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LANDSCAPE AND ECOLOGICAL ENVIRONMENT AS A FACTOR IN COGNITIVE DEVELOPMENT

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ABSTRACT

The main goal of the work was to assess the processes that ensure the stability of attention, memory, and

mental performance of schoolchildren studying in two ecologically different environments, favorable and unfavorable, as well as the indicators of social and psychological well-being characterizing their quality of life, and their comparative changes. The study participants were fifth- and sixth-grade schoolchildren living in two ecologically distinct regions. The first group consisted of students from ecologically disadvantaged environments. The second group consisted of students of the same age (11–12 years old) from relatively ecologically favorable environments. Methods: The computerized adaptation of the well-known Landolt Circles proofreading test, called Vigilance Research, was used to assess students' attention span, attention stability, and mental performance. The "Numerical Memory" and "Picture Memory" methodologies (tests) were used to assess short-term visual memory, its volume, and accuracy. The level of social and psychological well-being of pupils was determined using the electronic version of the SF-36 v2TM questionnaire, which characterizes the quality of life. Conclusion: The combined assessment of attention, memory, as well as physical and mental health, allows us to establish that the quality of the ecological environment is a key and most important factor in cognitive development.

KEYWORDS: Cultural Characteristics; Effectiveness of Children's Education; Mental and Physical Activity; Cognitive Development; Social and Psychological Well-Being; Social and Ecological Significance; Landscape and Ecological Factors; Harmful Effects; Damage to Health; Quality of Life.

1. INTRODUCTION

The problem of destabilization of landscape factors and environmental disruption is now relevant for the entire world (Liu, Ai, McCauley et al. 2012; Lu, Hackman & Schwartz 2021; Rumyancev, Koronkevich, Izmailova et al. 2021; Ngun, Pleshakova, Reshetnikov et al. 2023; Chen, Wang & Kong 2024; Stanek, Cascio, Barzyk et al. 2024; Kaleji, Kazemi, Kamkar et al. 2025; Polas, Topp, Ahammad et al. 2025). By now, the transformation of landscape factors, including climate and weather (World Health Organization. Climate Change and Health 2021; Mokhov 2022; Bukharina, Didmanidze, Pashkova et al. 2024; Sargsyan, Larionov, Saidumov et al. 2025; Yeghiazaryan, Galstyan, Sayadyan et al. 2025), geomorphological features (Volodkin 2022; Galstyan, Sayadyan & Sargsyan 2023; Sargsyan, Tovmasyan, Gharakhanyan et al. 2025) and biogeocenoses (Lubimov 2016; Makosko & Matesheva 2020; Kotegov 2025; Yeghiazaryan, Galstyan, Sayadyan et al. 2025), environmental conditions in natural (Larionov, Dogadina, Tarakin et al. 2025) is quite clearly evident. al. 2021; Larionov, Volodkin, Volodkina et al. 2023; Lebedev, Lebedev, Sorokopudov et al. 2023; Mordukhovich & Adrianov 2023; Slavskiy, Matveev, Sheshnitsan et al. 2024) and natural-economic complexes (Tong, von Schirnding & Prapamontol 2000; Rozhnov, Lavrinenko, Razzhivin et al. 2019; Larionov, Sargsyan, Sayadyan et al. 2024; Zaburaeva, Zaburaev, Sedieva et al. 2025). Violation and pollution of natural-economic complexes (Sanders, Liu, Buchner & Tchounwou 2019; Ivanov, Ivanova, Kartashov et al. 2021; Vivallos Soto, Ruiz Bertín, Robles Calderón et al. 2022; Ngun, Pleshakova, Reshetnikov et al. 2023), including various settlements (Nazaryan 2009; Liu & Lewis 2014; Larionov 2013, 2022; Gibadulina 2022; Ramesh, Khiratkar, Sindhu et al. 2022), and natural geosystems (Lebedev, Lebedev, Sorokopudov et al. 2023; Baharane, Shatalov & Igwe 2025; Zhao, 2025) now represents a socio-ecological and an ecological and economic problem of interregional, transboundary and even global nature (Makosko & Matesheva 2012; Reuben, Caspi, Belsky et al. 2017; Heng, Asad, Coleman et al. 2022; Kaleji, Kazemi, Kamkar et al. 2025). Unfortunately, many engineering and infrastructural, technogenic and chemical, landscape and environmental factors cause unfavorable socio-medical and biological processes, including a decrease in the level of public (population) health (Liu, Ai, McCauley et al. 2012; Lim, Ha, Hwang et al. 2015; Pryor, Cowley & Simonds 2022; Stanek, Cascio, Barzyk et al. 2024; Baharane, Shatalov & Korsakov 2025; Dousset, Paiola, Chauvin et al. 2025).

The harmful effects of adverse environmental factors (air pollution, heavy metals, noise exposure, climate change, desert storms, forest fires, etc.) on human health (shortening of life expectancy, manifestation of diseases in the cardiovascular, respiratory, digestive, circulatory, endocrine systems, damage to the CNS, blood-brain barrier, malignant neoplasms, occurrence of congenital abnormalities in children) are an undeniable fact. According to the World Health Organization, air pollution and climate change are the number one threats to human health (World Health Organization. Climate Change... 2021).

Air pollution causes 9% of deaths worldwide, of which 58% are due to ischemic heart disease and cerebrovascular disease, 18% to chronic obstructive pulmonary disease and acute lower respiratory tract infections, and 6% to lung cancer. The remaining 18% have other causes of death (World Health Organization. Global Health... 2021). Scientific data on the impact of toxic substances (lead, mercury) on the cognitive development and intelligence of the growing generation are worrying (Gladieux, Gimness, Rodriguez et al. 2023). They document the risks of developing dementia and Alzheimer's disease in the future. In numerous studies, the negative effects of air pollution on the cognitive abilities of learners occupy a special place (Mullen, Grineski, Collins et al., 2020; Votruba-Drzal, Betancur, Spielvogel et al. 2021). The latter leads to a reduction in knowledge and the ability to acquire it (Ebenstein, Lavy & Roth 2016; Sanders 2012; Zivin & Neidell 2012; He, Liu & Salvo 2019). In this regard, the poor academic performance of children exposed to ambient air pollution is noteworthy. The authors argue that further improvements in air quality could have a positive impact on children's overall academic performance and their socioeconomic achievements throughout their lives (Lu, Hackman & Schwartz, 2021).

Among the factors that cause great harm to the health of the population, the most worrying in terms of its impact is environmental pollution with pesticides and heavy metals. According to estimates, about 20,000 deaths have been recorded as a result of 1-5 million poisonings with pesticides, with a large number of them being children. It should be noted that children (adolescents, young people) are one of the vulnerable groups (underprivileged segments of the population, the elderly) suffering from the harmful effects of the environment, their developmental disorders are mainly associated with the effects of heavy metals, especially lead and

mercury. In the last decade, about 600,000 new cases of developmental disorders recorded each year are associated with the effects of lead. (World Health Organization…, 2008, 2010, 2013; Danielyan 2014; The Global Environmental... 2016). In 2022, scientists from several European countries discovered a negative relationship between hemoglobin in the blood and lead. The highest prevalence of anemia was diagnosed among children of both sexes aged 1-9 years and female adolescents aged 15-19 years. (Capitão, Martins, Santos et al., 2022). The negative impact of environmental toxins (lead, mercury) on children's cognitive development is accompanied by low IQ, memory problems, and leads to low learning efficiency.

