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# Russian Psychological Journal

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## СОДЕРЖАНИЕ

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# Dynamics of the components of the value-semantic sphere in the process of implementing the technology of psychological rehabilitation of the population living in conditions of military conflict

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## Abstract

**Introduction.** The relevance of the research is determined by the need to analyze the dynamics of the value-semantic sphere of the civilian population living in conditions of local armed conflict and substantiate psychological technologies that contribute not only to reducing symptoms of distress, but also to restoring life meanings and prospects for the future. The purpose of the study was to study the changes in the components of the value-semantic sphere during the implementation of the program of psychological rehabilitation of civilians in the conflict zone. **Methods.** The sample included 494 respondents (208 men, 286 women) aged 19 to 53 years, divided into experimental and control groups. The diagnostic complex included the SAN method (well–being–activity-mood), an express method for assessing social isolation, a morphological test of life values, a test of life orientations (SOE) and a scale of basic beliefs (WAS). The 12-week rehabilitation program was aimed at stabilizing the emotional state, developing communicative resources and forming progressive life-meaning strategies. **Results.** In the experimental group, after participating in the program, there was a statistically

significant improvement in SAN scores, a decrease in subjective social isolation, an increase in the importance of self-realization values, social contacts and one's own prestige, increased goal setting and meaningfulness of life, as well as positive dynamics of basic beliefs about the benevolence and justice of the world, luck and the image of "I"; in the control group No comparable changes have been recorded. Gender differences in the nature of value-semantic dynamics are noted. **Discussion.** The results allow us to consider the developed program as a significant tool for psychological support of the civilian population in conditions of armed conflict and indicate the prospects for further longitudinal studies of the mechanisms of transformation of the value-semantic sphere in the rehabilitation process.

## Keywords

military conflict, value-semantic sphere, civilian population, meanings, values, meaningful strategies, technology of psychological rehabilitation

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# Introduction

Armed conflicts are extreme situations that create conditions for massive psychological stress among the civilian population. Civilians in a local armed conflict may experience the unforeseen effects of multiple stressors: direct threat to life, destruction of habitual social structure, loss of property and instability, uncertainty of the environment.; Such conditions can lead to the development of a wide range of psychological disorders, adjustment disorders, post-traumatic stress and, of course, to the transformation of fundamental life meanings and values.

Research over the past two decades has significantly expanded the understanding of how the extreme stress of combat transforms the human psyche: armed conflict initiates

the development of specific extreme mental states (Alexandrovsky, 2022), acute stress reactions and reactive states (Chepur, 2024), and chronic forms of psychopathology, including post-traumatic stress disorder (Bonkalo, 2023). Considerable attention in the research is paid to the processes of adaptation of the civilian population to the conditions of uncertainty and unpredictability typical of military conflicts (Deryagina and Bulatetsky, 2021; Protsenko, 2024). However, these studies, although they reveal the clinical and psychopathological picture, pay less attention to the fact that under the influence of prolonged extreme exposure, profound transformations occur not only in the psychopathological sense, but also in the personal organization as such.

Thus, personal and professional deformations that develop under conditions of prolonged stress are described (Amsalem et al., 2025), however, the mechanisms of value-semantic sphere restructuring underlying these deformations remain insufficiently investigated. In other words, if it is known what changes in the human psyche under the influence of conflict (symptoms of PTSD appear, maladaptation develops, destructive behavioral patterns form), then it remains unclear "how" and "why" these changes occur at the level of the semantic organization of the individual, and, most importantly, how these processes can be reversed through purposeful psychological rehabilitation.

The relevance of the research is determined by the need for: (1) a comprehensive analysis of structural changes in the value-semantic sphere of the civilian population under the influence of armed conflict, considered not in isolation, but as the fundamental basis of other psychopathological and personal deformations; (2) the development and empirical testing of psychological rehabilitation technologies capable of not only reducing clinical symptoms, but also providing constructive experience. extreme situations and the restoration of a positive life perspective; (3) to identify the mechanisms of dynamics of the value-semantic sphere in the process of rehabilitation intervention and the factors that determine the variability of psychological outcomes.

The purpose of the study is to analyze the dynamics of the components of the value-semantic sphere of the civilian population in the process of implementing psychological rehabilitation technology in the context of armed conflict and to identify the mechanisms of constructive transformation of the semantic organization of personality.

## *Prevalence and clinical manifestations of stress disorders among the civilian population in areas of armed conflict*

Accumulated epidemiological data indicate a high prevalence of psychopathological symptoms among citizens exposed to combat operations. Students living in active conflict zones have a statistically significant increase in vegetative, somatized, asthenic, and depressive-anxiety symptoms (Denisov, Abramov, and Plotnikov, 2015). Moreover, 55.95% of the civilian population have a marked deterioration in mental health with changes in self-efficacy parameters both in professional activities and in interpersonal interaction (Kovalenko, 2016). A critical mechanism has been identified in the

pathopsychological study of chronic stress caused by combat: patients show not just a lack of personal resources in general, but a shortage of constructive coping strategies while strengthening maladaptive behavioral patterns (Abramov, 2015).

However, based on the clinical and dynamic analysis in the study of N.P. Soboleva (2017), a model of psychotherapeutic rehabilitation was developed, which made it possible to identify the mechanism: structured psychotherapeutic work can not only reduce symptoms, but also qualitatively change the way personal functioning is organized under conditions of ongoing stress; we can rely on the conclusion that psychological disorders with prolonged The impact of conflict is not an inert state, but a dynamic process that is subject to targeted correction.

## *Differentiation of psychological resources and gender-specific adaptation*

Extreme conditions of armed conflict have a differentiated effect on personal potential depending on gender: in women, a decrease in adaptability is much more pronounced than in men (Abramov et al., 2015). More critical is the identification of the mechanism of maladaptation: the key trigger of emotional disorders and frustration is a sense of loss of meaning. The psychopathological process, therefore, is not reduced to pure anxiety or depression as phenomenological symptoms – it is based on the destruction of the semantic system of personality, which requires interventions aimed not at reducing individual symptoms, but at restoring the semantic framework as an integral structure.

Empirical data demonstrate a regular organization of psychological factors in the process of experiencing conflict. Different types of experience of a situation show a direct correlation with specific configurations of individual psychological characteristics (Novikova, 2024). At the same time, the semantic and value parameters of a personality are of decisive importance, rather than temperamental traits as such. With the destructive type of experience, the high internal organization of psychological characteristics is paradoxically manifested precisely through the value-semantic level, which indicates that a person is actively but maladaptively restructuring his semantic sphere.

Studies of the subjective well-being of civilians in areas of armed conflict show a paradoxical picture: the majority of respondents have indicators in the range of moderate values, which can be regarded as the absence of serious psychopathology (Solovyova, 2016). However, a more detailed analysis reveals an important mechanism: individuals with increased subjective well-being are characterized by the presence of positive personality traits that function as internal psychological buffers.

## *Mechanisms of value-semantic transformation under the influence of threat and loss*

Cross-cultural analysis of the psychological changes of the inhabitants of geographically and historically different zones of armed conflict – Yugoslavia and Donbass – He identified

the typological identity of psychological shifts despite various etiological factors of conflict (Ryadinskaya, 2018): armed conflict initiates a deep reassessment of life values and meanings, a weakening of future orientations and a decrease in motivational activity in relation to constructive planning of life prospects, and the described changes represent a universal psychological response of the individual to a large-scale existential threat.

An analysis of the mechanisms of value reassessment reveals the central role of the fear of death as a catalyst for rethinking life priorities (Abakumova et al., 2024). Under the influence of this existential fear, there is a development of depressive decreased activity and the actualization of unproductive coping strategies. It is critically important that the restructuring of the value hierarchy reflects a realistic reformatting of priorities: for civilians in areas of intense hostilities, the survival and preservation of the family come to the fore, while concern for the future of children occupies a dominant place in the system of motives.

Value-semantic transformations under the influence of intense military stress reveal a dichotomous character: progressive changes associated with a reassessment of priorities towards deeper and existentially significant values are possible, as well as regressive destructive processes manifested in the degradation of the value system and orientation towards primitive survival (Volobuyev, Kovalchishina, Volobuyev, 2023). The variability of outcomes indicates that the direction of value changes depends on the presence of certain psychological conditions that mediate the transition from maladaptive reactions to constructive transformation. At the level of ontological analysis, the traumatic experience of armed conflict does not transform individual value contents, but transforms the entire personality structure, including the level of self-identity (Magomed-Eminov, 2024).

## *The effectiveness of psychological rehabilitation*

Integrated approaches to the rehabilitation of civilians, combining medical, psychological and psychotherapeutic components, demonstrate effectiveness in restoring adaptive functioning (Kivorkova and Solovyov, 2017). Structured rehabilitation work aimed at increasing stress tolerance and correcting emotional disorders ensures not only the reduction of individual symptoms, but also the harmonization of personal functioning as a whole. With timely implementation of rehabilitation measures in the early stages of development, the risk of developing stable emotional, cognitive and behavioral deficits is significantly reduced (Shirokira and Yershova, 2018).

Thus, the aim of the study was to study changes in the components of the value-semantic sphere during the implementation of the program of psychological rehabilitation of civilians in the conflict zone.

# Methods

## *Study Design*

### *Stage 1. Baseline Assessment (2023)*

At the first stage, an empirical study of the psychological characteristics of civilians living under armed conflict conditions was conducted. The main objective of this stage was to identify baseline indicators of the value-meaning sphere, meaning-in-life strategies, well-being, and social isolation/connectedness. The data obtained served as the rationale for justifying the need to develop and test a targeted rehabilitation technology.

At this stage, the following psychodiagnostic tools were used:

1. **SAN Technique (Well being–Activity–Mood)** (V. A. Doskin, M. P. Miroshnikov et al., 1973) is designed to assess the functional psychoemotional state. The technique includes 30 bipolar adjective pairs organised into three corresponding scales; higher scores indicate positive well being, high activity, and favourable mood; lower scores reflect discomfort, apathy, and depressive states.
2. **Morphological Test of Life Values (MTLV)** (V. F. Sopov, L. V. Karpushina, 2001) diagnoses the structure and hierarchy of life values. It comprises 112 items organised into two blocks: 8 terminal values (self development, spiritual satisfaction, creativity, social contacts, personal prestige, achievements, material status, preservation of individuality) and 6 life domains (professional life, education and learning, family life, social activity, hobbies, physical activity). Higher scores indicate the significant importance of a given value within the personality structure.
3. **Meaning in Life Orientations Test (MLOT)** (J. Crumbaugh, L. Maholick, 1964; adapted by D. A. Leontiev, 1988) consists of 20 items organised into 5 subscales: goals in life, process of life, life effectiveness, locus of control–Self, locus of control–Life. Each item is rated on a 7 point scale. Higher scores indicate life meaningfulness, presence of goals, and active engagement in the life process; lower scores suggest lack of meaning and inner emptiness.
4. **Social Isolation Assessment Technique** (D. Russell, M. Ferguson, 1978) is designed to evaluate subjective feelings of loneliness and social alienation; high scores indicate a pronounced sense of social isolation; low scores suggest favourable inclusion in social connections.
5. **World Assumptions Scale (WAS)** (R. Janoff Bulman, 1989; adapted by M. A. Padun, A. V. Kotelnikova, 2008) measures fundamental beliefs about the world and the self. It consists of statements organised into 5 domains: benevolence of the world, justice of the world, self image, luck, and beliefs about control. Higher scores reflect positive basic beliefs; lower scores indicate destructive beliefs about the world, others, and one's own competence.

### *Stage 2. Development and Implementation of the Rehabilitation Programme (2024–2025)*

At the second stage, based on the analysis of the empirical data obtained, a program was developed for the formation of a value-semantic sphere and meaningful strategies (hereinafter referred to as the FSWS program) for civilians living in armed conflict. The program is based on the theoretical principles of existential psychology, the theory of self-determination and a personality-oriented approach, and aims to activate personal potential through a purposeful rethinking of life priorities and the development of adaptive meaning-based strategies in conditions of ongoing stress.

The purpose of the program was to activate the personal resource and transform regressive semantic strategies into progressive ones through work with the value-semantic sphere of personality.

The program was implemented for 12 weeks (the total amount was 72 hours). The program's structure implied a consistent immersion of the participant in self-improvement: from awareness of resources to acceptance of the need to transform life prospects. A mandatory element was the continuous monitoring of changes in the psychoemotional state and beliefs of the participants. The general scheme of the program is presented in Table 1.

**Table 1**
*The general scheme of the Program*

| Stage (Block) | Volume | Tasks and Focus of Work (Content) |
|---|---|---|
| Block I. «Emotional Status and Flexibility of Behavioral Programs» | 16 hours (2 weeks) | Goal: the focus is on working with the «self-concept» and self-regulation skills. Participants study the physiological and psychological mechanisms of stress, learn methods to reduce anxiety, and work on forming a positive identity, which often erodes under conditions of chronic threat. Exploring states and self-regulation:<br>– Analysis of physiological, psychological, and mental status.<br>– Development of a high level of self-awareness and the ability to control oneself.<br>– Control of destructive manifestations (aggression, impulsivity, anxiety).<br>– Activation of self-motivation and social activity processes. |

| Stage (Block) | Volume | Tasks and Focus of Work (Content) |
|---|---|---|
| Block II. «Social Interaction» | 20 hours (4 weeks) | Goal: to teach a person experiencing war stress to communicate positively, be active in establishing contacts with others, avoid withdrawing into oneself, and restore communication skills. Restoring communicative resources:<br>– Overcoming withdrawal and restoring lost communication skills.<br>– Developing the ability to exchange not only ideas but also volitional impulses to achieve common goals (coordinating actions).<br>– Working with emotional unification/separation within the group.<br>– Teaching safe communication in the online space as a coping strategy. |
| Block III. «Planning a Life Perspective» | 36 hours (6 weeks) | Goal: for the individual to build new life-meaning strategies, develop skills to use new life prospects, learn to preserve and accumulate resources necessary for personal growth, form adequate life realities, and reshape life-meaning orientations. Building the future (Transformation):<br>– Developing skills to use new life prospects.<br>– Learning to preserve and accumulate resources for personal growth. – Forming an adequate perception of life realities.<br>– Final reshaping of life-meaning orientations (from regression to progress). |

In addition to standard psychocorrective techniques and role-playing games, the program was based on problem-based learning methods. Participants were offered specially modeled problematic issues and situations that require the activation of hidden personal resources, making non-standard decisions in conditions of uncertainty, and developing skills to adapt to a new reality.

### *Stage 3. Evaluation of the effectiveness of the Program (2025)*

At the third stage, the developed rehabilitation program was empirically tested and its effectiveness was evaluated on an independent sample using an experimental design with control and experimental groups.

## *Study participants*

The sample consisted of 494 respondents permanently residing in conditions of armed conflict, aged from 19 to 53 years (M = 35.4, SD = 10.2). Gender distribution: 208 men (42.1%) and 286 women (57.9%).

The groups were formed as follows:

- Control group (n = 247): 104 men and 143 women. The participants in this group did not receive rehabilitation intervention and served as a baseline for comparison.
- Experimental group (n = 247): 104 men and 143 women. The participants actively participated in the FSWS program for 12 weeks.

The alignment of groups according to the main socio-demographic variables and initial psychological indicators was confirmed at the initial stage.

Criteria for inclusion in the study: permanent residence in an armed conflict zone during the last 12 months, age from 19 to 55 years, absence of acute psychotic disorders, informed consent to participate in the study. All respondents participated in the ascertaining study (the first stage) and gave written consent to participate in the third stage. Contact with potential participants for inclusion in the testing of the program was carried out through the telecommunication channels indicated in the initial questionnaires of the first stage.

## *Methods of statistical data analysis*

To process the data obtained and identify statistically significant differences between the control and experimental groups, as well as changes within each group, a package of statistical methods was used: descriptive statistics, verification of the normality of the data distribution using the Shapiro–Wilk criterion, the Wilcoxon T-test (to compare indicators within the same group before and after the intervention), Mann-Whitney U–test (to identify differences between the control and experimental groups at the stages before and after the intervention), $\varphi$ is the criterion of the Fisher angular transformation (for comparing the relative frequencies (fractions) of qualitative features in two independent samples.

