth factor".

3. "Growth factor" is not relevant for young adults, the original configuration of factor structures is preserved after the visual work, and the number of significant connections is not changed. The factors, which were allocated in the factor structures, makee the biggest contribution into total dispersion (higher than 90%) compared to other age groups, and the configuration of connections, which indicates the presence of specialized mechanisms of the perception of objects, located at various distances, that at its turn indicates the completion of the visual information reception and the initial processing of visual information.

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