According to the 2017 study, children exposed to lead prenatally had lower IQ scores at both ages 4 and 8 than children who were not exposed to the substance (Taylor, Kordas, Golding et al., 2017).

Lead is believed to increase oxidative stress, promote neuronal apoptosis, and reduce or inhibit the synthesis of neurotransmitters (Shih, Hu, Weisskopf et al. 2007). The long-term effects of lead on overall cognitive development are of concern. It has been found that cognitive development deficits (low IQ) in childhood are caused by the negative effects of lead on the body both prenatally and postnatally (Reuben, Caspi, Belsky et al. 2017; Sanders, Liu, Buchner et al. 2019).

Several studies have linked lead exposure to poor social environments, with evidence that lead exposure is more prevalent in families with lower socioeconomic status, living in areas with old plumbing systems (old housing structures with lead-based paint or buildings built on lead-contaminated land) (World Health Organization 2010; Ferrie, Rolf & Troesken 2015). It is worth noting that low socioeconomic status, insufficient level of parental education, their employment and low income are social indicators of health. It is now a global concern and is present in many countries (Liu, Ai, McCauley et al. 2012; Lim, Ha, Hwang et al. 2015; Li, Qin, Wei et al. 2016; Halabicky, Pinto-Martin, Compton et al. 2023; Martínez-Hernanz, González-Estecha, Blanco et al. 2020; Ramesh, Khiratkar, Sindhu et al. 2022). From this perspective, the characteristics of unacceptable levels of lead in the blood of children in the number of towns and cities of the Caucasus are worrying: it was found in 75.4% of the examined children in Alaverdi, and in 57.4% in Yerevan (Sargsyan 2013; Petrosyan & Grigoryan 2014). According to a number of expert studies, including in the town of Alaverdi, the amount of lead in the blood of children was 10-20 mcg/dl, and 20 mcg/dl and more (Saghatelyan, Gevorgyan, Arevshatyan et al. 2008; Nazaryan 2009; Sargsyan 2013; Akopyan, Petrosyan, Grigoryan et al. 2014; Petrosyan & Grigoryan 2014). Meanwhile, children with lead concentrations even below 10 mcg/dl are at risk for impaired cognitive development and functioning, including decreased IQ and poor academic performance (Grandjean & Landrigan 2006; Liu & Lewis 2014).

It is quite logical that the United Nations Children's Fund (UNICEF) has been implementing many projects towards the implementation of the complex strategic plan "UNICEF Strategic Framework for Environmental Sustainability for Children" (UNICEF Strategic Framework… 2015).

However, the importance of such research for the Caucasus Region is unique. Numerous complex environmental problems characterize this region's mountainous landscapes, with their heterogeneous and complex terrain (Larionov, Galstyan, Ghukasyan et al. 2024; Osipova, Mkrtchyan, Ghukasyan et al. 2024) are combined with the increasing risks of modern climate extremes (Sargsyan, Tovmasyan, Gharakhanyan et al. 2025; Sargsyan, Larionov, Saidumov et al. 2025) and various disasters (Institute of Oncology of the Ministry of Health of the Republic of Armenia 2016, 2022). From the point of view of the impact of degraded ecosystems on the health of the population, particularly children, the data presented by specialists, independent experts and relevant institutions (UNICEF, Ecolur NGO, Ministry of Health of the Republic of Armenia, Ministry of Environment of the Republic of Armenia, American University in Armenia, Center for Ecological and Noosphere Research of the National Academy of Sciences of the Republic of Armenia, Kh. Abovyan ASPU, Heratsi YSMU) allow us to conclude that each region of the Republic of Armenia has its own characteristics of the reasons for being considered at risk, but in Lori region the primary problem is the contamination of soil, water and the food chain with heavy metals as a result of mining production (Institute of Oncology of the Ministry of Health of the Republic of Armenia 2016, 2022).

Our choice of the town of Alaverdi in the Lori Region of the Caucasus (Armenia) is due to its greater vulnerability, in particular, as a result of the combination of several obvious factors (the mining and processing activities in the area of Alaverdi and the consequences of the former activities of the Vanadzor Chemical Factory: environmental pollution and the impact of the toxic waste landfill), according to the incidence of malignant neoplasms and cancer mortality, the worst picture is recorded in

Lori itself, without age restrictions (Institute of Oncology of the Ministry of Health of the Republic of Armenia 2016, 2022). The next important factor is the connection between the ecological problems of Alaverdi and the ecological problems of the Caucasus (Sargsyan, Tovmasyan, Gharakhanyan et al. 2025; Sargsyan, Larionov, Saidumov et al. 2025; Yeghiazaryan, Galstyan, Sayadyan et al. 2025). The environmental problems of the town of Alaverdi, by their nature and scale, have a profound impact on the landscape system of the entire South Caucasus. The transboundary Debed River flows through the city. The forest biogeocenoses of this region extend into the surrounding areas and into Georgia and Azerbaijan (Fig. 1). This creates a unified landscape-ecological system with complex topography and ecosystem diversity (Nazaryan, 2009).

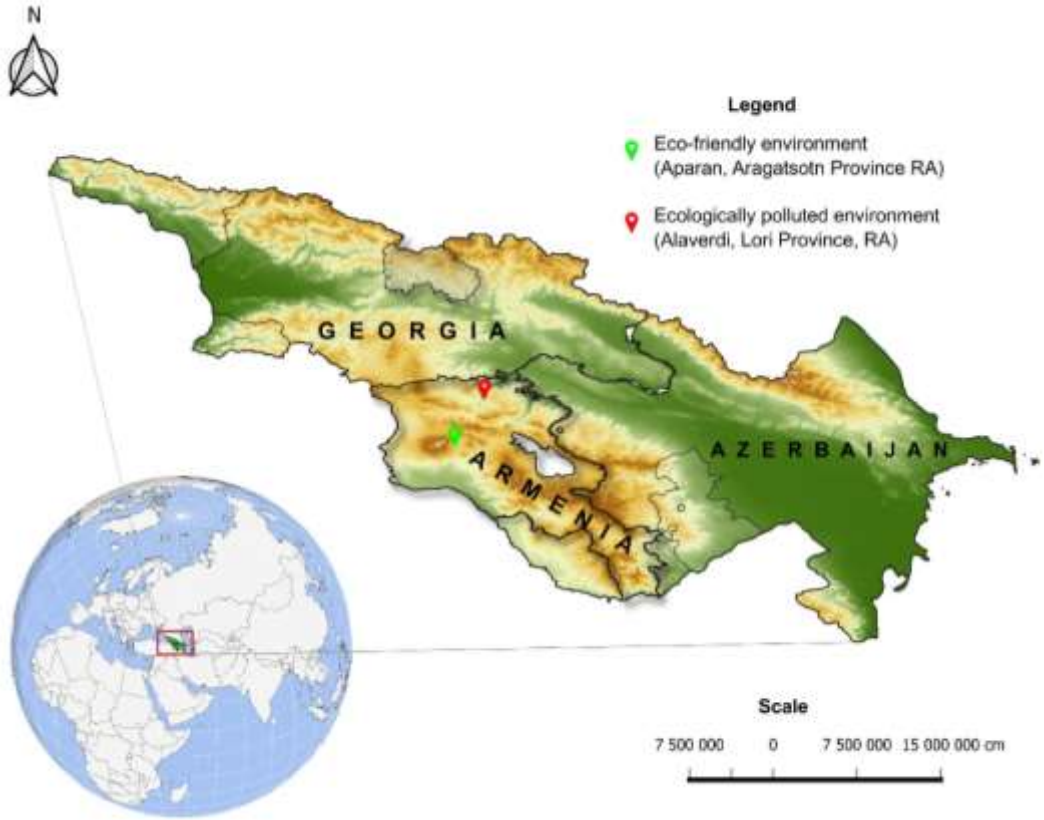


Fig 1: Geographical Location Of The Towns Of Alaverdi (Lori Region) And Aparan (Aragatsotn Region) Of The Caucasus.