# Results

## *Results of the participant survey on the usefulness of the programme (self-report)*

After completion of the FSZhS programme, a survey was conducted with participants from the experimental group (n = 247) to assess the subjective significance and perceived effectiveness of the rehabilitation intervention. The results across the main question blocks are distributed as follows:

- **Assessment of the programme's content and quality.** The vast majority of participants provided a positive evaluation of the programme: 84.6 % of men and 89.4 % of women noted its informativeness and practical value. Participants highlighted the effectiveness of systematic problem-area coverage, video materials, and situational modelling in re-evaluating life difficulties and activating personal potential.
- **Dynamics of personal attitudes and life meanings.** A substantial portion of the sample (30.7 % of men and 37.2 % of women) reported significant personal changes over the 12-week programme. Qualitative shifts in worldview and goal-setting were noted: increased positivity in life perception (63.15 %), greater meaningfulness of life activities (71 %), and the emergence of motivation to plan for the future. Behavioural manifestations included professional changes (11 % of participants changed their job) and improved physical indicators (normalisation of blood pressure, reduction of somatic symptoms of chronic conditions).
- **Self-understanding and socio-communicative skills.** More than half of the participants (53.8 % of men and 64.3 % of women) reported a qualitative improvement in self-understanding and enhanced competence in interpersonal interactions. A considerable portion of the sample expressed an intention to continue personal development through further education.
- **Future orientation and long-term plans.** 89.5 % of participants stated their intention to apply the acquired knowledge and skills in the long term. Behavioural changes towards a healthier lifestyle included engagement in physical development (47.1 % of men) and creative self-expression (59.4 % of women).

The subjective evaluations obtained indicate that the FSZhS programme met the participants' expectations and served as a catalyst for re-evaluating life priorities and reorienting towards constructive future planning.

## *Dynamics of Respondents' Indicators According to the SAN Method*

At the initial stage of the study, participants in the experimental group exhibited reduced indicators of psycho-emotional state. 50.9–55.2 % of respondents reported unfavourable well-being. 55.7–62.2 % demonstrated an average level of activity. Mood corresponded

to normal values — likely due to the activation of protective personal resources. Only 5.9–8.4 % of participants showed favourable well-being at the initial stage.

After completion of the FSZhS programme, a significant dynamics in psycho-emotional indicators was observed in the experimental group. Mean values of well-being increased from 3.13–3.23 to 4.48–5.37 points (a gain of 43–66 %). Activity increased from 4.07–4.21 to 4.64–5.45 points (a gain of 14–29 %). Mood improved from 4.16–4.53 to 5.35–5.61 points (a gain of 24–29 %).

The differences between pre- and post-programme measurements were statistically significant ($p < 0.05$, according to Fisher's angular transformation φ-criterion). The most pronounced dynamics were observed among women, especially in the well-being indicator (66 % gain) (Table 2).

**Table 2**

*Mean values of the experimental group respondents' indicators before and after participation in the programme (SAN method, points)*

| Indicator | Before participation (men, n=104) | Before participation (women, n=143) | After participation (men, n=104) | After participation (women, n=143) |
|---|---|---|---|---|
| Well-being | 3,13 ± 0,27 | 3,23 ± 0,17 | 4,48 ± 0,29 | 5,37 ± 0,48 |
| Activity | 4,07 ± 0,43 | 4,21 ± 0,32 | 4,64 ± 0,35 | 5,45 ± 0,17 |
| Mood | 4,16 ± 0,28 | 4,53 ± 0,26 | 5,35 ± 0,23 | 5,61 ± 0,17 |

In the control group (which did not participate in the programme), minimal changes in psycho-emotional indicators were recorded. There was a 2.0–2.1 % decrease in unfavourable well-being, a 0.7–1.7 % increase in activity, and a 3.6 % improvement in mood over the same period. These minor changes can be interpreted as a result of natural fluctuations in external conditions (e.g., reduced intensity of hostilities) rather than as an effect of a targeted intervention.

### *Dynamics according to the social isolation level assessment*

Before the programme, nearly half of the men (48.2 %) and 40.5 % of women did not perceive themselves as socially isolated, despite objectively difficult living conditions. However, a third of respondents exhibited a pronounced tendency towards loneliness. Among them, 36.3 % were men and 33.2 % were women. Notably, 6.7 % of respondents reported a deep sense of isolation directly linked to the traumatic experience of losing children during hostilities.

After the programme, a decrease in social isolation indicators was observed in the experimental group. Statistical analysis using Fisher's angular transformation φ-criterion confirmed the significance of positive changes ($p < 0.05$). Significant shifts were found on the «moderate isolation level» scale among men and on the «high isolation level» scale among women.

Over the same period, no substantial changes were observed in the control group. Fluctuations in indicators were situational and lacked statistical significance.

### *Dynamics according to the MTZhTs method (Method for Assessing Life-Meaning Orientations)*

The mean values across the method's scales are presented in Table 3.

**Table 3**
*Features of the life value structure among experimental group respondents (mean values in stens, M ± SD)*

| Life values | Before participation (men, n=104) | Before participation (women, n=143) | After participation (men, n=104) | After participation (women, n=143) |
|---|---|---|---|---|
| Self-development | 4,17±0,39 | 4,34±0,65 | 6,52±1,43 | 7,12±0,39* |
| Spiritual satisfaction | 4,11±0,61 | 4,21±1,73 | 5,15±0,96 | 5,73±1,23 |
| Creativity | 3,92±0,64 | 5,76±1,18 | 4,17±1,23 | 6,56±0,67 |
| Active social contacts | 5,91±0,86 | 5,95±1,23 | 6,45±0,85 | 7,81±0,22 |
| Personal prestige | 5,93±0,38 | 4,72±1,23 | 7,57±0,54* | 5,65±0,83 |

| Life values | Before participation (men, n=104) | Before participation (women, n=143) | After participation (men, n=104) | After participation (women, n=143) |
|---|---|---|---|---|
| High material status | 7,74±0,89 | 7,91±2,56 | 7,74±0,78 | 7,86±1,57 |
| Achievements | 4,82±0,75 | 4,13±2,73 | 5,93±0,83 | 4,47±1,86 |
| Preservation of personal individuality | 4,46±0,72 | 4,51±0,84 | 4,98±0,62 | 5,23±0,23 |

***Note: * — the differences are statistically significant (p < 0.05) according to the Wilcoxon signed-rank test.***

At the stage of the ascertaining cut ("Before"), the value of "High financial status" dominated in both gender subgroups (men: 7.74±0.89; women: 7.91±2.56), reflecting the high importance of resource support for survival in extreme conditions. At the same time, higher-order values ("Self-development", "Spiritual satisfaction", "Creativity") occupied lower positions in the hierarchy, especially among men. In addition to the material factor, women had relatively higher positions in "Active social contacts" and "Creativity," which indicates the continued need for communication and self-expression even in a stressful environment.

After the implementation of the program ("After"), structural shifts in the value hierarchy of the respondents were recorded:

1. Men showed a statistically significant increase in the importance of the "Own prestige" value (from 5.93 to 7.57 walls, p <0.05 according to the T-Wilcoxon criterion). There is also a tendency to increase the importance of the values of "Self-development" (from 4.17 to 6.52) and "Achievements" (from 4.82 to 5.93).
2. Women recorded a statistically significant increase on the scale of "Self-development" (from 4.34 to 7.12 walls, p <0.05). In addition, the indicators on the scales of "Active social contacts" (up to 7.81) and "Creativity" (up to 6.56) increased significantly.

In the control group, there were no statistically significant changes in the hierarchy of life values over the same period, and the priority structure remained rigid.

## *Dynamics of respondents' indicators according to the CSR methodology*

At the stage of the ascertaining cut ("Before"), the profile of life sense orientations was characterized by a moderate decrease in indicators for all subscales relative to the

normative values. The most problematic areas were the "Locus of control – I" (especially in women: 20.22±3.12) and "Goals in life" (in women: 20.28±4.32), which indicated a lack of goal setting and a feeling of inability to control the events of their own lives in conditions of uncertainty (Table 4).

**Table 4**

*The average values of the GCSE test subscales among the respondents of the experimental group before and after participating in the program (M ± SD)*

| Subscales | Before participation (men, n=104) | Before participation (women, n=143) | After participation (men, n=104) | After participation (women, n=143) |
|---|---|---|---|---|
| Life goals | 26,71±2,19 | 20,28±4,32 | 35,41±2,22* | 29,15±1,12 |
| Life process | 25,37±4,65 | 28,16±2,65 | 31,15±1,14 | 37,16±1,17* |
| Life effectiveness | 25,13±3,32 | 21,38±3,43 | 29,13±2,31 | 33,27±1,18* |
| Locus of control «Self» | 21,47±2,73 | 20,22±3,12 | 29,34±2,15 | 29,23±2,27 |
| Locus of control — life | 29,34±3,45 | 23,83±3,84 | 36,13±2,51 | 31,24±1,52 |
| Meaningfulness of life (overall score) | 96,32±3,61 | 91,37±2,56 | 106,31±11,21 | 101,31±12,13 |

***Note: * — the differences are statistically significant (p < 0.05) according to the Wilcoxon signed-rank test.***

After the implementation of the program ("After"), positive dynamics was recorded in all parameters of the methodology, however, the statistical significance of the changes (p <0.05 according to the Wilcoxon T-test) was selectively revealed:

1. Men showed a statistically significant increase on the scale of "Goals in life" (from 26.71 to 35.41 points). This indicates the formation of clearer life plans and the restoration of a temporary perspective for the future. There is also a pronounced positive trend on the scale of "Locus of control – life" (from 29.34 to 36.13), indicating an increase in confidence in the ability to control their own destiny.

2. Women showed statistically significant shifts on the scales of "Life process" (from 28.16 to 37.16 points) and "Life effectiveness" (from 21.38 to 33.27 points). These changes reflect an increase in satisfaction with the current moment of life (perception of the life process as interesting and fulfilling) and a reassessment of the passed life path as productive.

According to the integral indicator "Meaningfulness of life", an increase was recorded in both groups (for men: from 96.32 to 106.31; for women: from 91.37 to 101.31), which confirms the overall effectiveness of the intervention in terms of restoring semantic regulation. The lack of statistical significance on some scales may be explained by the inertia of deep semantic structures that require a longer time for complete transformation. В контрольной группе за аналогичный период статистически значимых изменений профиля СЖО не выявлено. Колебания средних значений по шкалам «Цели» и «Локус контроля» не превышали ошибки измерения, что подтверждает устойчивость дефицитарного смыслового состояния при отсутствии психологической помощи.

## *The dynamics of respondents' indicators according to the WAS methodology*

The results of the comparative analysis in the experimental group before and after participating in the program are presented in Table 5.

**Table 5**
*Mean scores of experimental group respondents on the WAS (M ± SD)*

| Scales | Before participation (men, n=104) | Before participation (women, n=143) | After participation (men, n=104) | After participation (women, n=143) |
|---|---|---|---|---|
| Benevolence of the world | 4,2±1,35 | 4,3±1,25 | 6,9±1,31* | 5,7±1,28* |
| Justice | 5,6±1,67 | 4,7±1,23 | 7,7±1,26* | 8,9±1,32** |
| Self-image | 5,5±2,31 | 5,4±1,17 | 8,4±1,54** | 7,7±1,22* |

| Scales | Before participation (men, n=104) | Before participation (women, n=143) | After participation (men, n=104) | After participation (women, n=143) |
|---|---|---|---|---|
| Luck | 4,5±1,17 | 4,3±1,42 | 8,9±1,33 | 8,6±1,32 |
| Belief in control | 6,3±1,32 | 5,3±1,64 | 6,4±1,37 | 7,2±1,51* |

***Note: * — the differences are statistically significant (p < 0.05) according to the Wilcoxon signed-rank test.***

At the stage before the start of the program ("Before"), the profile of the respondents' basic beliefs was characterized by a deformation of cognitive schemas: the lowest values were recorded on the scales of "Goodwill of the world" (men: 4.2±1.35; women: 4.3±1.25) and "Luck" (4.5±1.17 and 4.3±1.42, respectively); ideas about the hostility of the environment and the unpredictability of events. A relatively safe resource was the "Belief in control" (men: 6.3±1.32; women: 5.3±1.64), reflecting the desire to maintain agency even in extreme conditions.

After completion of the program ("After") A positive transformation of the system of basic beliefs has been revealed. Statistically significant changes ($p < 0.05$ and $p < 0.01$ according to the Wilcoxon T-test) were recorded for most parameters:

1. The indicators on the scale of "Goodwill of the world" have increased (for men, the growth has increased from 4.2 to 6.9; for women, from 4.3 to 5.7; $p < 0.05$). Respondents began to perceive the social environment as supportive more often, and the level of threat expectation decreased.
2. The most pronounced dynamics was noted on the "Luck" scale (high statistical significance of changes $p < 0.01$ in both subgroups: growth to 8.9 in men and 8.6 in women). Faith in the "Justice" of the world has also significantly strengthened (especially among women: growth from 4.7 to 8.9; $p < 0.01$).
3. Scores on the "Self-image" scale have significantly increased (men to 8.4, $p < 0.01$; women to 7.7, $p < 0.05$). The participants began to evaluate their own value and competence more highly.
4. Women showed an increase in the indicators on the scale of "Beliefs about control" (from 5.3 to 7.2; $p < 0.05$), which indicates a decrease in feelings of helplessness. For men, this indicator remained consistently high (6.3 – 6.4), i.e. this resource remained intact.

Thus, during the course of the program, participants can note a cognitive restructuring of traumatic experience: the image of the world transformed from "hostile and chaotic" to "more just and benevolent," and the image of "I" from "victim of circumstances" to "worthy and successful subject."

In the control group, there were no statistically significant changes in basic beliefs over the same period; the indicators on the scales of "Benevolence" and "Luck" remained at a low level.

### *Differences in the experimental and control groups (Mann-Whitney U)*

A comparative analysis of the indicators of the experimental (EG) and control (KG) groups was performed at the post-test stage ("After") using the nonparametric Mann–Whitney U-test for independent samples; the results of the analysis are presented in Table 6.

**Table 6**

*Comparison of mean scores between experimental (EG, n = 247) and control (CG, n = 247) groups post-programme (Mann–Whitney U test)*

| Scale | Experimental Group (after) | Control Group (after) | U-test | p-value |
|---|---|---|---|---|
| Well-being | 4,92 | 3,10 | 875 | 0,00005 |
| Activity | 5,04 | 2,66 | 112 | 0,000001 |
| Mood | 5,48 | 3,83 | 528 | 0,00001 |
| Self-development | 6,81 | 4,25 | 1064 | 0,187 (н/з) |
| Personal prestige | 6,61 | 3,87 | 117 | 0,000001 |
| Life goals | 32,28 | 22,51 | 662 | 0,00001 |
| Life process | 34,16 | 23,12 | 596 | 0,00001 |

| Scale | Experimental Group (after) | Control Group (after) | U-test | p-value |
|---|---|---|---|---|
| Life effectiveness | 31,45 | 20,80 | 659 | 0,00001 |
| Benevolence of the world | 6,32 | 4,16 | 891 | 0,00003 |
| Justice | 8,46 | 4,32 | 116 | 0,000001 |
| Self-image | 8,17 | 4,75 | 100 | 0,000001 |
| Luck | 8,82 | 4,11 | 102 | 0,000001 |

***Note: * — the differences are statistically significant (p < 0.05) according to the Wilcoxon signed-rank test.***

Statistical analysis revealed significant differences (p <0.001) between the groups in most key parameters.:

1. Psychoemotional status (SAN): The severity of all three indicators in the experimental group was significantly higher than in the control group: "Well-being" (U=875, p<0.001), "Activity" (U=112, p <0.001) and "Mood" (U=528, p <0.001). Compared with the control group, the participants of the program showed an improvement in their psychoemotional state, while the control group's indicators remained at a low, close to subdepressive level.
2. In the experimental group, the level of severity of such parameters as "Goals in life" (U=662, p<0.001), "Life process" (U=596, p<0.001) and "Life effectiveness" (U=659, p<0.001) was significantly higher. This suggests that the program participants, unlike the control group, were able to restore a time perspective and a sense of fullness of life.
3. The program participants demonstrated statistically significantly higher levels of positive core beliefs on the scales of "Justice" (U=116, p<0.001), "Luck" (U=102, p<0.001) and "Self-image" (U=100, p<0.001) compared with the control group.

4. The experimental group recorded a statistically significantly higher level of importance of the value of "Own prestige" ($U=117$, $p<0.001$) compared with the control group.

Thus, we can conclude that the results of the mathematical and statistical analysis confirm that the positive dynamics in the experimental group is not accidental or caused by external factors (stabilization of the situation), since there were no similar changes in the control group. It can be said that the implementation of the program has led to a systemic effect: from stabilization of the emotional background to a profound restructuring of semantic regulation of behavior (restoration of goal setting, cognitive reframing of the image of the world and oneself), and the developed program can be considered a significant tool of work.

## Discussion

The results of the study show that participation in the psychological rehabilitation program was accompanied by positive changes in a number of indicators among the respondents in the experimental group compared with the control group. In particular, an improvement in the psycho-emotional state (SAN), a decrease in subjective social isolation, changes in the structure of life values (MTLC), an increase in life-meaning orientations (SOE) and a positive dynamics of basic beliefs (WAS) were recorded. These data are consistent with the fact that the psychological consequences of armed conflicts affect not only the level of symptoms, but also the value-semantic sphere of personality (Alexandrovsky, 2022; Bonkalo, 2023) and fit into the idea of rehabilitation as a process affecting the organization of personal functioning in general (Soboleva, 2017; Kivorkova, Soloviev, 2017). Similar conclusions are drawn in modern reviews on psychosocial support for victims of military operations, which emphasize the need to move from symptom-centered to more comprehensive, personality-oriented models of care (Andersen et al., 2022; Russo-Netzer et al., 2025).