The ecologically clean environment selected within the framework of the study (Aparan, Aragatsotn region) is marked in green, and the ecologically polluted environment (Alaverdi, Lori Region) is marked in red. The map includes the Caucasus Region, including Armenia, Georgia and Azerbaijan, as well as the general location shown on a world globe. It was prepared using the QGIS (v3.42.2), an open source geographic information system for viewing, editing, analyzing and visualizing geographic data.

The Alaverdi Community is currently an ecological disaster zone. Here, there is a decrease in the population, multiple excess of atmospheric air pollution over the maximum permissible concentrations (10-12 times the maximum permissible concentration (MPC) of sulfur dioxide in atmospheric air, which poses a real threat to human health), soil pollution with heavy metals, uncontrolled arsenic landfill, vegetation pollution with heavy metals, reduction of forested areas, absence of a landfill, direct discharge of untreated wastewater into the Debed River, an increase in diseases, including cancer, etc. (Nazaryan, 2009). Excessive amounts of heavy metals in food products are also a serious threat to public health. According to research data from 2023-2024, food of animal and plant origin (eggs, milk, quince, red apples, dates, potatoes) in the vicinity of the Alaverdi Copper Chemical Factory is contaminated with heavy metals (Zn, Cu). The average concentrations of Cu and Zn in some products exceeded the maximum levels set by

international organizations. Even at the distance of 5000–8000 m from Alaverdi, where the Copper Chemical Factory was located, levels of copper and zinc above the norm were recorded (Mirumyan, Hovhannisyan, Harutyunyan et al. 2024). All of these unbearable conditions have an irreversible impact on the environment and the population, including the growing generation. In addition to this, the difficult socio-economic situation, low awareness of the population about environmental issues, healthy lifestyle and incomplete understanding of the danger is also added.

We consider it worth noting that according to ecological research data, the Aparan Community stands out among relatively favorable communities for its stability.

The levels of atmospheric air pollution in the town of Aparan are within the norms set for the residential area. There are a number of small businesses operating in the town, which are not sources that contribute significantly to the town pollution levels. The population's provision of green spaces for general use is 3.3 hectares more than the urban development norm (Decision of the Government… 2007).

Aparan is a community with developed tourism infrastructure, especially in the fields of agro-, winter and active tourism. It has a developed and highly efficient agriculture, whose ecologically clean and certified final products are in great demand both in Armenia and abroad ("BSC" Business Support… 2017).

Thus, combating environmental pollution requires an interdisciplinary approach that encompasses multiple fields of study. From this perspective, the completeness of the ecological indicators of each village or city considered vulnerable, regardless of the region (Europe, Asia), can only be ensured today as a result of organizing complex research based on the interconnection of sciences. These studies should include not only ecological, but also multidisciplinary studies in biology, chemistry, neuroscience, and other fields, which can fill the gaps in science and more fully define the mechanisms of the impact of various pollutants on the brain and its higher functions.

The main goal of the presented article is to assess the processes that ensure the stability of attention, memory, and mental performance of schoolchildren studying in ecologically different environments, the indicators of social and psychological well-being characterizing their quality of life, and their comparative changes, which will allow us to understand the impact of environmental stressors on the cognitive abilities and social and psychological well-being of the growing generation. In the study of public health and cognitive development, taking into account landscape-ecological factors represents an important scientific and applied interdisciplinary direction in the modern period.

2. MATERIAL AND METHODS

2.1. Participants

The research was conducted in 2024-2025 among 11-12 year old schoolchildren studying in schools in the towns of Alaverdi and Aparan (n= 68). The first group was formed from 5-6th grade schoolchildren from the town of Alaverdi (an ecologically unfavorable environment) in Lori province, and the second group was formed from schoolchildren of the same age from the town of Aparan (a relatively ecologically favorable environment). Considering the fact that the decrease in cognitive performance after the lesson process may be due to mental fatigue, we chose a period when schoolchildren were not exposed to an academic load (vacation period) for conducting the research. The chosen format made it possible to evaluate not the impact of workload, but the impact of favorable and unfavorable ecological environments on the cognitive processes of schoolchildren. All stages of the study were conducted in a quiet, well-lit room, in comfortable temperature conditions, without the influence of distracting and stressful factors, at around 11:00 AM. Participation in the study was voluntary. Participants were thoroughly familiarized with the experimental conditions, informed about the importance of all components, and provided with a test plan detailing the order and procedure for completing the assignments After receiving comprehensive information about the prerequisites for the correct implementation of all components of the experiment, the researched expressed a desire to participate in the experiment.

The study was conducted in accordance with the Declaration of Helsinki, the ethical standards for medical research involving human subjects (Ethics Committee of the Yerevan State Medical University after M. Heratsi (N12-1/22).

3. METHODS

3.1. Psychophysiological Studies

To study mental performance and attention processes, the computer version of the "Landolt Rings" corrective psychophysiological test called "Clocks Carousel" was selected, which is part of the "Vigilance Research" specialized software program

for psychophysiological tests (Tumanian, Tadevosyan, Khachunts et al. 2021) developed according to the analogue of the d2 test (Brickenkamp & Seisdedos Cubero 2012). During the test, the researched was asked to rotate the on-screen spherical cursor continuously and as quickly as possible in the circle, trying to correctly mark the "clocks" showing the certain "time" (23:00; 17:00). The pre-test instructions explained that the circles themselves represent "clocks," and the lines inside are the small hands of the clocks. Attention and mental performance assessments were performed by the program that took into account the speed of test completion and the number of errors made (incorrect markings, omissions).

The following functional indicators of attention were assessed:

AP/min - Test performance efficiency index per minute

Ac% - Test performance accuracy indicator

The following time indicators of attention were assessed:

R M-PT (average time to process a proofreading character)

DCF _pT (Time spent on correctly selected check digits)

WDOF_pT (Time spent on incorrectly pressed ordinary characters)

WSCF_pT (Time spent on incorrectly missed check characters)

3.2. "Number Memory" Methodology /Test/

The test is designed to assess short-term visual memory, its volume and accuracy. When performing the test, the researched was given 20 seconds to accurately and sequentially memorize the 12 two-digit numbers presented in the displayed table. After removing the tables, the researched reproduced them on paper. Short-term visual memory was assessed by the number and sequence of correctly reproduced numbers. The normative limit is 7 and higher indicators (Azatyan, Avetisyan, Arakelyan et al. 2015).