Firstly, an improvement in well-being, activity, and mood in the experimental group in the absence of comparable shifts in the control group may indicate that programmatic intervention is associated with stabilization of the respondents' emotional state. Similar effects have been described in studies of group and short-term interventions for civilians and refugees, where participation in structured programs was accompanied by a decrease in the severity of depressive and anxiety symptoms (Farhood et al., 2014; Acarturk et al., 2022). The combination of psychotherapeutic and psychosocial approaches in the context of armed conflict makes it possible to reduce the severity of symptoms and improve subjective functioning, even if the external situation remains unstable (Andersen et al., 2022). In our study, no changes were recorded in the control group, and it can be assumed that the program was one of the significant factors of the observed dynamics, although the influence of contextual conditions cannot be completely excluded.

Secondly, a decrease in social isolation and an increase in the importance of values related to communication and self-realization correlate with ideas about the special role of "everyday stressors" (isolation, loss of social roles and resources) in the formation of distress among the civilian population (Miller & Rasmussen, 2017). Research on psychosocial support for the wounded and war victims shows that effective programs necessarily include components of restoring social bonds, group support, and participation in meaningful activities (Andersen et al., 2022). Our results are also consistent with evidence on the benefits of art and group interventions when working with traumatized groups (Bosgraaf et al., 2020; Farhood et al., 2014; Peltonen & Kangaslampi, 2019), as well as with research demonstrating that autobiographical reflection on past events and working with a personal narrative help maintain a sense of integrity. The "I" of refugees and people with war experiences (Camia & Zafar, 2021). In this context, the inclusion of group work, art methods and exercises related to the discussion of the life path in the program can be considered as one of the possible mechanisms for reducing isolation and strengthening subjectivity.

Thirdly, changes in the scales of SOE and WAS indicate possible dynamics in the sphere of life meanings and basic beliefs. The increase in indicators of "Goals," "Process," and "Performance" in life, combined with increased faith in the benevolence and justice of the world, luck, and a more positive self-image, partially echoes the concept of post-traumatic growth, which emphasizes the revision of "core beliefs" as an important component of constructive adaptation (Tedeschi, 2023). Similar trends have been described in studies of meaning-centered interventions with refugees, where dealing with issues of meaning, values, and the future reduced existential emptiness and increased a sense of inner support (Costanza et al., 2022). In addition, recent data on populations in protracted conflict show that the combination of meaningful work and resilience building contributes to better mental health and crisis management (Marciano et al., 2024; Russo-Netzer et al., 2025). In our study, the selective nature of statistically significant changes (not across all subscales) indicates a high inertia of the value-semantic sphere and the potential need for longer or multi-stage programs for its deep restructuring.

The revealed gender features (a more pronounced increase in the importance of goals and "one's own prestige" for men and the values of self-realization, creativity, social contacts and justice for women) are consistent with data on the differentiated impact of extreme conditions on men and women and differences in their adaptation strategies (Novikova, 2024).

At the same time, our results are consistent with studies emphasizing the role of hope, semantic perspective, and resilience as key predictors of resilience in protracted conflicts (Marciano et al., 2024), as well as longitudinal work showing that the intensity of military experiences and repeated stressors can sustain symptoms of mental distress for a long time if adequate psychological and social resources are not involved. (Amsalem et al., 2025). In this context, strengthening goal-setting and strengthening basic beliefs related to justice and the benevolence of the world in the experimental group can be considered as a possible step towards a more stable position in relation to the life situation, however,

such interpretations require caution, given the quasi-experimental nature of the design and the absence of distant longitudinal assessments.

### *Limitations of the study*

A number of factors require caution in interpreting the results. First, the work used only self-reporting techniques, which increases the risk of subjective bias; the inclusion of clinical interviews or behavioral indicators could enhance the validity of the conclusions. Secondly, there are no long-term follow-up measurements, so it is impossible to judge the duration and stability of the identified effects. Thirdly, although the presence of a control group makes it possible to partially separate the impact of the program from background changes, it is not possible to completely exclude the influence of external conditions (the dynamics of hostilities, socio-economic shifts).

### *Research perspectives*

A promising area of further research is the longitudinal tracking of the dynamics of the value-semantic sphere and basic beliefs after the completion of the program, as well as a comparison of various intervention formats (individual, group, online formats). Of additional interest is a more detailed analysis of the mechanisms of change, such as the role of psychological flexibility, hope, and specific coping strategies, which are indicated (Marciano et al., 2024). Finally, expanding the sample to include other regions and categories of the civilian population could make it possible to assess the degree of universality and cultural sensitivity of the proposed rehabilitation technology.

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## Authors' Contributions

**Irina Vladimirovna Abakumova** – overall research management, reviewing and editing of the article, final approval of the version for publication.

**Evgeniya Nikolaevna Ryadinskaya** – development of the research methodology, preparation of the experimental programme, data analysis, preparation of the article text.

**Natalya Ivanovna Kovalchishina** – literature analysis, work with scientific sources, data collection, visualization of results, preparation of the article text.

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# Measuring User Engagement in Interaction with a Chatbot: Adaptation of the UES Scale in a Russian-Speaking Sample

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## Abstract

**Introduction.** Chatbots based on generative artificial intelligence (AI) have rapidly gained popularity and are increasingly influencing various aspects of daily life. An important component of the user experience is engagement, which reflects the depth and intensity of a person's interaction with AI systems. The aim of this study was to adapt the User Engagement Scale (UES) to assess engagement among Russian-speaking users interacting with generative AI–based chatbots. **Methods.** The study involved 210 respondents aged 18–60. The linguistic adaptation procedure included forward and backward translation, expert review, and a focus group. To evaluate the psychometric properties of the scale, exploratory and confirmatory factor analyses were conducted, along with assessments of test–retest reliability, convergent and divergent validity. **Results.** Exploratory factor analysis identified a four-factor structure—positive interaction experience, engagement (immersion), interface appeal, and interaction difficulties—explaining 74.3% of the variance. Confirmatory factor analysis supported the adequacy of the proposed model. Cronbach's alpha (0.83) and test–retest reliability (r = 0.81) indicated high stability of the instrument. Convergent validity was demonstrated by strong correlations with perceived usability (r = 0.823) and absorption by activity (r = 0.834), while divergent validity indicated weak correlations with negative affect and life satisfaction. **Discussion.** The adapted version of the scale retains its theoretical foundation and accurately measures key aspects of user engagement. Interaction with generative AI chatbots emphasizes positive experience and immersion, whereas interaction difficulties have a smaller impact due to intuitive interfaces and the ability of AI systems to imitate interpersonal communication. The Russian version of the instrument demonstrated high reliability and validity and can be used in further studies of human–AI interaction.

## Keywords

user engagement, scale adaptation, chatbots, generative artificial intelligence, linguistic adaptation, psychometric analysis, exploratory factor analysis, confirmatory factor analysis

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# Introduction

In recent years, the rapid development of artificial intelligence (AI) technologies has significantly influenced multiple spheres of human life. AI is increasingly used in education (Von Garrel & Mayer, 2023), scientific research (Bin-Nashwan et al., 2023), programming (Akbar et al., 2024), psychometrics (Valueva et al., 2024), marketing (Gupta et al., 2024), and many other domains. Generative AI, in particular, has substantially expanded the possibilities for everyday applications. The launch of ChatGPT in 2022 marked a turning point and popularized the use of generative AI for a wide user audience.

A key aspect of human–AI interaction is user satisfaction, which encompasses several components, including engagement, trust, and overall user experience. User engagement reflects the depth and intensity of an individual's interaction with a digital system (O'Brien, 2016). As generative AI systems increasingly approximate human conversational patterns, they create more contextually meaningful and interactive exchanges, thereby enhancing user engagement (Bragazzi et al., 2023). These systems may be perceived not merely as tools but as social agents capable of following social norms and politeness strategies, which is essential for fostering user satisfaction and trust.

One of the primary determinants of satisfaction with generative AI tools is perceived usefulness. Research shows that users experience satisfaction when AI technologies meet their needs in learning, task completion, or simplification of complex activities (Almufarreh, 2024). Usefulness therefore plays a central role in shaping both engagement and satisfaction. Additionally, the concept of parasocial interaction—users perceiving AI as a social entity—contributes to engagement formation. Interaction with AI can elicit

a sense of social presence, which enhances the overall user experience (Kronemann et al., 2022). Studies indicate that when users develop a feeling of connection with AI, their engagement increases, resulting in higher satisfaction (Kronemann et al., 2022).

Given the rapid growth of generative AI–based chatbots among Russian-speaking users, there is a pressing need for valid assessment tools to evaluate user satisfaction and engagement. Therefore, the aim of the present study is to adapt the User Engagement Scale (UES) (O'Brien et al., 2018) for a Russian-speaking sample in the context of interaction with a generative AI–based chatbot.

# Methods

## *Sample*

The study involved 210 participants (147 women and 63 men) aged 18 to 60. Among them, 135 participants held a higher education degree, 63 had incomplete higher education, and 9 held an academic degree. A total of 144 participants had a social sciences or humanities background, 26 a technical background, 23 a natural sciences background, 7 a medical background, and 7 a mathematical background.

The second stage of the study, conducted 1–2 months later to assess test–retest reliability, included 98 respondents (68 women and 30 men) aged 18 to 56. Of these, 63 held a higher education degree, 30 had incomplete higher education, and 4 held an academic degree. Sixty respondents had a social sciences or humanities background, 16 a technical background, 15 a natural sciences background, 3 a medical background, and 3 a mathematical background. Data collection was carried out using Google Forms and Yandex Forms from July to October 2024. All respondents provided informed consent to participate in the study.

## *Instruments*

The short version of the **User Engagement Scale (UES)** (O'Brien et al., 2018) is designed to measure the degree of user engagement during interaction with digital systems. Its central purpose is to capture how deeply users perceive and interact with content and system functionality. The scale consists of 12 items rated on a five-point Likert scale.

The translation of the User Engagement Scale into Russian was conducted in accordance with established standards of linguistic adaptation and test validation (Van de Vijver & Hambleton, 1996). The procedure involved two professional psychologists fluent in both Russian and English, as well as two linguists specializing in psychological translation. Forward and backward translations were prepared, after which discrepancies between the original and back-translated versions were examined by experts and resolved through collaborative discussion. Additionally, a focus group of eight psychology students, all

active users of chatbots, was organized to evaluate the clarity and appropriateness of the translated items. The discussion was conducted via ZOOM, and necessary modifications were introduced to improve the comprehensibility of specific statements.

The **UMUX-LITE** (Usability Metric for User Experience) (Lewis et al., 2013) is a brief instrument assessing perceived usability of interactive digital systems. It consists of two items rated on a seven-point Likert scale.

The **Absorption by Activity** subscale of the Flow Short Scale (Engeser & Rheinberg, 2008) measures a state characterized by a balance between a person's perceived skills and the complexity of an activity. This subscale contains five items rated on a seven-point Likert scale.

Since UMUX-LITE and the Flow Short Scale have no officially adapted Russian versions, both instruments were translated using forward and backward translation followed by expert evaluation of semantic and terminological equivalence. The translation was performed by the same group of specialists who participated in the adaptation of the User Engagement Scale, ensuring consistency of expert judgments. The translated versions were used in the present study to assess the convergent validity of the main instrument.

The **Satisfaction With Life Scale** by E. Diener in the adaptation by E. N. Osin and D. A. Leontiev (Osin & Leontiev, 2008) was used to measure overall life satisfaction independent of specific life domains. The scale consists of five items rated on a seven-point Likert scale.

The **Positive and Negative Affect Schedule (PANAS)** in the Russian adaptation by E. N. Osin (Osin, 2012) was used to assess levels of positive and negative affect. It consists of 20 items rated on a five-point Likert scale.

The **Short Boredom Proneness Scale**, adapted by A. A. Zolotareva (2020), consists of eight items rated on a seven-point Likert scale and was used to assess boredom proneness.

## Results

An initial item analysis was conducted to assess the suitability of the scale items. Item difficulty indices ranged from 0.46 to 0.79, with several items (2, 11, 5, 3) showing a shift toward higher ease, approaching 80%. The item–total correlations ranged from 0.40 to 0.77 for all items. Internal consistency of the overall scale "User Engagement in Interaction with a Chatbot" was high, with Cronbach's alpha of 0.83. Table 1 presents descriptive statistics for the full sample (n = 210).

**Table 1**

*Descriptive statistics for the "User Engagement" scale*

| Statistic | Value |
|---|---|
| Mean | 2.99 |
| Standard deviation | 0.56 |
| Skewness | –0.51 |
| Kurtosis | 0.56 |
| Minimum | 1.5 |
| Maximum | 4.67 |
| Cronbach's alpha | 0.83 |
| Standardized alpha | 0.88 |
| Average inter-item correlation | 0.38 |

Exploratory factor analysis (principal component analysis with varimax rotation) was used to examine the scale's structure (KMO = 0.855; Bartlett's test: $\chi^2 = 1261.62$, df = 66, $p < 0.001$). Based on Kaiser's criterion, three factors with eigenvalues greater than 1 were extracted, jointly explaining 68.44% of the variance. A fourth factor had an eigenvalue of 0.704 and explained an additional 5.86% of variance. Together, the four extracted factors fully reproduced the structure of the original questionnaire (Table 2):

- **Factor 1** (41.9%) – Positive interaction experience
- **Factor 2** (17.9%) – Engagement (immersion)
- **Factor 3** (8.7%) – Interface appeal
- **Factor 4** (5.9%) – Difficulties and discomfort during interaction

**Table 2**

*Rotated component matrix*

| Item | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 11. The interaction experience with the chatbot was useful for me. | .846 | .162 | | .194 |
| 10. The interaction with the chatbot produced the result I needed. | .755 | .238 | –.234 | .155 |

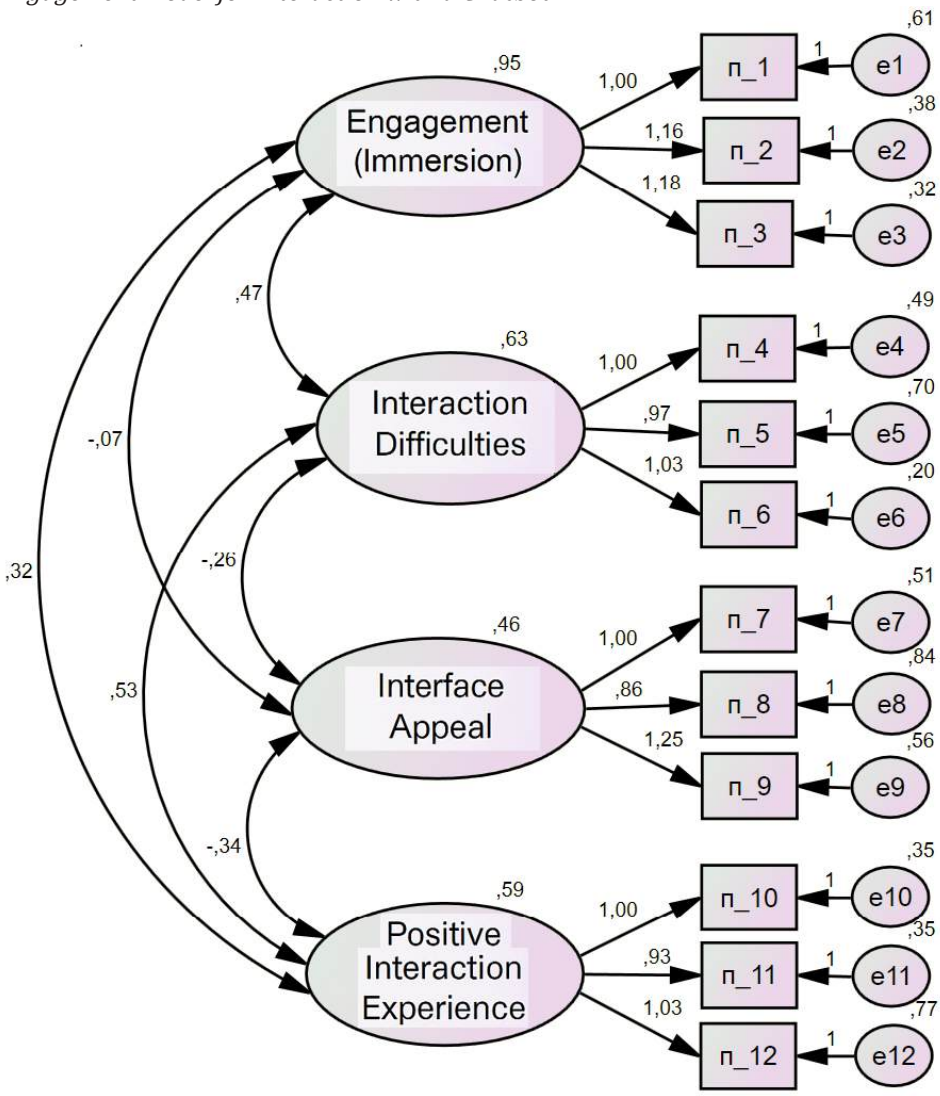
| Item | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 12. I found it interesting to interact with the chatbot. | .674 | | –.425 | |
| 3. I was completely absorbed in interacting with the chatbot. | | .902 | | .186 |
| 2. While interacting with the chatbot, I did not notice how time passed. | .124 | .888 | | .187 |
| 1. I became deeply immersed in the interaction with the chatbot. | .246 | .813 | | .180 |
| 8. The chatbot looked aesthetically pleasing. | | | .799 | –.160 |
| 7. The chatbot's interface was appealing. | –.284 | | .761 | |
| 9. The interaction with the chatbot was pleasant. | –.332 | | .710 | –.136 |
| 5. The chatbot seemed confusing to use. | .138 | .300 | –.135 | .850 |
| 6. Interacting with the chatbot was tiring. | .578 | .241 | –.225 | .596 |
| 4. I was disappointed with my interaction with the chatbot. | .521 | .325 | | .573 |

*Extraction method: Principal Component Analysis; Rotation method: Varimax with Kaiser normalization; rotation converged in 6 iterations.*

The four-factor solution obtained via exploratory analysis was further evaluated using confirmatory factor analysis (CFA). The four-factor model demonstrated acceptable fit to the data. The $\chi^2$/df ratio was 2.777, indicating a reasonable balance between model fit and complexity. The fit indices—GFI = 0.911 and AGFI = 0.855—showed good agreement with the data, while high CFI (0.930) and TLI (0.904) values confirmed that the model adequately represented the empirical structure. The RMSEA value of 0.074 fell within the acceptable range, and the RMR value of 0.084 indicated an acceptable level of residual error. Parsimony indices (PRATIO = 0.727, PNFI = 0.652) further supported the balanced nature of the model. **The CFA model is presented in Figure 1** (not reproduced here).

**Figure 1**

*User Engagement Model for Interaction with a Chatbot*



Test–retest reliability was assessed over a one-month interval across four weeks using Spearman's rank correlation. Ninety-three participants took part in the repeated assessment. The Spearman correlation for the Russian version of the User Engagement Scale was 0.81, indicating high temporal stability.

Convergent validity was evaluated through correlations between overall engagement scores and the UMUX-LITE usability measure (Lewis et al., 2013), the Positive and Negative Affect Schedule (PANAS; Osin, 2012), and the "Absorption by Activity" subscale of the Flow Short Scale (Engeser & Rheinberg, 2008). Divergent validity was assessed through comparisons with the Boredom Proneness Scale (Zolotareva, 2020) and the Satisfaction With Life Scale (Osin & Leontiev, 2008). Results are presented in Table 3.

**Table 3**

*Convergent and divergent validity indicators of the User Engagement Scale*

| N | UMUX-LITE (Usability) | Positive Affect (PA) | Negative Affect (NA) | Absorption by Activity | Boredom Proneness | Life Satisfaction |
|---|---|---|---|---|---|---|
| 210 | .823** | .643** | –.120 | .834** | –.120 | .024 |

**Note. p** < *0.01 (two-tailed).*

The results demonstrated strong positive correlations between overall engagement and both perceived usability (r = 0.823) and absorption by activity (r = 0.834). A moderate positive correlation with positive affect (r = 0.643) suggested that engagement is associated with positive emotional experiences during interaction with a chatbot. In contrast, negative affect (r = –0.120), boredom proneness (r = –0.120), and life satisfaction (r = 0.024) showed weak or negligible associations with engagement. These findings indicate that the scale effectively differentiates engagement from unrelated psychological characteristics.

Overall, the adapted instrument demonstrated high convergent and adequate divergent validity, confirming its reliability for assessing user engagement in interaction with a chatbot.

## Discussion

The adaptation of the instrument for assessing user engagement in interaction with a chatbot demonstrated that the Russian-language version preserved the key components necessary for diagnosing this aspect of the user experience. The observed shift in item difficulty toward "ease" is consistent with the preferences of users who choose chatbots for convenient and effortless interaction. The high item–total correlations and Cronbach's alpha indicate strong internal consistency, confirming the reliability of the scale for measuring user engagement with a chatbot.

The exploratory factor analysis revealed substantial differences in factor loadings when comparing the original engagement measure with its Russian adaptation. In the original version, positive interaction experience was the least prominent factor, whereas in the adapted version it became the dominant one. Conversely, difficulties and inconveniences of interaction emerged as comparatively less significant in the adapted scale. This discrepancy may reflect changes in user perception related to the affordances of generative AI. In interactions with earlier, non-generative technologies, users may have been less sensitive to nuances of experience and more focused on basic functionality and ease of use. However, generative AI provides unique opportunities: chatbots based on generative models can participate in interactions that closely resemble human communication, substantially influencing users' perceptions of the interaction (Al Lily et al., 2023; Israfilzade, 2023; Orrù et al., 2023; Wang et al., 2023).

Furthermore, users may pay less attention to interface usability and functionality due to the intuitive design and high level of accessibility typically associated with modern generative AI systems (Shete, 2023). These characteristics likely reduce the salience of perceived difficulties and enhance the importance of pleasant and meaningful interaction, thereby contributing to the increased relevance of positive experience and immersion in the adapted model.

Confirmatory factor analysis supported the four-factor structure, demonstrating adequate model fit and overall quality. Fit indices, error measures, and parsimony indicators all confirmed the appropriateness of the model for describing the underlying structure of the data and indicated its suitability for further research applications.

The results of convergent validity analysis revealed strong positive correlations between overall engagement and both usability (as measured by UMUX-LITE) and absorption by activity. These findings are consistent with prior research demonstrating close relations between engagement and various aspects of user experience with interactive technologies (Avila-Garzon et al., 2023; Fergencs & Meier, 2021; O'Brien & Lebow, 2013). Similarly, the link between engagement and absorption aligns with previous work showing that a state of flow or deep involvement enhances engagement during interaction with AI-based technologies (Arghashi & Yuksel, 2022; Cha et al., 2024).

The moderate positive association between engagement and positive affect suggests that emotional responses play a meaningful role in shaping user engagement. Prior research indicates that the expression of positive emotions by conversational agents can improve interaction quality (Andrade-Arenas, Yactayo-Arias & Pucuhuayla-Revatta, 2024; Park et al., 2023; Tsai et al., 2021). However, the influence of the user's own emotional state on engagement remains less clear. Existing studies suggest that the impact of positive emotions on engagement with interactive systems may vary depending on context and individual characteristics (Zheng et al., 2024).

The findings also demonstrated weak associations between engagement and both negative affect and boredom proneness. This indicates that even under conditions of general negative mood or heightened boredom, engagement with a chatbot may remain relatively unaffected. Additionally, the absence of a correlation between life satisfaction and engagement suggests that cognitive aspects of subjective well-being do not influence the degree of engagement in interaction with a chatbot. Overall, these results support the divergent validity of the measure, confirming that engagement constitutes a distinct construct independent of emotional background and general life satisfaction.

## Conclusion

The four-factor structure of the Russian-language version of the User Engagement Scale, identified through exploratory factor analysis and confirmed via confirmatory factor analysis, includes the following components: positive interaction experience, engagement (immersion), interface appeal, and interaction difficulties. These results replicate the structure of the original scale and confirm its theoretical soundness. In the context of interaction with generative AI, positive experience emerged as the most influential factor, which may be explained by the intuitive interfaces of such systems and their ability to simulate interpersonal communication.

The Russian version of the instrument demonstrated high reliability and validity. Elevated Cronbach's alpha (0.83) and test–retest reliability (Spearman's r = 0.81) indicate strong internal consistency and stability over time. Convergent validity was supported by high correlations between overall engagement and both chatbot usability (UMUX-LITE; r = 0.823) and absorption by activity (r = 0.834), highlighting the relevance of these psychological characteristics for the construct of engagement. Divergent validity was confirmed by minimal correlations with negative affect, boredom proneness, and life satisfaction.

Overall, the instrument effectively differentiates user engagement as a distinct dimension of the user experience and can be confidently applied in research aimed at assessing interaction with interactive technologies, including generative AI–based systems.

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# Appendix 1.

## *User Engagement Scale — Russian Adapted Version (12-item short form)*

**Dear Participant,**

Thank you for taking part in the assessment of engagement during interaction with a chatbot.

**Please follow the instructions below when completing the questionnaire:**

- Respond sincerely and without prolonged reflection.
- Your immediate impressions are most valuable.
- Do not overthink the items.
- Answer based on your actual experience of interacting with a chatbot.
- It is important that your responses reflect your real feelings and impressions.

Please indicate the degree to which you agree with each statement based on your experience of interacting with a chatbot. Use the following response scale from **1 (Strongly disagree)** to **5 (Strongly agree).**

**Response options**

1 — Strongly disagree
2 — Disagree
3 — Not sure
4 — Agree
5 — Strongly agree

**Items (Russian Adapted Wording)**

6. Я погрузился с головой во взаимодействие с чат-ботом.
7. Взаимодействуя с чат-ботом, я не заметил, как пролетело время.
8. Я был полностью поглощен взаимодействием с чат-ботом.
9. Я был разочарован взаимодействием с чат-ботом.
10. Чат-бот показался мне запутанным в использовании.
11. Взаимодействие с чат-ботом было утомительным.
12. Интерфейс чат-бота был притягательным.
13. Чат-бот выглядел эстетически привлекательно.
14. Взаимодействие с чат-ботом было приятным.
15. Взаимодействие с чат-ботом дало тот результат, который был мне нужен.
16. Опыт взаимодействия с чат-ботом был для меня полезным.
17. Мне было интересно, когда я взаимодействовал с чат-ботом.

**Subscale Scoring Instructions**

- Engagement (Immersion): mean of items 1, 2, 3
- Interaction Difficulties: mean of items 4, 5, 6
- Interface Appeal: mean of items 7, 8, 9
- Positive Interaction Experience: mean of items 10, 11, 12
- Overall User Engagement: mean score across all 12 items

**Note**

This appendix presents the final Russian-language version of the User Engagement Scale adapted for use with generative AI–based chatbots. Only the validated Russian wording is reproduced here in accordance with translation and publication guidelines.

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## Author Contributions

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## Conflict of Interest Information

The authors have no conflicts of interest to declare.

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# Life-Meaning Orientations, Attitude to Time and Resilience in Women with Various Types of Eating Behavior

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## Abstract

**Introduction.** The increasing prevalence of obesity underscores the importance of examining eating disorders as a key contributing factor. Eating disorder tendencies are frequently linked to individuals' psychological characteristics, particularly their capacity to manage challenges in the contemporary world. The present study aims to investigate life-meaning orientations, time perspectives, and resilience among women exhibiting varying degrees of eating disorder severity. **Methods**. The sample comprised 152 women aged 18–56 years. Participants were categorized into groups based on low versus high severity of eating disorders. **Methods.** 'Dutch Eating Behavior Questionnaire'; ' Life-meaning Orientation Test';' Time Perspective Questionnaire'; 'Resilience Test', body mass index. Statistical analysis: U-Mann-Whitney criterion, r-Spearman's rank correlation coefficient. **Results.** In groups with different severity of eating disorders, differences in the parameters of life -meaning orientations 'Process' and 'Locus of Control-I', aspects of the time perspective 'negative past', 'hedonistic present', 'fatalistic present' and all parameters of resilience were confirmed. In both groups, there were direct links between the restrictive type of eating disorders and the body mass index: the higher the actual weight of the respondents, the greater the tendency to establish strict dietary requirements and restrictions. The 'negative past' in both groups of respondents is directly related to the severity of eating disorders. Eating disorders of the emotionogenic type

are inversely related to all scales of resilience and meaningfulness of life, and directly to the level of negative past and fatalistic present. **Discussion.** It is promising to develop a program for psychological correction to reduce the severity of eating disorders in terms of strengthening the individual's ability to cope with stress, working out negative past experiences, developing meaningful life and goal-setting skills, and reducing anxiety.

## Keywords

eating disorders, risk-taking, resilience, time perspective, negative past, obesity, emotionogenic overeating, external overeating, restrictive overeating

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# Introduction

Despite the abundance of information on a healthy lifestyle, the dangers of improper nutrition, and modern medical and nonmedical ways to combat excess weight, population obesity will remain one of the most pressing problems (Alferova, Mustafina, 2022). The main cause that leads to obesity and increases the risk of other comorbidities is eating disorders (hereinafter referred to as ED) (Mikhailova et al., 2023; Akhriani et al., 2025, Anil et al., 2025). Several studies have proved the association of overweight with restrictive (Bessolitsyna et al., 2024), emotionogenic (Ermakova et al., 2024), and external (Lyasnikova et al., 2024) types of eating behavior.

Researchers in the medical field have shown a link between AP disorders and type 2 diabetes mellitus (Kristo et al., 2024; Demicheva and Smirnova, 2023; Alekseeva, 2022); irritable bowel syndrome (Jia et al., 2022); an increase in gastroenterological symptoms (Shklyaev et al., 2022); and the prevalence of dependence on nonalcoholic alcohol. fatty liver disease in children (Gibson et al., 2015); clinical anxiety (Yankova et al., 2022); sensitivity to bitter taste (Lin et al., 2025); cardiac and gastric interception (Tiemann et al., 2025).

A study of gender aspects of eating disorders has shown that men are more prone to an external type of eating behavior (Vetoshkin et al., 2023), while women are more characterized by emotionogenic eating behavior or a combination of emotionogenic with restrictive or external types (Halashte et al., 2023).

At the same time, eating disorders can be a consequence of the psychological instability of the individual caused by stress or personal characteristics. Thus, situational

anxiety is directly related to emotsiogenic eating behavior (Chapala and Ilich, 2022); the level of depression in young men correlates with the severity of emotsiogenic and external EB (Filatova et al., 2022); the severity of eating disorders in adolescent girls is associated with dissatisfaction with their own body image (Dorraj & Hatamipour, 2025); external depression in young men is associated with the severity of emotsiogenic and external EB (Filatova et al., 2022). Emotsiogenic eating behavior reduces the quality (Shafiee et al., 2025); a direct linkbetween emotsiogenic eating behavior and the component of perfectionism was revealed (Krapivina, 2023). People with a high level of willpower are less likely to eat stress, are less sensitive to external stimuli to eat, and at the same time, they are more often resorting to self-control. excessive self-restrictions in nutrition, which subsequently lead to breakdowns and overeating (Grafova, 2024; Petrova and Kozyreva, 2022). There is a direct link between restrictive eating behavior and cycloid, sensitive, excitable types of character accentuations and emotionogenic eating behavior with hyperthymic, asthenoneurotic, and sensitive types, as well as direct links between restrictive and emotionogenic eating behavior and orientation to the negative past (Avdulovaand Antonikova, 2023). Direct relationships are also revealed between the characteristics of a person's self-attitude and types of eating behavior. Therefore, external eating behavior is associated with an indicator of closeness, restrictive EB with self-confidence, emotionogenic eating behavior with factors of internal conflict and self-blame (Chernyaeva, 2023).

Therefore, the problem of eating disorders is the focus of research by various authors, but its connection with the semantic sphere of the individual, combined with the attitude to time and resilience, is poorly understood.

The purpose of this work is to study life-meaning orientations, attitudes toward the time perspective, and resilience of women with different degrees of eating disorders.

Research hypotheses:

1. Life-meaning orientations, attitudes towards time perspective, and resilience indicators may differ between women with different degrees of eating disorders.
2. The psychological characteristics of the individual (life-meaning orientations, attitude to time, resilience) and types of eating disorders can be interrelated.

## Methods

The study involved 152 women aged 18 to 56 years (mean age 23 years, standard deviation 9.1 years).

To achieve the research goal, the following methods were selected:

1. 'Dutch Eating Behavior Questionnaire' T. Van Strien et al. (translated by I. G. Malkin-Pykh, 2007) for studying the peculiarities of eating behavior, including the scales of 'Restrictive eating behavior', 'Emotionogenic eating behavior' and 'External eating behavior';

2. The test of life-meaning orientations (adapted by D. A. Leontiev) to identify the main characteristics of life-meaning orientations, including the scales "Goals", "Process", "Result", "Locus of control - I', 'Locus of control-life", and "Overall score of meaningfulness of life".

3. F. Zimbardo's 'Time Perspective Questionnaire' (adapted by E. T. Sokolova, O. V. Mitina, etc.) for diagnosing attitudes to time, including the scales 'Negative Past', 'Hedonistic Present', 'Future', 'Positive Past', 'Fatalistic Present';

4. 'Resilience test' by S. Muddy (adapted by D. A. Leontiev and E. I. Rasskazova) for studying the ability to cope with stress, including the scales 'Involvement', 'Control', 'Risk acceptance', 'Overall resilience score';

5. For each respondent, the body mass index was calculated using the formula BMI = weight (in kg) / rost2 (in m).

To analyze the results of the study, two groups with high and low scores were selected using the 'Dutch Eating Behavior Questionnaire' method. Respondents whose results fell in the middle range were not taken into account in the study. Group 1 (n=55) -women with low severity of eating disorders, group 2 (n=61) -women with high severity of eating disorders.