3.3. "Image Memory" Methodology /Test/

Designed to explore figurative memory. The researched was shown a table of 16 images for 20 seconds. After 20 seconds, the chart was removed and within one minute the researched reproduced (draw or write/describe in words) the images on paper. Short-term visual memory was assessed by the number of correctly reproduced images. Normative limit is 6 and higher indicators (Azatyan, Avetisyan, Arakelyan et al. 2015).

3.4. Life Quality SF - 36 Questionnaire Describing The Quality Of Life

The study used the electronic version of the SF-36 v2™ questionnaire describing the quality of life. The SF-36 has been translated and adapted into a number of languages around the world (Svanborg & Åsberg 1994; Anagnostopoulos, Niakas & Pappa 2005; Grassi & Nucera 2010; Guermazi, Allouch, Yahia et al. 2012; Arefnasab, Ghanei, Noorbala et al. 2013). The armenian version of the program was used in our research (Hovhannesyan, Gevorgyan, Pogosyan et al. 2012). The program grouped 36 items from 8 questionnaires: **PF**-physical functioning ,**RP**-role physical, **BP**-bodily pain, **GH**-general health, **VT**-vitality **SF**-social functioning, **RE**-role emotional and **MH-**mental health: The results of all surveys are evaluated with points and are structured in such a way that a high point value corresponds to a high level of quality of life. The scores on each scale range from 0 to 100, where 100 indicates excellent health on that scale.

To assess the interconnected nature of cognitive processes, the correlation analysis was conducted between functional (AP_min attention efficiency per minute) and temporal (M-PT - mean character processing time) indicators characterizing the stability of voluntary attention in the two studied groups. Scatterplots with fit lines and confidence intervals (dotted lines) were used to graphically represent them. Pearson's correlation coefficient was used to measure the relationship between variables.

3.4. Research Process

The research was conducted on 68 schoolchildren. All stages of the study were conducted in a quiet, well-lit room, in comfortable temperature conditions, without the influence of distracting and stressful factors, at around 11:00 AM. Participants did not use any medications in the period prior to the study. Before the main phase, all researched underwent a preliminary phase, where the following data were recorded: name, surname and patronymic, gender, age, place of residence (town or village), weight (expressed in kg), height (expressed in cm), and blood pressure.

The following psychophysiological computer tests were applied:

"Clocks Carrousel" test - assessment of attention processes and mental performance;

"Number Memory" and "Image Memory" methods /tests/ - assessment of short-term visual memory, its volume and accuracy;

"Life Quality SF - 36" version questionnaire – assessment of the components of the quality of life of

schoolchildren.

All of the tests presented were performed by the researched while sitting in front of a computer. Three separate days were selected for their implementation: before performing each test, the researched was familiarized with the task before him. The research was voluntary. Participants provided verbal consent, and written consent was obtained from the relevant institution.

3.5. Statistical Data Analysis

Statistical analysis of two independent groups was performed. The normality of data distribution was checked using the Kolmagorov-Smirnov (KS) and Anderson-Darling (AD) tests, and the homogeneity of variances was checked using the Levene test. In the case of the Gaussian, parametric distribution of data, intergroup comparison and reliability were determined using the independent sample t-test (the Student's t-test for homogeneous variances, Welch's t-test for heterogeneous variances), and in the case of non-normal distribution, the non-parametric Mann–Whitney U-test. The significance level was set at $\alpha = 0.05$, and values of $p<0.05$ and $p<0.01$ were considered reliable. Statistical analysis was performed using the SPSS Statistics 27.0 (IBM), GraphPad Prism 10.0 (GraphPad Software), and Excel 2021 LTSC (Microsoft) software.

4. RESEARCH RESULTS

To assess the impact of ecologically different environments on the development of learners' cognitive abilities, we studied the dynamic changes in attention time indices (RDCF_pT, M-PT, WDOF_pT, WSCF_pT) in two research groups. The changes in the presented indicators show that all the studied time indicators: RDCF_pT (Time spent on correctly selected control characters), M-PT (average time for processing a correction character), WDOF_pT (Time spent on incorrectly pressed ordinary characters), WSCF_pT (Time spent on incorrectly omitted control characters), in contrast to the first group (Aparan), in the second group (Alaverdi) they showed higher values, amounting to 15.37% ($p < 0.01$), 24%, 9.68% ($p < 0.05$) and 22.4% ($p< 0.01$) respectively. Thus, the increase in attention span indicators among schoolchildren representing the Alaverdi Community (from 15.37% to 24%) indicates a decrease in the optimality of analytical processes and a decline in the efficiency of decision-making. Schoolchildren representing the Aparan Community demonstrate higher speed of orientation and efficiency of voluntary attention. The dynamic changes in the time indicators of the studied groups are presented in Fig. 2.

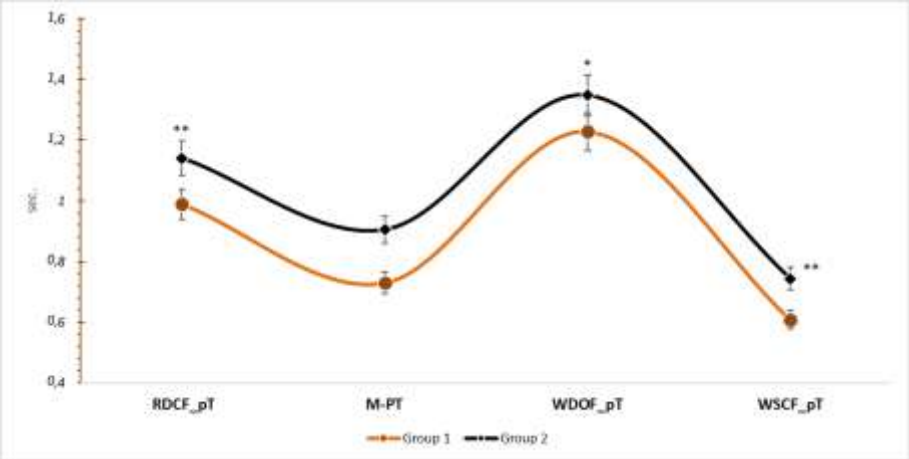


Fig 2: Designations: RDCF_Pt - Time Spent On Correct Control Characters, WDOF_Pt - Time Spent On Incorrectly Pressed Ordinary Characters, WSCF_Pt - Time Spent On Incorrectly Omitted Control Characters, M-PT - Average Time For Processing A Correction Character.

The values of the indicators are shown on the ordinate axis, expressed in seconds. The abscissa axis shows the time indicators studied. The error bars of the sample series are given according to the standard deviation of the mean, expressed as a percentage. *, ** - reliability at the levels $p<0.05$, $p<0.01$

The dynamics of changes is also characteristic of functional indicators. In particular, AP/min - The test performance efficiency index per minute, for the first group of schoolchildren, exceeds the index recorded for the second group of schoolchildren by 31.8% (Fig. 3).