The obtained data were processed using standard methods of descriptive statistics, the Kolmogorov-Smirnov test was used to determine the normality of the distribution, the nonparametric Mann-Whitney U-test was used to analyze the significance of differences, and significant correlations were studied using the calculation of the rank correlation coefficient r-Spearman. The data obtained were processed using Jamovi 2.3.28 software.

## Results

As a result of the study using the method of 'Life-meaning orientations' by D. A. Leontiev, the following results of comparing groups were obtained and presented in Table 1.

**Table 1**

*Results of the study using the method of 'Life-meaning orientations' D. A. Leontiev for groups with different levels of severity of eating disorders (in points)*

| Variable | Averages | | Statistics | p |
|---|---|---|---|---|
| | Group 1 | Group 2 | | |
| Goals | 34.21 | 32.2 | 1440 | 0.188 |
| Process | 33.27 | 29.54 | 1288 | 0.031* |
| Result | 28.76 | 26.75 | 1394 | 0.116 |
| Control locus-I | 23.05 | 20.93 | 1297 | 0.035* |

| Variable | Averages | | Statistics | p |
|---|---|---|---|---|
| | Group 1 | Group 2 | | |
| Locus of control-life | 33.04 | 31.44 | 1433 | 0.176 |
| Total life meaningfulness score | 110.42 | 102.95 | 1377 | 0.097 |

***Notes:*** *the symbol ' * ' indicates differences at the level of p <0.05. Group 1 — women with low severity of EB disorders, group 2 — women with high severity of EB disorders.*

According to the results of statistical data analysis, significant differences were found between the groups on the 'Process' scale (33.27 and 29.54, U=1288, p <0.05) and 'Locus of control I' (23.05 and 20.93, U=1297, p <0.05). Therefore, respondents with a high level of severity of eating disorders are less satisfied with their lives and believe in the possibility of changing it for the better than the group with a low severity of eating disorders. Consequently, in the absence of severe eating disorders, women perceive their lives as more emotionally rich, filled with meaning, and feel able to build it according to their own plan.

As a result of the study using the 'Time Perspective Questionnaire' method by F. Zimbardo, the following comparison group results were obtained, presented in Table 2.

**Table 2**

*Results of the study using the 'Time Perspective Questionnaire' method by F. Zimbardo for groups with different levels of severity of eating disorders (in points)*

| Variable | Average values | | Statistics | p |
|---|---|---|---|---|
| | Group 1 | Group 2 | | |
| Negative past | 2.49 | 3.1 | 1039 | <. 001*** |
| Hedonistic Present | 3.17 | 3.46 | 1182 | 0.006** |
| Future | 3.69 | 3.64 | 15.79 | 0.587 |
| Positive past | 3.62 | 3.46 | 14.44 | 0.196 |
| Fatalistic present | 2.51 | 2.83 | 1207 | 0.009** |

***Notes: the symbol '* * 'indicates differences at the level of p <0.01, the symbol' * * * ' indicates differences at the level of p < 0.001. Group 1 — women with low severity of EB disorders, group 2 — women with high severity of EB disorders.***

Significant differences between the groups were found on the scales of 'Negative past' (2.49 and 3.1, U=1039, p <0.001), 'Hedonistic present' (3.17 and group 3.46, U=1182, p <0.01) and 'Fatalistic present' (group 2.51 and group 2.83, U=1207, p<0.01). It can be concluded that respondents with a high level of severity of eating disorders have a statistically significantly higher perception of their past as painful, an important aspect of the present is getting pleasure 'here and now', and life events are seen as predetermined and subordinate to fate. Whereas a person without pronounced eating disorders differs more than in the other group in accepting their past, the ability to sacrifice something in the present for the sake of reward in the future, and the belief in the possibility of their own influence on their own lives.

As a result of the study using the 'Resilience Test' method by S. Muddy, the following results of comparing groups were obtained, presented in Table 3.

**Table 3**

*Results of the study using the S. Muddy 'Resilience Test' method for groups with different levels of severity of eating disorders (in points)*

| Variable | Average values | | Statistics | p |
|---|---|---|---|---|
| | Group 1 | Group 2 | | |
| Engagement | 38.4 | 31.02 | 1008 | <. 001*** |
| Monitoring | 31.64 | 26.85 | 1123 | 0.002** |
| Risk | acceptance | 19.53 16.46 | 1139 | 0.003** |
| Overall Resilience | Score | 89.56<br>74.33 | 1021 | <. 001*** |

***Notes:*** *the symbol '* * 'indicates differences at the level of p <0.01, the symbol' * * * ' indicates differences at the level of p < 0.001. Group 1 — women with low severity of EB disorders, group 2 — women with high severity of EB disorders.*

According to the 'Resilience Test' method, differences in groups on all scales of the method were revealed: 'Engagement' (group 1— 38.4, and group 2— 31.02, U=1008, p <0.001), 'Control' (31.64 and 26.85, U=1123, p <0.01), 'Risk taking' (19.53 and 16.46, U=1139, p <0.01) and 'Overall resilience score ' (89.56 and 74.33, U=1021, p <0.001). Respondents with a high degree of eating disorders are more likely to feel out of life, their own helplessness, and the desire for comfort and safety as a means against everyday stress. On the contrary, a person with a low level of eating disorders is more confident in their own ability to influence their life, actively takes steps to improve it, even in the absence of reliable guarantees of success, and generally successfully copes with stressful situations, perceiving them as less significant.

The results of a comparative analysis of data for all methods according to the Mann-Whitney criterion allow us to conclude that hypothesis 1 is confirmed. Respondents without pronounced eating disorders are more active in their lives, are focused on building and implementing long-term plans, which is made possible by their ability to take risks and believe in the ability to manage their life events. Although respondents with a pronounced violation of the AP are more passive, the past is painful for them and the future is not subject to the individual, one of the behavioral strategies is to enjoy the present. Food, in this case, is an affordable and guaranteed pleasure, as well as a temporary cure for painful experiences.

To study the relationship between the severity of eating disorders and the psychological characteristics of the respondents, a correlation analysis was performed using Spearman's criterion. The results are presented in Tables 4,5.

Table 4 shows the results for group 1 (women with a low level of severity of eating disorders).

**Table 4**

*Analysis of correlations in the group of respondents with a low level of severity of eating disorders (group 1)*

| № | Parameters | Spearman's criterion |
|---|---|---|
| 's Criterion 1 | Restrictive EB / BMI | 0.468*** |
| 2 | Restrictive EB / emotionogenic EB | 0.268* |
| 3 | Emotionogenic EB / external EB | 0.352** |
| 4 | External EB / negative past | 0.336* |
| 5 | External EB / future | 0.326* |

***Note:*** *the symbol '* * 'indicates differences at the level of p <0.01, the symbol' * * * ' indicates differences at the level of p < 0.001*

Correlation analysis revealed a number of relationships between indicators. Thus, the external type of eating behavior in the group with low severity of eating disorders is positively associated with the parameters 'future', 'negative past', which indicates that an external type of eating disorder in this group is possible in respondents with a rejection of their past and/or in respondents who are highly focused on achieving their goals in the future. It can be assumed that their lifestyle includes frequent business events that involve eating, which contributes to an increase in the food intake.

Interestingly, restrictive eating behavior in this group is positively associated with body mass index. So, the higher the actual weight index, the higher the tendency of the individual to set strict limits in nutrition and the tendency to self-blame in case of breakdowns.

There were no correlations of eating disorders by emotionogenic type and psychological characteristics of the individual in this group.

Consider the results for group 2 (women with a high level of severity of eating disorders), which are presented in Table 5.

**Table 5**

*Analysis of correlations in the group of respondents with a high level of severity of eating disorders (group 2)*

| № | Parameters | Spearman |
|---|---|---|
| 1 | Restrictive EB / BMI | 0.442*** |
| 2 | Restrictive EB / external EB | -0.261* |
| 3 | Emotionogenic EB / BMI | 0.295* |
| 4 | Emotionogenic EB / negative past | 0.509*** |
| 5 | Emotionogenic EB / positive past | -0.277* |
| 6 | Emotionogenic EB / fatalistic present | -0.395* * |
| 7 | Emotionogenic EB / engagement | -0.525*** |
| 8 | Emotionogenic EB / control | -0.455*** |
| 9 | Emotionogenic EB / Risk taking | -0.534*** |
| 10 | Emotionogenic AP / Overall resilience score | -0.533*** |
| 11 | Emotionogenic EB / goals | -0.474*** |
| 12 | Emotionogenic EB / process | -0.375** |
| 13 | Emotionogenic EB / result | -0.384** |
| 14 | Emotionogenic AP / locus of the ego | -0.464*** |
| 15 | Emotionogenic EB / locus life | -0.399** |
| 16 | Emotionogenic AP / Overall life meaningfulness score | -0.479*** |
| 17 | External EB / positive past | 0.317* |
| 18 | External EB / fatalistic present | 0.340** |

***Note:*** *The symbol ' * 'indicates differences at p <0.05, the symbol '* * 'indicates differences at p <0.01, and the symbol' * * * ' indicates differences at p <0.001.*

Summarizing the results of the correlation analysis in the group with a high severity of eating disorders, we note that the types of eating behavior have a greater number of relationships with the parameters studied than in the group with a low severity of eating disorders and they are closer. Thus, emotionogenic eating behavior has an inverse relationship with all parameters of resilience and life-meaning orientations, which characterizes this group of respondents as prone to eating in response to stressful factors and situations, in other words, to 'jamming' problems, using food as coping behavior. With regard to the attitude to the time perspective, we note that feedbacks of the emotionogenic type of eating disorders with the parameter 'positive past' and direct

links with the 'negative past'," fatalistic present ' indicate that in the case of weak ability of women from this group to cope with negative experiences of the past and trust external circumstances in solving important issues, they are ready to take food in response to their emotional experiences.

External eating behavior has direct connections with the parameters 'positive past', 'fatalistic present', and feedback with restrictive eating behavior. So, the more 'warm' the attitude to their past and a fatalistic view of life, the more typical for women from this group is eating under the influence of external stimuli (an attractive type of food, eating in a company). The relationship between the actual weight index-the body mass index-and the restrictive type of eating behavior shows that the greater the weight, the more a person is prone to excessive self-restrictions in the diet, leading to breakdowns and, ultimately, to overeating.

## Discussion

After reviewing a number of recent works, we note several interesting related studies. Surkova E. G. writes that people with eating disorders "*are distinguished by their focus on their own needs, a weak desire to control their own impulses, a low level of purposeful behavior, high sensitivity to stressful situations, and the ease of negative emotions*." This conclusion is consistent with our results on a low level of meaningfulness of life, resilience, and higher rates of negative past in the group with a high severity of eating disorders (Surkova, 2015, p. 463).

The study of Danilova M. A., Fil A. S. concluded that emotionogenic overeating, night snacking, and other forms of eating disorders become habitual ways of regulating the psycho-emotional state and existing internal contradictions. The author's data are consistent with our conclusions about the positive association of negative past experiences with emotionogenic overeating. Therefore, food intake acts as a coping behavior that reduces negative experiences (Danilova, Fil, 2019).

Prodovikova A. G., Zyryanova K. K. obtained a negative relationship between body attitude, body mass index and indicators of resilience, and also identified coping strategies that are more often used by overweight people - avoidance and accepting responsibility. The authors' results overlap with ours in terms of reduced resilience indicators in the group with low severity of eating disorders (Prodovikova, Zyryanova, 2023).

Therefore, the study revealed differences in life-meaning orientations, attitudes toward the perspective of time, and resilience in women with low and high levels of severity of eating disorders. Respondents of both groups differ in the relative formation of the value-semantic sphere, and the results are within the average range. However, significant differences were obtained on the scales 'life process' and 'locus of Control-I', so, in the group with a low severity of eating disorders, the pleasure of living in the present and greater faith in the ability to influence the events of one's own life were significantly higher.

The time perspective also differs. So, in the group with a high degree of eating disorders, the level of negative past, hedonistic present, and fatalistic present is significantly higher, which allows us to characterize them as less resistant to negative experiences, more likely to receive momentary pleasures, and believe in the power of external circumstances.

The level of resilience in the group with a high level of severity of eating disorders is significantly lower in all indicators, which shows a reduced ability to take risks, control the situation, and less involvement in activities.

The interrelations between the psychological characteristics of the respondents and the types of eating disorders are revealed. Therefore, in the group with a low level of severity of eating disorders, positive relationships were found between the external type of eating disorders and the negative past and future.

In the group with a high degree of eating disorders, positive correlations of emotionogenic overeating with a negative past, fatalistic present and inverse relationships with all scales of resilience and meaningfulness of life were revealed. That is, the higher the level of resilience and meaningfulness of life, the less the individual's desire to use food intake as a coping behavior. Since both groups showed positive associations with a negative past, it can be stated that the inability to cope with negative experiences is a common factor of maladjustment and increases the risk of eating disorders. Also common among the two groups is the relationship between body mass index and the restrictive type of eating behavior, indicating an increase in restrictions, prohibitions, and strict dietary requirements with actual weight gain.

Thus, both hypotheses of the study were confirmed. The prospect of further research may be to increase the sample size, analyze the results according to gender and age criteria, and develop a program to correct for eating disorders.

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**Luiza A. Etumyan** — analysis of the literature on the research topic, preparation of the sections "Introduction", "Discussion" and "Conclusion", participation in the discussion and preparation of the section "Results".

**Natalia E. Komerova** — selection of diagnostic methods, data collection, participation in the discussion and preparation of the sections "Methods" and "Results", participation in the preparation of the final text of the article.

**Darya P. Shchetinina** — collection, processing and statistical analysis of data, discussion and graphical presentation of the results, participation in the preparation of the final text of the article.

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# Systemogenetic Patterns of Development of Cognitive Determinants of Information-Related Activities

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## Abstract

**Introduction.** At the present stage of social development, the study of computer-related information activities and the identification and explanation of their subjective determinants as important professional characteristics are particularly important. Objectively, it is first necessary to give priority to the disclosure of the role of the cognitive qualities of the subject underlying the organization of these activities, as well as their genesis during the professionalization of the individual. To our knowledge, this study is the first attempt to identify and interpret new patterns of professiongenetic dynamics of basic cognitive qualities and show its belonging to the systemogenetic type of development. **Methods.** The sample (n = 230) comprised programmers of various profiles and levels working in organizations in Yaroslavl, Moscow, and Rybinsk. Psychological assessment was performed using traditional, most valid assessment instruments for components of the cognitive subsystem, as well as a number of techniques developed by authors. The methodology for structural and psychological analysis has also been implemented. **Results.** The dynamics of the development of basic cognitive qualities in the professionalization process is characterized by a combination of their transformations at two levels – analytical and structural. At the first level, there are changes in the degree of severity, that is, the development of individual cognitive qualities. At the second level, considerable changes occur in the organization of their entire system. In the most general and fundamental terms, the entire complex of established patterns indicates that the professionalization process of IT specialists is caried out according to the systemogenetic type, i.e., it represents the systemogenesis of information-related activity. **Discussion.** The results are interpreted from the perspective of the theory of activity systemogenesis, as well as

the psychology of professional activity of the information-related type. The development process of this activity during professionalization, taken in the perspective of one of the most important categories of its subjective determinants (basic cognitive qualities) is more deeply explained, since its subordination to the basic principles of systemogenesis is explicated.

### Keywords

subjective determinants, cognitive qualities, programmer activities, information-related activity, professiogenesis, cognitive subsystem, cognitive processes and operations, systemogenesis

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## Introduction

Two important problems occupy a special and largely decisive position in the enormous complexity of new tasks and research directions due to the widespread use of the subject-information class of activities. The first is the need to establish and further study the subject determinants that determine the procedural properties and effective parameters of the activity and are defined in the concept of important professional qualities. The second is the need to disclose the basic characteristics and patterns of formation of this class activities in the professionalization process, i.e. during professiogenesis. Both of these problems are characterized by a combination of high theoretical and practical importance with a clearly insufficient level of development, which is manifested, in particular, in their following aspects. Therefore, as regards the first one, the following can be stated. Despite attempts to establish the complex of PIQ activities of this class, there is still no generally accepted version and, moreover, justified with a sufficient degree of correctness. One of the main reasons is that this class of activity is exactly the class that synthesizes a wide range of activities that are quite heterogeneous according to a number of criteria, i.e. types of information activity. However, it is obvious that as a qualitatively specific

class, it is characterized by a sufficiently pronounced invariance of basic psychological characteristics and, accordingly, requirements for the sphere of subjective determinants, which requires the identification of this invariant "core". For example, the most well-known lists of this kind can be noted as follows: the ability to solve problems, an analytical mindset, perseverance, the ability to work in teams, good concentration, assiduity, an algorithmic approach, responsibility, sociability, and initiative (Plotkina, 2010). There are other versions of them, presented, in particular, in the works (Kuznetsova & Skrylnikova, 2017; Orel, 2007; Husenov, 2020; Connolly et al., 2016; Weinberg, 1971).

The main feature of the current state of the second problem is the insufficient level of its theoretical elaboration and, accordingly, emphasized pragmatism. This manifests itself, in particular, in a larger number of specific procedures and training programs that are primarily empirical and purely applied in nature, for example: Skillbox, Netology, ProductStar, Yandex Practicum, Skypro, Hexlet, GeekBrains, etc. (Alison, 2015; Attrill & Fullwood, 2016; Carter et al., 2020; Wyeld, Calder & Shen, 2013). Of course, this itself is absolutely necessary at a particular stage of its development, which, however, not only negates but also prescribes the need to address its theoretical aspects at other subsequent stages of its development. One of the most important is the definition of the patterns of genesis of information activity and personality.

We believe that when trying to understand these problems in this theoretical way, the following very important circumstances should be taken into account, which at the same time should serve as methodological guidelines for their study, including for what is presented in this paper. Firstly, we should start with the fact that the very concept of PIQ is fundamentally functional, i.e. it synthesizes all these subjective determinants that act in an identical function – as determinants and factors contributing to the effective implementation of activities. Their roles may be very different, heterogeneous in many respects, qualitative, and not only psychological. In this respect, this concept can also be considered as an umbrella term that combines functionally variable characteristics of the subject. This is exactly the case with regard to the subject-information class, manifested, for example, in the fact that two groups of qualities are differentiated as PIQ in relation to it – psychological qualities proper and the so-called "skills" (Demidenko & Yeratina, 2021; Karpov, 2024a, Karpov et al., 2024b; Dori, Mevarech & Baker, 2018; Yzerbyt (ed.), 2002; Sajaniemi, 2008). They are also divided into two subgroups, which are also very different in content – hard skills and soft skills. The first are primarily activity-driven, while the second are personality-driven. At the same time, in the whole complex of PIQ of this activity, there are also such qualities that are a kind of "nuclear" – they do not just affect the activity or even determine its effectiveness, but act as operational means of its implementation. This is especially evident in the most representative activity of this class – in the activity of programmers, which was the subject of research in this paper.

Indeed, in relation to it and many other types of activities included in this class, the following important features can be explained. In all its attributes and, in general, in almost all its substantive and structural characteristics, this activity not only closely

approaches what is usually referred to as its internal plan – as the structure and content of mental regulation, but also practically reduces to it. This activity in many or even almost all of its main aspects passes into the internal plan, and its structure and content become fundamentally similar to the structure of mental regulation. What acts as its regulator and therefore only as part of it in relation to all other types and kinds of activity in relation to this class becomes the whole activity – at least in its attribute characteristics and the main operational means of implementation. Consequently, the structure of the activity of the subject-information class and, accordingly, the complex of its PIQs largely repeats or even reproduces – multiplies – the structure of mental regulation. Therefore, the establishment of their entirety can and must be based on the content and composition, as well as on the structural organization of this regulation. However, for completely natural reasons, the leading and decisive role in ensuring this regulation is occupied by the cognitive subsystem of the whole psyche – in the whole complex of processes and mechanisms that form it, as well as by other operational means. This activity as a whole is almost entirely information-related. It is also important that the main attribute of this activity is its object, namely information, which again determines the crucial role of these processes and mechanisms in its supply, and its fundamentally cognitive nature. In this respect, one of the slogans of the IT industry is indicative: "The work of programmers is solving problems" (Attrill & Fullwood, 2016).

Due to these circumstances, it is even more difficult to identify the PIQ activities of this class, since their entire sphere is transposed into the internal plan. They are specifically represented in the intrapsychic plane and are therefore much less explicit and accessible for any research procedure. However, it is precisely this circumstance that makes it easier to identify the PIQ of this activity to a very significant extent. Since, as noted, the content – the composition and structure – of PIQ in it is the cognitive support of activity itself as the basis of its mental regulation and organization as a whole, the cognitive subsystem of the psyche is exactly the bearer of this content. Therefore, the components that are included in it – basic cognitive processes and qualities – are the main components of this activity. This is determined by the congruence and practical isomorphism of the content and composition of the activity as a whole, on the one hand, and the mental regulation implemented on the basis of its cognitive support, on the other. The cognition itself and its highest level, the thinking process, takes an active form and, in fact, becomes largely this activity, and the activity is almost completely cognitivized and realized as the function of the cognitive subsystem of the psyche.

Further, when substantiating the theoretical approach to the development of the second of these areas – professiogenetic – it is necessary, in our opinion, to rely on the results of a fairly extensive research cycle of theoretical, methodological and activity-analytical plan, carried out by us earlier. In the course of its implementation, the position was substantiated and implemented, according to which the most constructive methodological approach to the study of the occupational genesis of activities of this class is the concept of the *system-genesis* of activities. It was successfully implemented

earlier in relation to many activities of the other two classes (subject-object and subject-subject) (Karpov, 2021; Karpov & Shadrikov, 2017). As a result, the occupational genesis of two major subject determinants – basic *metacognitive personality traits* and a complex of *professional competences* – was studied in relation to them (Karpov, Karpov, & Prisyazhnyuk, 2024; Karpov, 2021). At the same time, on this basis, not only the possibility opens up, but also the need arises that their qualities are supplemented by another, to some extent, defined group – a group of cognitive qualities, a group of their complex, i.e. in their structural organization – as components of the cognitive subsystem of the psyche. Moreover, for obvious reasons, it should also be implemented based on the methodology of the system-genetic approach.

The main objective of the research presented below is therefore to investigate and explain the characteristics of the formation and development of the complex of cognitive qualities as determinants of information activity based on the concept of system-genesis.

## Methods

The following main problems must be solved in order to organize research.

Firstly, this is a problem related to the fact that the subject-information activity itself is characterized by a high degree of heterogeneity and therefore the question arises as to which specific type of activity is most representative in relation to the whole and should therefore be investigated first of all. As shown by our analysis of this issue in (Karpov, 2021), as well as in (Kuznetsova & Skrylnikova, 2017), it is the activity of programmers that is the most complex and rich in psychological content. This is why it was used as the basis for this study.

Secondly, it is the task of determining the totality of the most important and representative cognitive practices of this activity. Based on the theoretical provisions formulated above, its solution should be carried out as follows. First of all, their complex should represent the cognitive subsystem as a whole and therefore include qualities related to the main cognitive *processes* – first of all, of course, the main and hierarchically higher of them, i.e. thinking. Furthermore, this complex should include qualities related to the basic – core – operational components of cognitive processes, i.e., to their actual *operational composition.* At the same time, it should be taken into account that it is the operational composition of any process, and especially thinking, that forms the basis of its qualitative certainty and acts as a bearer of its specific content. For this reason, it is necessary to include in the complex of the studied qualities those that relate to the basic operations of thinking itself – with the operations of analysis and synthesis, abstraction and concretization, etc.

Finally, these two circumstances, combined, allow for the implementation of another important requirement. It consists in the fact that this complex should contain components (in this case, cognitive PIQs) that differ significantly in their degree of complexity and level

of localization. This allows us to take into account an important feature of the cognitive subsystem – its multidimensionality and qualitative heterogeneity. In this regard, their entire complex was divided into two groups. The first included cognitive qualities related to the level of the processes as a whole, and the second – to the level of their operational content, i.e. with individual operations. The first group included the following qualities (with instruments for their assessment). First of all, these are the three main qualities of the basic cognitive process of thinking, including analyticity, abstractness, and practicality. Analyticity was determined by the Raven Progressive Matrices Test, and abstractness and practicality were determined by V. A. Hansen assessment instrument (Hansen et al., 2001). Further, the ability to operate with two–dimensional spatial images was diagnosed as an important quality of the imagination process (based on the subtest Geometric Addition – GS, Amthauer Intelligence Structure Test (Intelligence Structure Test, 1996)). Another cognitive process, attention, was assessed using the F. D. Gorbov diagnostic instrument to manometrically identify the main properties of attention – distribution, volume, switchability, and stability (Gorbov & Lebedev, 1975). Finally, an individual measure of the severity of another important cognitive quality correlated with another major cognitive process (memory) – visual working memory – was determined (using G. N. Khilova assessment instrument (Khilova, 1975)).

There are much more difficulties in diagnosing the second group of qualities – those related to cognitive operations. The fact is that individual operations revealed as part of a particular cognitive process are virtually impossible to study or diagnose, so to speak, "in their pure" form. There is a problem with "operationalizing the operations themselves" – bringing them into a form that allows them to be studied experimentally or empirically. This difficulty can be minimized by taking into account one of the main principles underlying almost all diagnostic methods of the cognitive sphere in general and intelligence in particular ((Psychodiagnostics: Theory and practice, 1986; ed. by N. F. Talyzin).

It consists in the fact that the performance of any test task involves, of course, relying not only on one or another individual process, but on their totality. However, and this is the essence of this technique, the following important and indispensable condition must be observed. Any individual subtest is designed so that the main functional load when it is performed falls on a specific cognitive process. This can be described as the principle of *functional dominance* of certain processes. This is the basis for almost all intelligent tests. However, the same can rightfully be stated with respect to the study and diagnosis of individual operations. They are also impossible to model or diagnose in their pure form. At the same time, this can be approached by creating conditions in which one or the other of them will functionally dominate. This is exactly what is known to be implemented in one of the most well–founded intellectual tests, Amthauer Intelligence Structure Test, so it was used as the basis for this part of the study. Therefore, the components of the operational composition of thinking (operations) were diagnosed using the following subtests of the Amthauer Intelligence Structure Test:

1. The Logical Selection (LS) subtest evaluating the *inductive* components of thinking.
2. The General Features (GE) subtest evaluating the ability to *generalize* and operate with concepts.
3. The Analogies (AN) subtest evaluating combinatorial abilities and operations by *analogy.*
4. The Pattern Identification (PI) subtest evaluating one of the most famous mental operations, *synthesis.*
5. The Classification (CL) subtest, which focuses on another equally fundamental mental operation, *analysis.*
6. Another basic operation, abstraction, was investigated using the procedure developed by us in (Karpov & Karpov, 2019) for diagnosing the level of basic cognitive operations.

Thirdly, since the study had a profession-genetic focus, it was based on the methodology of comparative study of the degree of formation of cognitive qualities at different stages of profession-genesis. A special review of the literature conducted in this regard showed that, as a rule, three main stages are differentiated in the general process of professionalization of programmers – 1.5 years, 3-4 years and 7 years. It is also important that these three stages are in good agreement with the most traditional differentiation of the main levels of professional qualification of programmers, which also involves the differentiation of three levels – junior, middle and senior.

Finally, since the implemented study was carried out in line with the system-genetic approach, the tools developed in it were applied to its organization and processing of the results. This is a methodology of structural psychological analysis, the essence of which is as follows. It involves the implementation of a multidimensional correlation analysis procedure, which includes a method for determining intercorrelation matrices of the studied parameters (in this case, the main qualities of the cognitive plan); a method for constructing structurograms of significantly correlating parameters; a method for calculating indices of structural organization, the $\chi 2$ test for determining the homogeneity-heterogeneity of intercorrelation matrices. The main indices of structural organization are the structure coherence index (SCI), the structure divergence (differentiation) index (SDI) and the structure organization index (SOI). The first is defined as a function of the number of significant positive correlations in the structure and the degree of their significance; the second is defined as a function of the number and significance of negative correlations in the structure; the third is as a function of the ratio of the total number of positive and negative correlations and their significance (Karpov, 2015).

The *study participants* (n = 230; 155 males, 75 females) were programmers of various profiles and levels (application programmers, system programmers, graphics programmers, database engineers, quality assurance specialists, frontend developers, web developers) living in three Russian cities (Yaroslavl, Moscow, Rybinsk) aged 24 to 61:

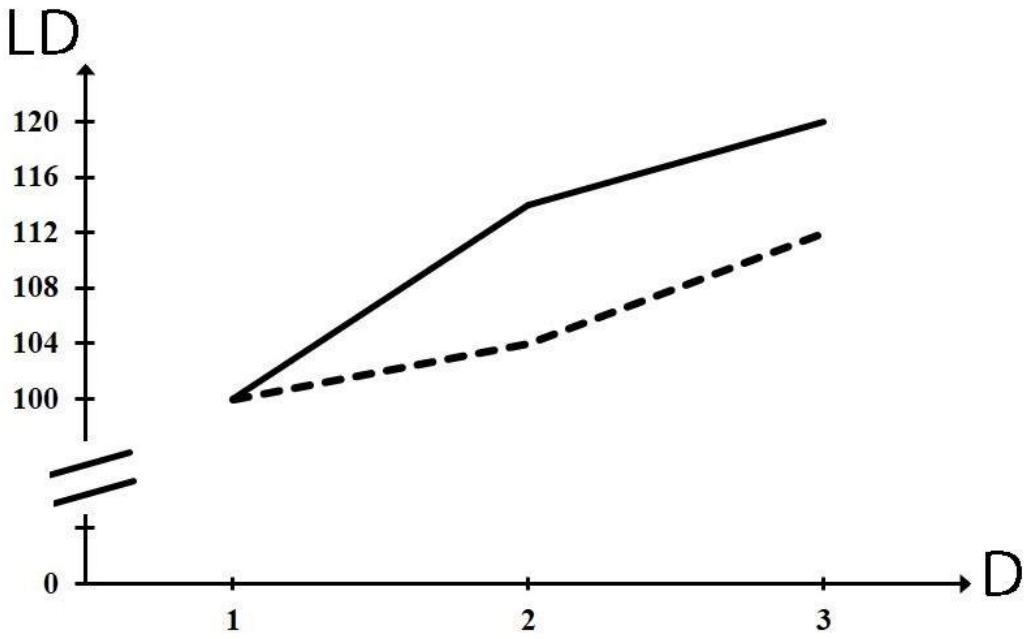
<31 years – 98 subjects (42.60 %), 31-45 years – 92 subjects (40.00 %), > 45 years – 40 subjects (17.39 %).

## Results

The first and most general result of the study was to establish a significant increase in the individual level of almost all the cognitive qualities considered to be PIQs in the professionalization process. Furthermore, this applies both to individual qualities and to the two groups of them as a whole (these were, on the one hand, qualities correlated with the main cognitive processes in general, and on the other – with the main cognitive operations). Therefore, this result can be illustrated in the most general form in the following results. Figure 1 shows data on the dynamics of the development of qualities that form two main determinants groups. These data were defined as the average of the sum of diagnostic indicators of all qualities included in each group. The diagnostic indicators of each group of qualities in the first time-related interval, that is, the interval related to work experience, were taken as the initial level, that is, as 100%, and the diagnostic indicators of the second and third stages were calculated in relation to it.

**Figure 1**

*Dependence of the level of development of cognitive processes (solid line) and cognitive operations (dotted line) on work experience*

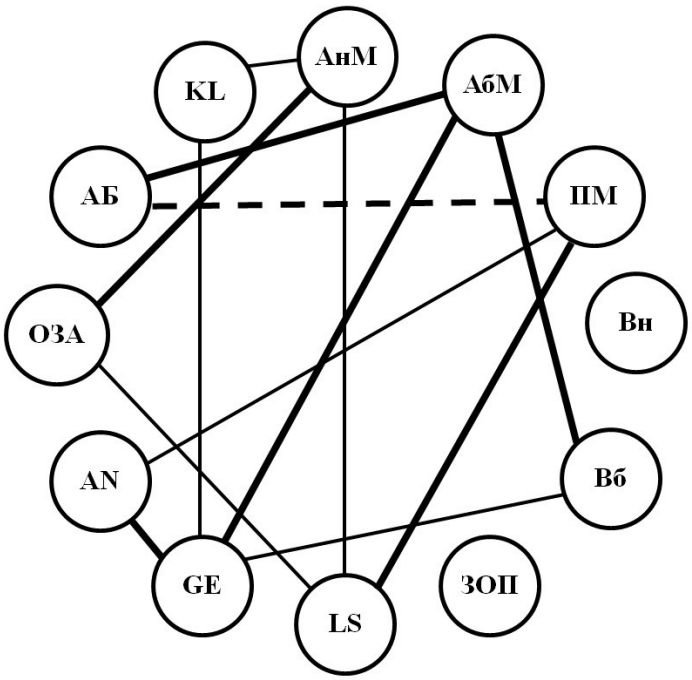


For example, the value of 114% in relation to the group of process-related qualities at the second stage means that the level of their severity increased by 14%. In addition, we should note that in general, a similar dynamics has been found in relation to certain features of the cognitive plan. This means that it is typical not only for the dynamics of the formation of quality groups, but also for each of them individually. At the same time, we should note that this kind of dynamics is very moderate – both in absolute and relative terms. It is significantly less represented than the similar professiongenetic dynamics that we established earlier in relation to other basic types of subject determinants of activity, in particular, professional competencies and metacognitive qualities (Karpov et al., 2024; Karpov et al., 2024a), which requires explanation in further discussion.