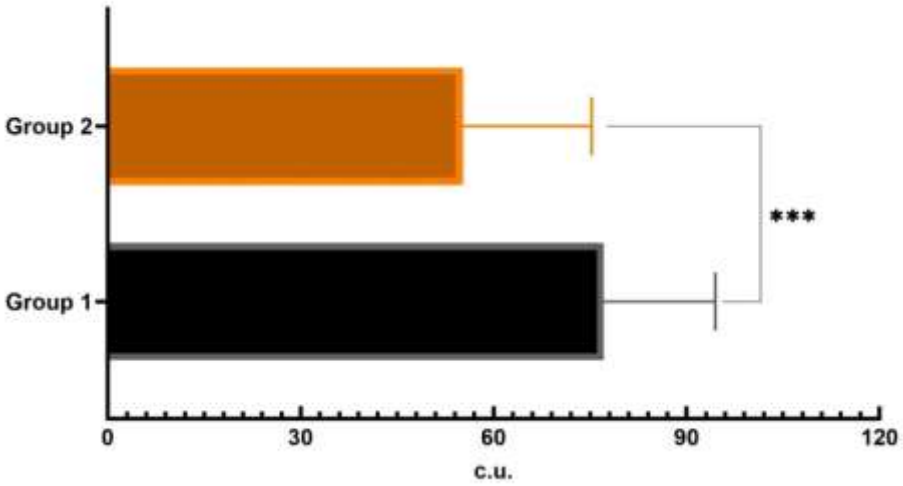


Fig 3: Designations: AP/Min - Test Performance Efficiency Index Per Minute.

The ordinate axis shows the groups under study, the abscissa axis shows AP/min (c.u.) values. *** - reliability at the p<0.001 level. The error bars are given according to the standard deviation of the mean.

The dynamics of the change in the Ac% accuracy indicator is manifested by the same patterns: unlike the first group of schoolchildren, the indicator presented by the second group of schoolchildren significantly decreases, amounting to 9.42% (p<0.05) (Fig. 4).

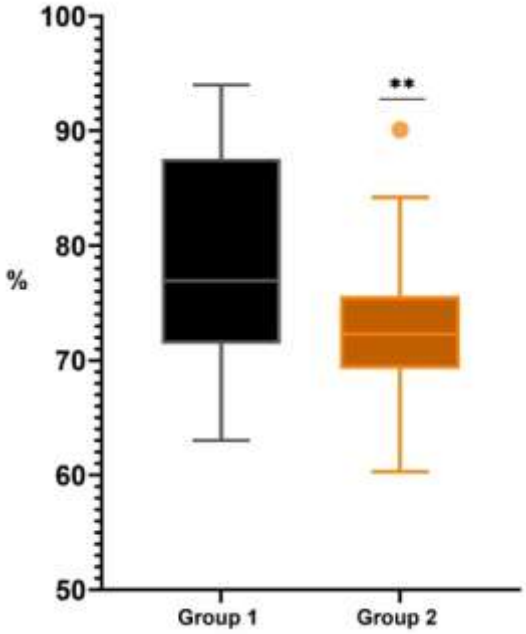


Fig: 4: Designations: Ac% - Test Performance Accuracy Indicator.

The ordinate axis shows the values of the indicators, the abscissa axis shows the groups participating in the study.** - reliability p<0.01 Boxes represent the interquartile range (IQR), which includes the middle 50% of the research data. The horizontal solid line corresponds to the median, the central value of the data when they are arranged in ascending order. The T-shaped vertical lines /whiskers/ show the distribution of the data with maximum and minimum values. The point represents the extreme value (outlier).

Thus, the changes recorded in the AP/min and Ac% indicators of schoolchildren representing the Alaverdi Community also indicate a slowdown in their task performance and a reduction in their processing abilities.

The correlation analysis between functional (AP_min attention efficiency per minute) and temporal (M-PT - mean character processing time) indicators characterizing attention stability in the two studied groups is presented. It was conducted to assess the interconnected nature of cognitive processes (Fig. 5).

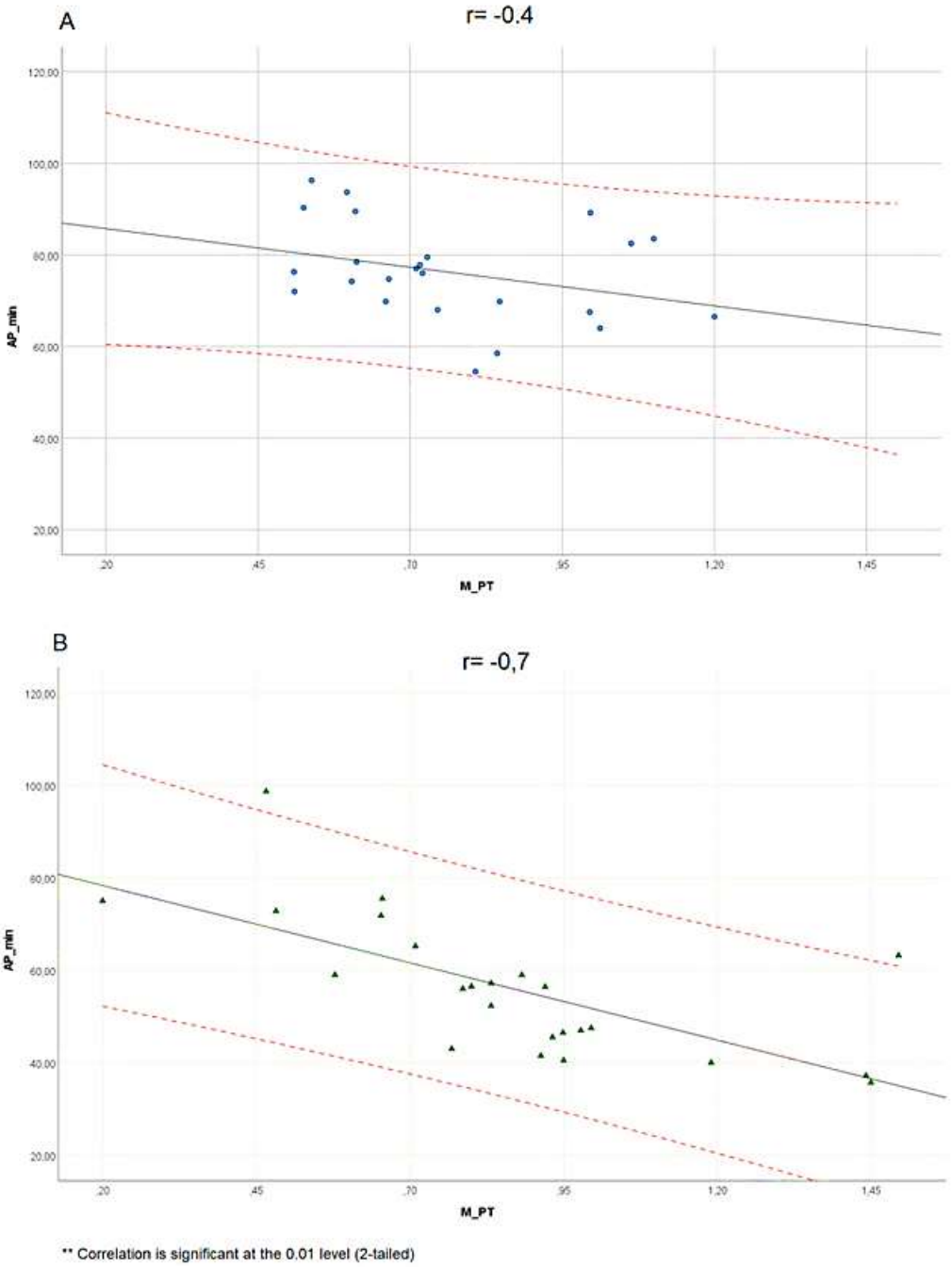


Fig: 5: Correlation Analysis of Functional.