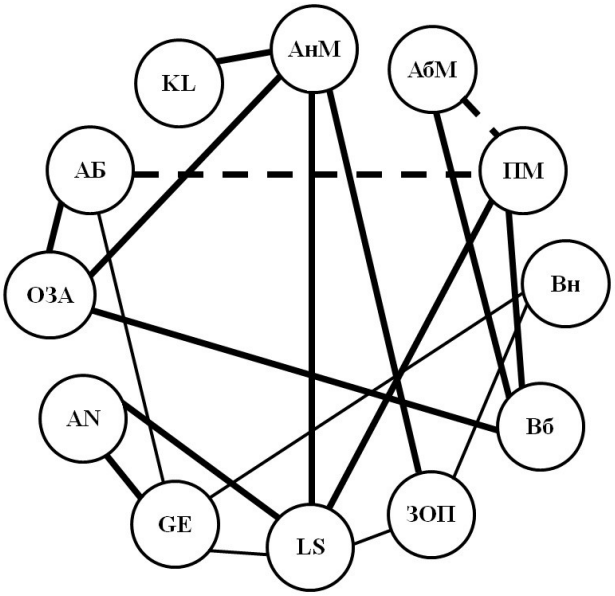
Furthermore, in terms of the results obtained, not the analytical level, but the structural level of research was implemented. It involves determining the structurograms of the subject determinants of activity – in this case, cognitive qualities, as well as their subsequent comparative consideration. Figure 2 shows the structurograms of these qualities for two groups with different work experiences (1.5 years and 7 years).

**Figure 2**

*Structurograms of cognitive qualities*




а




b

***Note***: "a" – 1.5 years *of work* experience, "b" – 7 years *of work* experience; AnT – analytical thinking, AbT – abstract thinking, PT – practical thinking, *At* – attention, *Im* – imagination, *VWM* – visual *working memory,* LS – logical selection subtest, *CD* – common definition subtest, *PD* – pattern definition subtest, AN – analogies subtest, AB – abstraction method, *C*L – classification subtest; bold lines – *correlations* significant at p <0.01, *to* which *a "*weighting" coefficient *of* 3 points *is* attributed; *semi*-bold lines – *correlations* significant at p < 0.05, which *is* attributed *a* coefficient *of* 2 points*;* dotted lines *represent* negative *correlations*. *The* "weights" for all *correlations are* summed *up*, which gives *the* values *of the* structural coefficients.

Table 1 shows data on the dynamics of the main structural indices, which characterize, respectively, the degree of coherence (integration) of the structures found, the degree of their differentiation, as well as their overall organization.

**Table 1**

*Structural indices of the complex of cognitive qualities in three groups with different work experiences*

| | Work experiences | | |
|---|---|---|---|
| | 1.5 years | 3-4 years | 7 years |
| SCI | 30 | 34 | 43 |
| SDI | 2 | 2 | 4 |
| SOI | 28 | 32 | 39 |

## Discussion

The analysis of the presented results allows us to draw the following conclusions. First, as mentioned above, the dynamics of the revealed cognitive qualities are very moderate, both in absolute and relative terms. It is much less pronounced than the similar dynamics we have established in relation to other – basic – types of subjective determinants of activity. Thus, in absolute terms it changes from the first level of professionalization to the third by 20%. However, with regard to the data obtained, for example, in the works (Karpov et al., 2024; Karpov et al., 2024a) in relation to other determinants, another situation can be observed. In particular, the dynamics of the development of professional competencies – skills – is from 68% (for soft skills) to 123% (for hard skills). The similar dynamics of the development of metacognitive determinants are even more pronounced – they are about 140 %. Finally, in relation to the category of basic individual qualities, which also function as PIQ, it is measured by 40% values. This result, in our opinion, indicates the existence of a significant professiongenetic pattern. It is based on the fact that this dynamic is less pronounced the more general and fundamental qualities themselves are in the organization of the psyche as a whole. Indeed, despite the importance of the subject determinants studied earlier and noted above, they are still obviously inferior in this regard to the totality of cognitive qualities, which manifest the most important – the *basic* operational means of organizing the psyche as a whole – the main cognitive processes. They underlie the entire structural and functional organization of the psyche; moreover, they are not only conditioned by this organization, but they themselves largely determine it. And precisely because of this fundamental nature, they should be relatively more tolerant of external influences, even strong ones such as profession-genetic factors.

Secondly, we can see that the comparative rates of formation of the studied cognitive qualities, that is, the intensity of their formation and development, are different at different stages of the professionalization process. This is particularly evident in the dynamics of the development of the qualities of the first group (related to cognitive processes) characterized by higher formation rates in relatively early stages of professionalization, and in subsequent stages these rates decline significantly. Conversely, the rate of formation of the second group of qualities (related to basic cognitive operations) is moderate in the early stages of professionalization. However, at its more advanced stages, they become much more obvious. Data processing also showed that a similar pattern exists in relation to the comparative dynamics of individual qualities included in these groups. For example, such a very important cognitive quality as analytical thinking develops significantly faster at relatively early stages, and at later stages these rates decline significantly. On the contrary, another important cognitive quality, abstract thinking, is characterized by a relatively low development rate in the initial stages, and then these rates become more pronounced.

Therefore, it is possible to describe an important circumstance: the dynamics of the major cognitive determinants of activity, as well as their groups, as a whole, have an important and general systemogenetic model, which is established on the basis of the *inequality* principle.

Thirdly, as established in the concept of systemogenetic, the *inequality* principle is objectively related to another important and also general principle – the *heterochrony* principle. It is based on the fact that the periods of the most intensive formation of the different "components" of the system, in general, do not coincide; they are "removed" in time. However, this is exactly what is clearly shown in terms of the comparative genetic dynamics of individual cognitive qualities and their groups. It can be seen, in particular, that the periods of the most intensive formation of the first group of qualities (procedural) and the second group (operational) are spaced apart in time – the second is formed much later. Consequently, these features indicate that in relation to the genesis of basic cognitive qualities as subject determinants of information activity, another basic principle of system-genesis is fulfilled – the *heterochrony* principle.

Furthermore, the combined effect of the principles of *inequality* and *heterochrony* determines that there appears to be a *sensitive period* for each cognitive quality and for their complexity. At the same time, the sensitive periods for different groups are at a temporary distance. This shows that the characteristics and patterns of development of significantly different cognitive qualities (process and operation) are also quite different.

Fourth, the data presented in Table 1 sufficiently reveal an increase in the value of the coherence index (SCI) of the entire complex of basic cognitive qualities acting as PIQ in the professionalization process. This means that in the course of professionalization, there is a significant increase in the degree of their integration. The implementation of Kruskal Wallis tests in relation to these data confirms the statistical reliability of the data presented on SCI dynamics ($p < 0.05$). However, we should note that the degree of such an increase is expressed to a lesser extent than it was previously established in relation to other subject determinants of information-related activity (metacognitive qualities, as well as a number of individual qualities acting as PIQs). If the increase for them was measured in multipliers – in "times", then in relation to the dynamics of cognitive qualities, it is measured, albeit significantly, but only as a percentage (by 43%). This circumstance can be explained as follows. The fact is that in relation to the profession-genetic dynamics of the cognitive subsystem, it cannot be said that it is precisely formed and then developed and improved in its process, since from the very first stages of its deployment it has already been presented in a well-developed form – precisely as a system. Therefore, it is not so much the subject of qualitative transformations as the continued improvement of the system integration tools already presented in it. The most important thing, however, is that the interpretation of these data from the point of view of the concept of systemogenesis clearly reveals the following important fact. In the professionalization process of personality in relation to

the dynamics of cognitive characteristics formation, one of the fundamental principles of systemogenesis is the principle of progressive *integration.*

Fifthly, during professionalization, the natural dynamics of the second main index – the differentiation of basic cognitive qualities – are revealed. It also increases, but which is also important, its dynamics is presented in a much more moderate form. Consequently, in relation to the professiogenetic dynamics of the general complex of cognitive qualities acting as PIQs, it can be said that there is another fundamental systemogenetic principle – the principle of increasing *differentiation.*

Sixth, the dynamics of the change in the SCI of the complex of the examined qualities are expressed much more than the degree of variability of the SDI values. Due to the superposition of these two dependencies, another, equally significant, pattern of this kind arises. This consists in the fact that with the increase in professionalization, the values of the most general structural index increase – the overall organization of the structure. At the same time, it is the most general indicator of the structural organization of any system (in this case, the complex of cognitive qualities as determinants of activity) that acts as the main indicator of the overall organization, the formation of the system as a whole. Thus, it shows how well the system itself is formed and how its main "components" are consolidated. Thus, in relation to the obtained results, the effect of another specific system-genetic pattern is clearly revealed – the *consolidation* principle.

Seventh, as is well known, the concept of system-genesis establishes other equally important principles — the "simultaneous establishment" of system components, "ensuring a sufficient effect" in its functioning, and target determination (Shadrikov, 1982). In this regard, it is very important and convincing that they are no less clearly evident in the profession-genetic dynamics of fundamental cognitive qualities. However, their action is more implicit and is not revealed by the empirical data obtained in this study, but also by the more general and well-known phenomena and patterns described both in cognitive psychology and in the psychology of professional activity. Therefore, in particular, the principle of the "simultaneous establishment" of system components is clearly obvious. Indeed, the very essence of the composition and content, as well as the overall organization of the cognitive subsystem of the psyche, which components are the qualities studied, lies in its being a formation of a specifically systemic type. But this means that all of its components—the fundamental cognitive qualities associated with both processes and operations—are already initially and, moreover, attributively represented, both synchronously and in an associated manner. During the acquisition of a professional activity, they are not so much formed as transformed and specified as already "established" that exists even before the activity is mastered. Their subsequent transformation takes place in accordance with the content of the activity to be mastered, as well as the combination of its requirements. This is even more important since the

basic content of the information activity is also highly cognitive in nature. The initially and "simultaneously established" components of the system (in this case, the cognitive subsystem of the psyche) and the most important attribute of information activity—its cognitive nature—are fundamentally congruent, which explicates the special importance of this principle in relation to this class of activities. Consequently, in relation to the professiogenesis of information-related activity, it is possible to fully justify the observation of the "*simultaneous establishment*" principle.

Furthermore, we can also ascertain the observance of the principle of "*ensuring a sufficient effect"*, which, as is well known, states that at any stage of system-genesis, each component of the emerging system is represented with a degree of development sufficient for its functioning as a whole. This is precisely one of the attributes of the cognitive subsystem of the psyche, since all of its components (processes and operations) at any level of development can objectively be represented within it only in a form sufficient for its functioning. Otherwise, that is, if even one cognitive process "fails" its functioning becomes objectively impossible. This, of course, is a consequence of another crucial regularity of cognitive organization, which is defined by the concept of "fully connected" cognitive processes (Anderson, 1985).

Finally, perhaps the most clear, the principle of goal *determination* is revealed, although in a specific form. The fact is that the main objective basis for distinguishing the important qualities of professional activity, as considered to be axiomatic in the theory of professional activity (Karpov, 2015), is a clearly functional criterion – its focus on ensuring a particular basic aspect of activity, as well as a particular function associated with its implementation. Consequently, this differentiation is carried out on the basis of the specific purpose for which these functions themselves are realized. In other words, each PIQ, including the cognitive qualities that serve as its functions, evolves as a kind of "functional organ" which ultimately aims to achieve a very specific goal.

Therefore, we can conclude that the profession-genetic dynamics of a complex of fundamental cognitive qualities as subjective determinants of information-related activity reveal all the most important system-genetic principles — inequality, heterochrony, progressive integration, increasing differentiation, sequential consolidation, simultaneous establishment, ensuring a sufficient effect, and goal determination. This is a very significant argument in favor of the fact that the very origin of the studied category of subjective determinants of activity – the fundamental cognitive qualities – is subject to the fundamental laws of systemogenesis – its principles – and therefore is systemogenesis itself. In addition, we point to another important circumstance: the increase in the SOI value, which indicates an increasing degree of structural consolidation, effectively means an increase in the overall degree of embodiment of the systemic form of organization within it. Therefore, the most general meaning of system genesis as a type of development

is that, during its course, the degree of realization of consistency as a form of organization in activities and its PIQs is consistently increasing. Therefore, system-genesis is not only the formation of a system, but also the formation of a *system* as a fundamental form of organization.

Eighth, in the final stage of interpreting the results, the matrices, which were determined based on the array of all the cognitive qualities examined and which characterize their structural organization in different experience groups, were compared using the $\chi 2$ test. This revealed the following facts. The matrices and, accordingly, the structures of cognitive qualities acting as PIQs, are qualitatively uniform – *homogeneous* – across all work experience groups. In other words, they differ not qualitatively, but only in terms of their degree of organization. This result, in our opinion, should be explained by taking into account the following defining circumstance. The fact is that all basic cognitive qualities, which form one of the basic categories of subjective determinants of activity as a whole and therefore act in relation to them as PIQs, are characterized simultaneously by another – more general, even attributive – characteristic. All of them, unlike other categories of the PIQs, are not so much *activity*-driven and therefore directly linked to the activity itself, but are determined by the *general organization* of the psyche as a whole and its procedural content in particular. In other words, their composition and content, structure and organization have a supra-activity, meta-activity character and determination. Consequently, this determination cannot and should not be transformed qualitatively "in response" into an activity-based determination (as in other categories of subjective determinants). On the contrary, their organization should be sufficiently tolerant of activity-based determination in terms of its structural characteristics. However, it can and, once again, must be sensitive to it in terms of the degree of structure itself, the degree of perfection and therefore effectiveness. This was exactly what was revealed in the overall results presented. They demonstrate that the structures of fundamental cognitive qualities remain invariant — homogeneous — at different stages of professionalization, but precisely in terms of their organization. However, they undergo significant transformations in the degree of this organization. Consequently, an important pattern in the professiogenetic dynamics of fundamental cognitive qualities is the prioritized development of their degree of organization — coherence, structure — which occurs in the context of maintaining the invariance of their character — the pattern of their organization. This also means that even such a powerful — actually activity-based — determination does not lead to fundamental transformations in the structure of cognitive qualities. The structural organization of the complex of fundamental cognitive qualities, which are PIQs of activity at different stages of its profession-genesis is fundamentally invariant in content and character — in terms of the general pattern — but equally variable in terms of the degree of organization. This is one of the main differences between the

profession-genesis of core cognitive qualities as determinants of information activity and all other categories previously studied (especially, professional skills, a number of individual-personal qualities, and metacognitive determinants).

## Conclusion

To summarize the above analysis, the following key *conclusions* can be formulated.

*First,* during the professionalization of IT specialists (programmers), significant and consistent transformations occur in one of the most important categories of subjective determinants of activity—core cognitive qualities, which function as the PIQ in relation to it. Consequently, their entire complex forms an important, qualitatively specific dimension of the overall professional genetic dynamics as such, and its study can significantly contribute to discovering the patterns of this dynamics as a whole.

*Secondly,* this dynamic is characterized by all the fundamental patterns captured in the concept of the principles of systemogenesis—the principles of unevenness and heterochrony, progressive integration and increasing differentiation, consolidation, the "simultaneous establishment" of system components, and the "ensuring of a sufficient effect" in terms of its functioning and target determination.

*Thirdly,* the dynamics of the development of core cognitive qualities during professionalization is characterized by a combination of their transformations at two levels—analytical and structural. At the former, changes in the degree of expression, that is, the development of individual cognitive qualities, occur. At the latter, significant changes in the organization of their entirety occur. The structural organization of the complex of core cognitive qualities, which function as the PIQs of activity, at different stages of professiogenesis is fundamentally invariant in content and character—in terms of the general pattern—but, at the same time, equally variable in its level in terms of organization degree.

*Fourth,* the identified dynamics also exhibit more specific, but also significant, genetic patterns—the coordinated nature of the restructurings, their fundamentally nonlinear nature, the phenomenon of the sensitive period, etc.—which provides further considerable evidence of the complexity of their transformations.

*Fifth,* the dynamics of the transformation of core cognitive qualities as subjective determinants at different stages of professionalization is characterized by a combination of quantitative and qualitative (structural) transformations. The former manifest themselves in changes in the degree of severity—their level of development. The latter consist of significant differences in the degree of structural organization of these determinants at different stages. Furthermore, an important and specific feature of core cognitive qualities

is the prioritization of the degree of their structural organization, rather than the level of their development—the individual measure of severity.

*Sixth,* in the most general and fundamental sense, the entire complex of established patterns indicates that the process of programmers' professionalization is realized according to a systemogenetic principle, that is, it represents one of the manifestations of systemogenesis as such.

*Seventh,* in terms of methodology, the obtained data, as well as their interpretation, enable us to draw two more important conclusions. They provide new major arguments for extending the fundamental principles of the theory of activity systemogenesis to a new, previously unexplored class—the subject-informational class—which increases its generalizability. At the same time, the process of developing this activity during professionalization, considered in terms of one of the most important categories of its subjective determinants—fundamental cognitive qualities—receives a more profound explanation, since its subordination to the basic principles of systemogenesis and, consequently, its belonging specifically to the systemogenetic type of development, is explicated.