(**AP_min** attention efficiency per minute) and temporal (**M-PT**- mean character processing time) indicators characterizing attention stability in two research groups (A-Group 1, B-Group 2). Scatterplots with fit lines (straight lines) and confidence intervals (dotted lines) were used for graphical representation. Pearson's correlation coefficient was used to measure the relationship between variables.

In the first group (Aparan), the value of the correlation coefficient (r= -0.4) indicates a medium-strength and negative-directional relationship between the variables. In other words, as the speed of character processing increases in this group, the efficiency of test performance per minute tends to

decrease. The relatively large and irregular dispersion of values around the line, as well as the presence of wider confidence intervals, indicate a medium-strength relationship between the variables. The presented results suggest that schoolchildren studying in environmentally favorable conditions respond differently to the same cognitive task, which may be due to individual differences (e.g., concentration level, sensitivity to stress, different genders, other external factors).

The analysis of the correlation coefficient between the functional and temporal indicators of attention in the second group ($r = 0.7$, $p < 0.01$), in contrast to the first group, shows a more pronounced and stable relationship, however, as in the first group, in this group the relationship between the studied variables also has a negative direction. That is, the increase in the average character processing time and test execution speed is accompanied by a consistent decrease in efficiency. Compared to the first group, the narrower confidence intervals and closer dispersion of values around the regression line confirm the presence of a more stable relationship between the variables. The data recorded in this group suggest that schoolchildren studying in environmentally unfavorable conditions are more sensitive to cognitive overload. Thus, as a result of the intergroup analysis, we can record that schoolchildren representing the Alaverdi Community have fewer attention resources (they consume their attention resources more quickly). Students representing the Aparan Community demonstrated high efficiency in the implementation of cognitive tasks. Unlike the first group, the attention resources of the schoolchildren in the second group are not homogeneous, they are distributed differently.

The results of the numerical memory test are presented (Fig. 6, A), which indicate different levels of cognitive function in the two study groups. According to the normative standard of memory (the normative limit is 7 points), the results of the first group, 7±0.9, correspond to the norm, and in the second group, 4.5±0.7, the recorded value is 35.7% lower than the established normative value.

Figure B shows the results of the image memory test in the two study groups. Although the results recorded in the first and second groups (10.5±1.6 and 8.3±2 respectively) are within the norm, but as a result of the intergroup comparison, the indicators of the second group are 21% lower than the first group, which indicates a certain decrease in the memory efficiency of the students representing the Alaverdi Community.

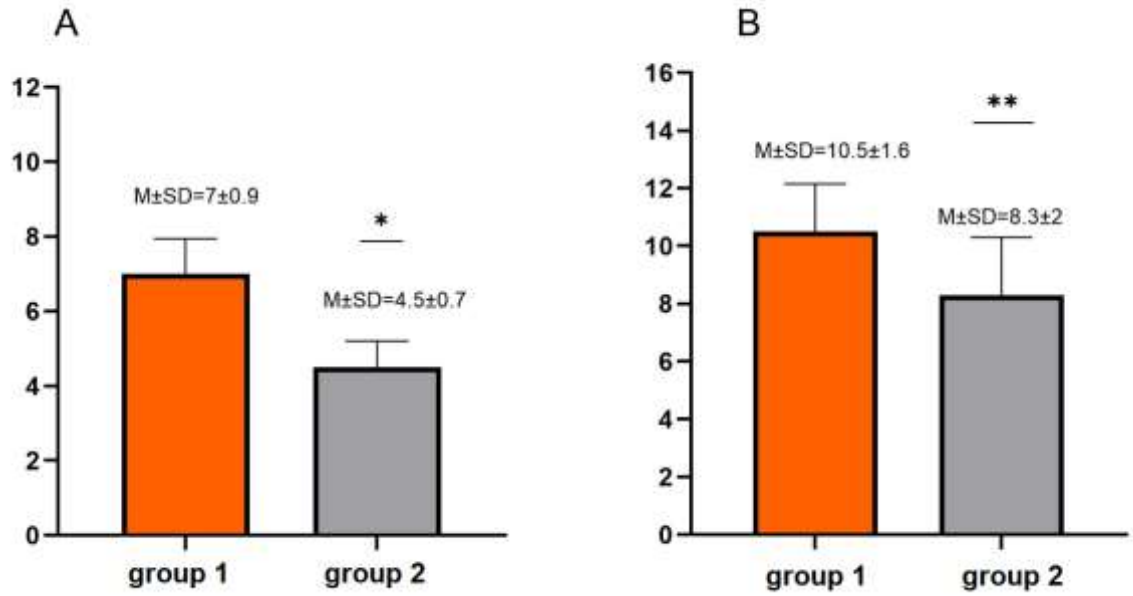
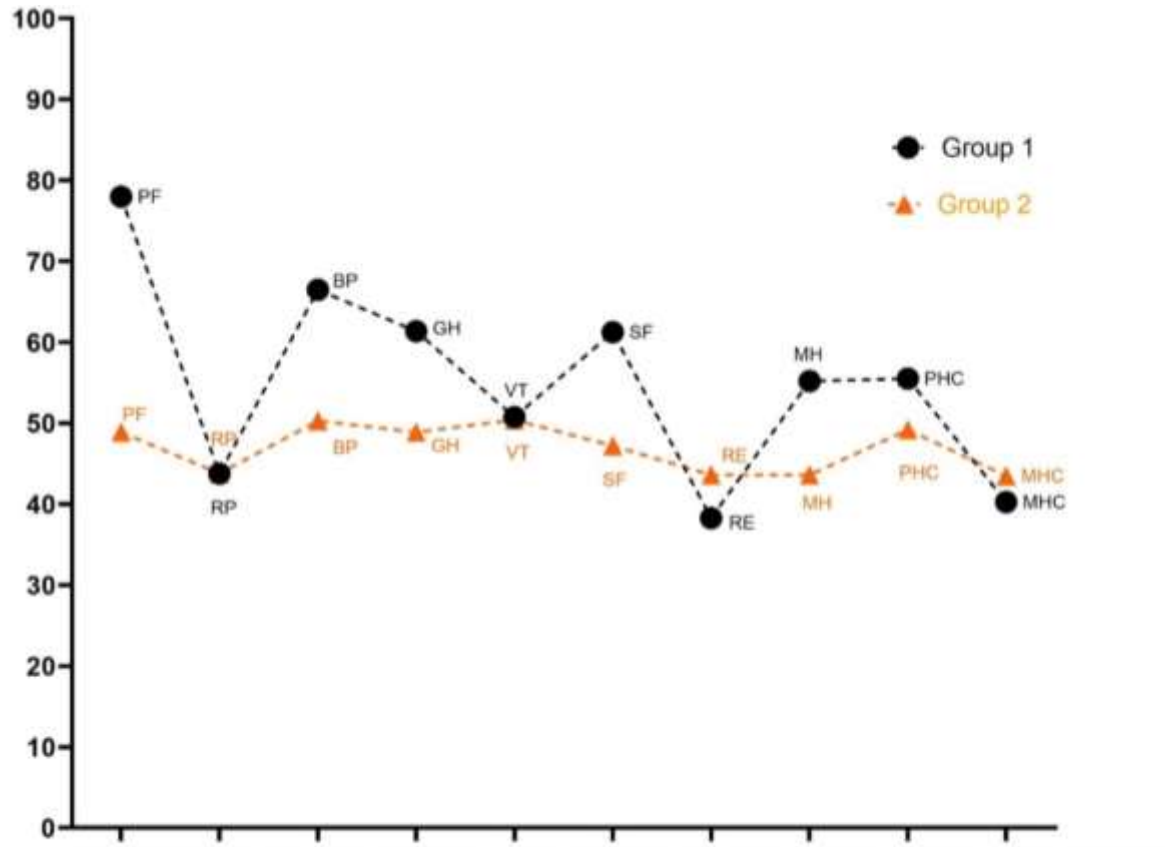


Fig: 6: Results Of The Short-Term Visual Memory Test (Number Memory (A) And Image Memory (B) Methods).

The ordinate axis shows the number of correctly remembered items, the abscissa axis shows the study groups. Data are presented as M±SD (mean and standard deviation). *,, ** - significance: $p<0.05$, $p<0.01$, respectively.

The values of the indicators expressing the quality of life of the SF-36 questionnaire are presented (Fig. 7).



	PF	RP	BP	GH	VT	SF	RE	MH	PHC	MHC
Group 1	78±18,1	43,8±26,8	66,5±24,6	61,4±16	50,8±15,8	61,2±25,6	43,3±27,5	55,2±16,1	55,5±7,8	40,3±3,2
Group 2	48,9 ±5	43,8±8,6	50,3±8,8	48,9±8,5	50,4±5,5	47,2±8,6	43,6±10,4	43,6±10,1	49,2±4,9	43,5±8,6

Fig: 7: PF-Physical Functioning, RP-Role Physical, BP-Bodily Pain, GH- General Health, VT- Vitality, SF-Social Functioning, RE-Role Emotional, MH-Mental Health.

The graph representing the "quality of life" shows that among schoolchildren studying in ecologically favorable conditions (Aparan, control), the physical health components (except for RP-role functionality-level of physical activity capabilities) and the general physical health component (PF: 78, BP: 66.5, GH: 61.4, PHC: 55.5) are within the normal range or exceed the population norm (50 points), which indicates a sufficient level of physical functions of the subjects, low pain intensity, and a positive perception of their own health status. Unlike the first group, schoolchildren studying in environmentally unfavorable conditions had the above categories (except BP), including the general physical health component, recorded levels below the normative limit (PF: 48.9, RP: 43.8, GH: 48.9, PHC: 49.2).

The analysis of mental health components in both groups shows that in the first group of subjects (Aparan, control), social functioning (SF: 61.2) and mental health (MH: 55.2) were within the normal range (above the norm), but the levels of vital activity (VT: 50.8) and role functionality (the fullness of roles related to everyday activities, related to the emotional state, RE: 43.3), as well as the general mental health component (MHC: 40.3) recorded a level below the normative limit. In the second group (Alaverdi), almost all mental health indicators: SF, MH, RE and MHC recorded a level below the normative limit. The presented data allows us to record that, in contrast to schoolchildren studying in favorable conditions, schoolchildren studying in environmentally unfavorable conditions have a lower level of mental health. This is clear evidence that this group is facing high psychophysiological stress.

5. DISCUSSION

The general increase in anthropogenic stress (Grandjean & Landrigan 2006; He, Liu & Salvo 2019; Larionov 2022; Bukharina, Vedernikov, Karelina et al. 2025; Larionov & Kotegov 2025; Petrushina, Gunya, Kolbovsky et al. 2023), including extensive forms of nature management and farming (Koronkevich, Barabanova, Georgiadi et al. 2020;

Pleshakova, Ngun, Reshetnikov et al. 2021; Slavskiy, Litovchenko, Matveev et al. 2023; Bukharina, Vedernikov, Didmanidze et al. 2025; Peng, Lou, Zhang et al. 2025), entails many socio-ecological (Ferrie, Rolf & Troesken 2015; Koronkevich, Barabanova, Georgiadi et al. 2020; Makosko & Matesheva 2020; Rumyancev, Koronkevich, Izmailova et al. 2021; Larionov, Zaripova, Matevosyan et al. 2025) and socio-medical-biological problems (Ebenstein, Lavy & Roth 2016; Galstyan, Sayadyan & Sargsyan 2023; Larionov, Galstyan, Ghukasyan et al. 2024; Korsakov, Domakhina, Troshin et al. 2025). Landscape, biogeocenotic environment and socio-ecological factors (Akopyan, Petrosyan, Grigoryan et al. 2014; Larionov, Volodkin, Volodkina et al. 2023; Elizbarashvili, Beglarashvili, Pipia et al. 2025; Petrov 2025; Zaburaeva, Zaburaev, Sedieva et al. 2025), of course, have a certain significance in shaping public health (Li, Qin, Wei et al. 2016; Zakharov, Revich. & Trofimov 2018; World Health Organization. Global Health… 2021; Capitão, Martins, Santos et al. 2022; Korsakov, Kryukova, Troshin et al. 2022; Larionov, Galstyan, Ghukasyan et al. 2024; Yang, Arifani, Liu et al. 2025), psychoemotional sphere (Boucher 2012; Sanders 2012; Arefnasab, Ghanei, Noorbala et al. 2013; Jenkins & Egger 2025; Markosyan, Korchazhkina & Nikitin 2025; Periyakaruppan, Rajendran, Kasinathan et al. 2025), neuropsychic and intellectual development (Bellinger 2008; Degermendzhi & Tikhomirov 2014; Azatyan, Avetisyan, Arakelyan et al. 2015; Mullen, Grineski, Collins et al. 2020; Lu, Hackman & Schwartz 2021; Gladieux, Gimness, Rodriguez et al. 2023; Liu, Wang, Xu et al. 2023; Kirpichnikov, Ilyina, Akhaev et al. 2024; Le, Rillotta & Robinson 2024; Li & Chung 2024).

It's important to focus on and address relevant environmental stressors. We sought to achieve this through our comprehensive psychological, educational, and socio-medical-ecological study, presented in this paper.

We believe that this is necessary in modern conditions and in the near future. There are many scientific research evaluating the impact of environmental stressors on human health, aimed at improving global health (Park, Joo, Lee et al. 2018; Xie, You, Zhi et al. 2021; Pryor, Cowley & Simonds 2022). We present the comparative analysis of the cognitive abilities of learners living in different ecological environments, which indicates marked differences in higher brain functions: memory, attention, and mental performance. The results of the research prove that environmental pollution has negatively affected the effectiveness of the overall cognitive activity of students representing the Alaverdi Community: there is a deterioration in short-term memory, a significant decline in attention management, information processing speed, and executive accuracy: the processes of attention mobilization and control are disrupted. Schoolchildren representing the Aparan Community are characterized by a higher speed of orientation and the efficiency of voluntary attention. The presence of heavy metals in the blood, particularly lead (Pb) and mercury (Hg), can significantly affect cognitive function. It is believed that metals (lead and mercury) present in an ecologically polluted environment, crossing the blood-brain barrier (BBB), accumulate in the central nervous system, and by affecting the frontal cortex and hippocampus, can have a significant impact on attention and memory processes. Furthermore, the effects of lead are modulated by oxidative stress, disruption of neuronal transmission, and damage to cellular structures. It should be noted that in the mechanisms of action of lead and mercury, the developing brain is considered to be the target, as the disruption of the brain's neurodevelopmental chain (neurogenesis, myelination, synaptic pruning) in the growing organism under the influence of the latter leads to impaired memory, attention, and behavioral processes (Bellinger 2008; Rivas-Arancibia, Guevara-Guzmán, López-Vidal et al. 2010; Heng, Asad, Coleman et al. 2022). Consequently, it is not excluded that the deterioration of cognitive processes in this age group may be caused not only by the influence of heavy metals in the postnatal period, but also in the prenatal period and their cumulative effects. The results of our research reflect a number of international scientific studies, which prove the negative impact of environmental pollution, particularly heavy metals: lead (Pb) and mercury (Hg), on memory and learning processes (Rice & Barone 2000; Tong von Schirnding & Prapamontol 2000; Boucher 2012).

The results of the physical and mental components also clearly emphasize the consequences of the influence of the ecological environment on the development of the growing organism, in particular, the oxidative stress in the body caused by the pollution of atmospheric air, soil, as well as food products with heavy metals in Alaverdi, and possible disturbances in mitochondrial activity at the cellular level can lead to homeostatic imbalance. Moreover, low levels of physical activity and health problems in this age group may also be a consequence of long-term toxic effects on the body, resulting in dysfunction of the neuromuscular, cardiovascular,

and immune systems. The emotional dysfunction that has developed against this background is logical: the level below the normative limit of almost all mental health indicators is clear evidence of the high psychophysiological tension of the schoolchildren representing the Alaverdi Community.

Psychoemotional disorders that develop against the background of stressful environmental factors, limited social opportunities, as well as possible somatic diseases, can lead to the development of depressive states. The above chain can, in the long term, contribute to functional impairments in the hippocampal and prefrontal cortex, leading to impaired memory, attention and decision-making. Analysis of data characterizing the physical health of schoolchildren representing the Aparan Community allows us to assume the relatively efficient functioning and homeostatic balance of physiological systems in their bodies. Schoolchildren in this group are presented with relative psychological stability and a sufficient level of social inclusion.

However, it is known that mental health is associated with stressful situations and is endowed with a certain sensitivity to them. From a physiological perspective, the low levels recorded in some indicators characterizing mental health among schoolchildren representing the Aparan Community may be due to the body's response to prolonged stressors and the activation of the hypothalamic-pituitary-adrenal (HPA) system. It is not excluded that chronically high levels of cortisol released as a result of activation of the hypothalamic-pituitary-adrenal system create an imbalance in the neurotransmitter systems (serotonin and dopamine) responsible for mood regulation and the stable functioning of motivational systems. Thus, the combined assessment of attention, memory, as well as physical and mental health, allows us to establish that the quality of the ecological environment is a key and most important factor in cognitive development.

5.1. Restrictions

The results of the above-mentioned researches show that adverse environmental conditions can lead to disruption of cognitive processes. However, one of the main problems with these researches is that it is often difficult to determine whether adverse environmental conditions are the sole cause of cognitive impairment, since there may be various unknown co-factors. For example, socioeconomic or genetic risk factors may play an important role in these processes. It is necessary to expand the research to include other communities and a larger sample to examine the long-term impact of environmental factors (heavy metal concentration levels, socioeconomic factors) on cognitive processes in different age groups, particularly from preschool age to adulthood. Such a format will make it possible to assess the combined impact of heavy metals and social determinants of health on outcomes, and to determine the dynamics of changes in cognitive abilities under the specified conditions.

5.2. Opportunities For Practical Use Of The Ideas And Materials Of Our Work

Our completed research series and the results obtained provide the basis for psychological, pedagogical, and socio-medical-biological assessments of students in relevant landscape and environmental conditions. Taking into account landscape features and limiting environmental factors, including man-made stressors, allows us to further develop individual and group educational and developmental pathways for children and young people. Emotional assessment, attention, and task performance, coupled with an analysis of environmentally conditioned psychophysiological and anatomical characteristics, are used in relevant groups of schoolchildren and students and in specific areas. A further development of our research also includes the development of a matrix for comprehensive psychological, pedagogical, and socio-medical-biological assessments for social, pedagogical, medical, preventive, and environmental expert state and municipal services and institutions. Essentially, we have presented for public review an example of a methodology for comprehensively assessing children's cognitive abilities in the context of regional, limiting landscape and environmental conditions. This methodology can be implemented directly in general and supplementary education organizations, in scientific, educational, and research institutions, and in expert institutions in the social, pedagogical, social, psychological, medical, and environmental fields. Our methodology can also be useful in the work of medical, pedagogical, psychological, and pedagogical commissions of schools and other educational institutions, as well as in administrations. This is necessary for countries in the Caucasus Region and Russia, as well as for adjacent territories: Iran, Turkey, the Caspian and Black Sea Regions, the Middle East, and Central Asia. Our methodology can be scaled geographically (interregionally). For example, it can be applied in the South, Southeast, and East Asia, Africa, South and North America. Consideration and analysis of local and regional landscape and socio-ecological

characteristics will be crucial in researching and processing data on cognitive and psychological characteristics across different age and environmental groups. International collaboration and the creation of international scientific and expert associations on the issues discussed in this work are encouraged.

6. CONCLUSION

The combination of research data with scientific literature and the influence of ecological factors shows that the quality of the ecological environment is a key factor in cognitive development. The cognitive dysfunction recorded among schoolchildren living in ecologically polluted areas is a clear signal to emphasize the role of environmental health in ensuring pedagogical and psychological well-being. The research work highlights the urgency of creating favorable development conditions for learners through the implementation of programs to reduce and prevent environmental pollution.

This work presents the comprehensive methodology for psychological, pedagogical, and socio-medical-biological assessment of students in relevant landscape and environmental conditions. It is promising and feasible to scale up the application of our methodology and materials to educational, training, and research institutions, monitoring and expert services, and organizations engaged in psychological, pedagogical, and socio-environmental monitoring at the municipal and district levels, nationally, and internationally.

Declarations

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Data Availability: The datasets for this study are available from the corresponding author upon reasonable request.

Ethics And Consent to Participate Declarations: The students voluntarily took part in the research. The Ethics Committee of Yerevan State Medical University after Mkhitar Heratsi approves that the presented project is in accordance with the WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects; Conclusion of the Ethics Committee of the Yerevan State Medical University after M. Heratsi, N12-1/22, dated June 22, 2022.

Competing Interest Declaration: The authors declare no conflict of interest.

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