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## Author Contribution

**Anatolii Viktorovich Karpov** provided academic guidance for the study, based on the application of the methodology of professional activity systemogenesis to the development of information-related activity issues; analyzed data, and contributed to theoretical generalization of research findings.

**Anna Vadimovna Chemyakina** developed the concept of the study using the methodology of metacognitivism, analyzed data, and interpreted the results.

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# Cognitive resources of older preschool children in developmental and educational contexts caused by bilingualism in a multinational state

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## Abstract

**Introduction.** The article presents the results of a study of the cognitive domain of older preschool children as a function of sociocultural conditions shaped by bilingualism, primarily in the cases of coincidence, non-coincidence or partial coincidence of the language(s) of communication in the family with the language(s) of upbringing and education in a preschool general education organization. The research focuses on basic cognitive functions and those indicators of cognitive functioning that are associated with comprehension, analysis and use of language in interaction with the outside world. **Methods.** The sample included 818 preschool children aged 5.3 to 7.5 years old (mean age 6.4 years) from 8 subjects of the Russian Federation (54.3% girls). Of the study participants, 71.5% communicated at home in one language, while 28.5% used two languages—Russian as the state language and their native language from among the languages of the peoples of Russia. All children attended preschool educational organizations: 64.1% were enrolled in preparatory groups, where upbringing and education were conducted exclusively in the state Russian language, and 35.9% were enrolled in classes, which implemented regional educational component in the native language alongside the state language. **Results.** The findings revealed specific features of the cognitive domain of older preschool children depending on the coincidence, non-coincidence, or partial coincidence of the language(s) of communication in the family and preschool education, which leads to change in the capacity of the cognitive resource when performing everyday and learning-related tasks. Intergroup differences were determined not only in the level of development of individual cognitive functions, but also the structure of

the relationships among all elements of the cognitive domain. This made it possible to assess the cognitive resources of older preschool children as a function of sociocultural conditions of development and education influenced by bilingualism in a multinational state. **Discussion.** The obtained results are interpreted in the context of the methodology of the theories of cognitive resource (Druzhinin, 2007) and language control (Green & Abutalebi, 2023).

## Keywords

information processing speed, visuospatial working memory, mental operations, state Russian language, native languages of the languages of the peoples of the Russian Federation, cognitive resource, language control, older preschool age

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# Introduction

The cognitive domain and the efficiency of its functioning constitute a prerequisite for constructive interaction between the individual and the outside world, representing a key personal resource for the successful acquisition of new knowledge and skills throughout the lifespan, including under conditions of atypical development (Tikhomirova, 2021). According to cognitive resource theory, the level of development and the degree of interconnectedness of individual components of the cognitive domain—including, among others, information processing speed, working memory, and basic thinking operations—make it possible to operationally describe individual capacities in the process of solving tasks of varying levels of complexity (Druzhinin, 2007). As a general characteristic of cognitive resources, the concept of cognitive system complexity is employed; it is equated with the degree of differentiation and is measured, among other things, by the number of interrelations among individual indicators of cognitive development (Druzhinin, 2007; Goryunova & Druzhinin, 2000).

At the same time, the development of the cognitive domain is characterized by heterogeneity, with more pronounced positive dynamics in some components (in particular, information processing speed; Tikhomirova et al., 2023) and less substantial changes in others (for example, perception of sets of objects; Kuzmina et al., 2020) over a given time interval. Such uneven development—and, consequently, individual differences in specific cognitive indicators—is especially pronounced during the preschool period, which constitutes the first level of the general education system. Previous studies indicate that it is precisely at this age stage that cognitive development is most sensitive to sociocultural conditions, primarily those of the family and the educational organization in which the child is raised and educated (Tikhomirova & Malykh, 2021; Von Stumm & Plomin, 2015).

## *Sociocultural conditions of development and learning associated with bilingualism*

Among the sociocultural conditions that can exert a significant influence on cognitive development—and, accordingly, "modify the capacity of cognitive resources" (Druzhinin, 2007, pp. 166–167)—in preschool children is bilingualism among children who are citizens of a multinational state (Verbitskaya et al., 2017; Ortiz & Rodríguez, 2025; Ali, 2023; Bialystok, 2017). According to data from the 2020 Russian Population Census, the national composition of the Russian Federation comprises 194 ethnic groups that, to varying degrees, command the state language and/or a native language (Federal State Statistics Service, https://rosstat.gov.ru/vpn/2020/Tom5_Nacionalnyj_sostav_i_vladenie_yazykami). At the same time, only a portion of preschool educational organizations (hereinafter, kindergartens) have introduced a regional component into their educational programs in a native language from among the languages of the peoples of the Russian Federation. This component provides for the study and active use of the native language alongside the state Russian language.

The combination of sociocultural conditions associated with bilingualism in older preschool children may lead to specific features of the cognitive domain and, accordingly, to changes in the capacity of children's cognitive resources, primarily among those who command two languages. Indeed, in a bilingual environment, one of three possible language-use contexts is activated: a monolingual context (e.g., one language used exclusively at home and the other exclusively in kindergarten), a bilingual context (both languages used in different educational activities in kindergarten when a regional educational component in the native language is implemented), or a "mixed" context (both languages used within a single utterance in cases of unequal proficiency or use of the native and state languages). Each of these contexts engages fundamentally different cognitive resources (Gallo & Abutalebi, 2024; Green, 2024; Green & Abutalebi, 2023; Frederiksen & Kroll, 2022; Calabria et al., 2018). According to language control theory, across all three contexts, the mechanisms that ensure successful switching between two

languages are gradually refined: at the initial stages of acquiring one of the languages, a maximum of cognitive resources is "absorbed," whereas subsequently the cognitive load decreases, leading to the "release" of resources for more efficient performance of current tasks (Green & Abutalebi, 2023; Bialystok & Craik, 2022).

## *Cognitive development in sociocultural bilingual conditions: meta-analyses and systematic reviews*

Meta-analyses and systematic reviews of studies examining the cognitive domain of children who command one or two languages (as a rule, a state language and a native language) often yield diametrically opposite results (Bialystok, 2017).

On the one hand, changes in the level of manifestation of certain cognitive functions are reported in children who command two or more languages compared with their monolingual peers. For example, preschool children from families where two languages are used demonstrate higher performance only on measures of cognitive control, but not working memory (a meta-analysis involving 18,200 children aged 5 to 7 years; Hartanto & Toh, 2019). A small but statistically significant advantage of bilingual children has also been documented in tasks assessing attentional switching, planning, and information processing speed (a systematic review of 143 studies involving children aged 1.5 to 14.5 years; Gunnerud et al., 2020; or a systematic review of 58 studies employing 125 cognitive tasks; Planckaert, Duyck, & Woumans, 2023). On the other hand, some authors conclude that there are no reliable group differences between preschool children who command one or two languages. Thus, no cognitive advantages of bilingualism were identified in analyses of cognitive control, reaction time, working memory, fluid intelligence, or vocabulary size (a meta-analysis involving 4,524 children aged 9 to 10 years; Dick et al., 2019).

Such discrepancies in findings may be attributable, among other factors, to approaches that examine children's bilingualism exclusively in the context of family communication—one or two languages—without considering the language of instruction in educational organizations, or, conversely, that focus solely on the language of instruction—native or non-native—without accounting for the number of languages used in the family. As a result, a substantial group of children for whom there is a partial coincidence between the language(s) of family communication and the language(s) of instruction in educational organizations is often overlooked. At the same time, this situation is widespread among Russian children. For instance, children who use both a native language and the state Russian language in the family may attend educational organizations where instruction is provided exclusively in Russian, while children of other nationalities from among the peoples of Russia who speak only the state Russian language at home may attend kindergartens with a regional educational component and receive instruction in two languages. Including a group of preschool children with a partial coincidence of the language(s) of family communication and the language(s) of instruction in preschool

educational organizations makes it possible to obtain new data on the specific features of the cognitive domain of older preschool children in differing sociocultural conditions of development, upbringing, and education.

Overall, greater "sensitivity" to sociocultural conditions associated with bilingualism was reported for basic cognitive indicators—particularly information processing speed and visuospatial working memory—as well as for indicators of cognitive functioning associated with understanding, analyzing, and using language, such as vocabulary, classification and generalization, and the ability to draw inferences based on given logical relations (Zinchenko et al., 2022; Tikhomirova & Malykh, 2021; Ortiz & Rodríguez, 2025; Ali, 2023; Han et al., 2022; Gunnerud et al., 2020; Oppenheim et al., 2020).

It should be noted that when analyzing the cognitive domain depending on the child's ability to command one or two languages, researchers typically consider only the level of development of a given cognitive characteristic. However, within the framework of cognitive resource theory, alongside the level of development of individual components of the cognitive domain, its structural organization is of fundamental importance (Druzhinin, 2007). Specifically, a smaller number of interrelations and lower correlation coefficients among individual cognitive functions indicate a higher degree of differentiation of the cognitive domain and, consequently, a greater capacity of cognitive resources in the performance of everyday and learning-related tasks (Goryunova & Druzhinin, 2000). A cross-sectional analysis of the level of development and the degree of differentiation of the cognitive domain makes it possible to assess the capacity of the cognitive resources of older preschool children in developmental and educational contexts shaped by bilingualism, including their readiness for successful knowledge acquisition, particularly during the age-relevant formation of reading skills.

## *The present study*

The aim of the present study is to examine the characteristics of the cognitive domain in older preschool age as a function of sociocultural conditions of development and education, primarily in situations of coincidence, non-coincidence, or partial coincidence between the language(s) of family communication and the language(s) of instruction in preschool educational organizations. The research focuses on basic cognitive functions as well as on those indicators of cognitive functioning that are associated with understanding, analyzing, and using language in interaction with the surrounding world. Within the framework of cognitive resource theory, the complexity of the organization of the cognitive domain—and, accordingly, the capacity of children's cognitive resources — will be assessed under conditions of family upbringing and preschool education associated with bilingualism in a multinational state.

This aim can be achieved only in a study involving older preschool children who use, within their families, two languages—Russian as the state language and a native language—and who also attend preschool educational organizations that include preparatory groups

implementing a regional component of the educational program in a native language from among the languages of the peoples of the Russian Federation.

## Methods

### *Sample and research procedure*

The study sample comprised 818 preschool children aged 5.3 to 7.5 years (mean age 6.4 years), of whom 54.3% were girls. The study included children from 8 subjects of the Russian Federation, including the Republic of Tatarstan (Tatars – 71.2%; Russians – 28.8%), the Kabardino-Balkarian Republic (Kabardins – 60.8%; Balkars – 26.1%; Russians – 8.7%; Dargins – 4.4%), the Chechen Republic (Chechens – 100%), the Republic of North Ossetia-Alania (Ossetians – 91.1%; Russians – 8.9%), the Republic of Bashkortostan (Bashkirs – 65.9%; Tatars – 20.9%; Russians – 13.2%), the Chuvash Republic (Chuvash – 87.1%; Russians – 12.9%), the Sakha (Yakutia) Republic (Yakuts – 96.2%; Russians – 3.8%) and the Moscow Region (Russians – 93.6%; Tatars – 4.4%; Ukrainians – 2%).

Among the study participants, 584 children (71.5%) communicated at home in one language, and 234 children (28.5%) in two languages—both Russian as the state language and a native language from among the languages of the peoples of the Russian Federation. The study involved preschool children whose families used, among others, Russian, Tatar, Ossetian, Chechen, Bashkir, Kabardian, Balkar, Chuvash and Yakut languages in communication with the child.

All children attended preschool educational organizations that included preparatory groups implementing a regional component in the educational program in a native language from among the languages of the peoples of the Russian Federation. Among the participants, 524 children attended preparatory groups where upbringing and education were conducted exclusively in Russian (64.1%), and 294 children (35.9%) were enrolled in preparatory groups with a bilingual model of preschool education.

Data collection was carried out individually with the direct participation of a member of the research team and a psychologist or other specialist working in the preschool educational organization, strictly according with the developed protocol. The parents of the study participants provided information about the child's nationality, the child's level of proficiency in Russian, as well as the language(s) used for communication with the child in the family.

Each participant completed the tasks on a computer under an individual login in a separate room of the kindergarten. The greeting and task instructions in Russian were read by a member of the research team to each participant, regardless of the child's ability to read the text on the computer screen independently. For children who did not fully understand the instructions for the tasks in Russian (2.3% of the total number of participants), part of the instruction was read aloud in the child's native language, which

was recorded in the study protocol. In tasks that required pressing keys or a key on the computer keyboard, the participant in the study performed these actions independently.

## *Measures*

### *"Choice reaction time" task, information processing speed*

The numbers 1, 2, 3, and 4 appear on the screen 40 times in a random order with an interstimulus interval ranging between 1 and 3 seconds (Tikhomirova, Kuzmina, Malykh, 2020). The participant's task is to quickly and accurately press the key that corresponds to the number displayed on the screen. The measure used in the study was reaction time for correct responses only, recorded in milliseconds. Higher values corresponded to lower processing speed.

### *"Corsi Block-tapping" task, visuospatial working memory*

In the task, sequences of cubes are presented on the screen one after another, each cube lits up in yellow for 1-second with a 1-second interval between stimuli (Tikhomirova, Malykh, Malykh, 2020). The participant was required to reproduce the entire sequence in the same order by clicking on the corresponding cubes with the mouse. The total number of correctly reproduced sequences was recorded.

### *"General knowledge and vocabulary" task, vocabulary and the ability to differentiate essential from non-essential object features*

The task instruction requires the child to choose one word that correctly completes the sentence. For example, the child was read the beginning of the sentence "A boot always has..." and was presented with a list of words from which to select the single correct option: "buttons, straps, sole, buckle, lace" (Zambatsyavichene, 1984). The total number of correctly completed sentences was recorded.

### *"Classification and generalization" task, ability to group objects based on given criteria and to unite them on the basis of common features*

The task instruction required the participant to choose one "odd" word that did not fit with the other words. For example, the child was read a list of words—"tulip, lily, bean, daisy, violet"—and was asked to think and name the word that did not belong with the others in the series (Zambatsyavichene, 1984). The total number of correct responses was recorded.

### *"Analogical reasoning" task, the ability to draw inferences by analogy based on given logical relationships between concepts*

In this task, the instruction was read aloud from the screen: "The words 'forest–trees' are related in the same way as the words in the second pair. Choose the word that matches the word from the second pair: 'library' is related to what?" A list of response options was then read aloud: "garden, yard, city, theater, books" (Zambatsyavichene, 1984). The total number of correct responses was recorded.

## Results

The statistical analysis included indicators of the development of the cognitive domain in older preschool children—information processing speed, visuospatial working memory, as well as general knowledge and vocabulary, the ability to classify and generalize concepts, and the ability to draw inferences by analogy based on given logical relations between concepts. The number of languages used for communication with the child in the family and for instruction in kindergarten was considered as an indicator of sociocultural conditions of development and education affected by bilingualism in a multinational state.

### *Descriptive statistics*

Table 1 presents the means and standard deviations (in parentheses) for information processing speed ("Choice reaction time" task), visuospatial working memory ("Corsi Block-tapping" task), as well as indicators related to understanding, analyzing, and using language ("General knowledge and vocabulary", "Classification and generalization", and "Analogical reasoning" tasks), including their variation depending on the number of languages used for communication in the family and instruction in the preschool educational organization.

In Table 1, for the "Choice reaction time" task, the mean reaction time for correct responses is presented in milliseconds; for all other tasks, the number of correct responses is reported, ranging from 0 to 12 for the "Corsi Block-tapping" task and from 0 to 10 for the "General knowledge and vocabulary", "Classification and generalization", and "Analogical reasoning" tasks.

**Table 1**

*Descriptive statistics of cognitive domain indicators in older preschool children depending on conditions of development and education associated with bilingualism*

| Indicator | General sample ( n=818) | Communication in the family | | Education and training in kindergarten | |
|---|---|---|---|---|---|
| | | One language ( n=584 ) | Two languages ( n=234 ) | One language ( n=524 ) | Two languages ( n=294 ) |
| "Choice reaction time" | 1425.16 (333.1) | 1423.89 (324.7) | 1435.01 (395.5) | 1407.34 (312.5) | 1471.97 (459.2) |
| "Corsi Block-tapping" | 1.51 (1.3 ) | 1.46 (1.3) | 1.61 (1.6) | 1.46 (1.3) | 1.59 (1.3) |
| "General knowledge and vocabulary" | 6.11 ( 2.1) | 6.21 (1.9) | 5.78 (2.7) | 6.19 (2.1) | 5.29 (2.1) |
| "Classification and generalization" | 5.24 (2.3) | 5.26 (2.2) | 5.07 (2.7) | 5.34 (2.2) | 4.86 (2.0) |
| "Analogical reasoning" | 5.44 (2.6) | 5.50 (2.5) | 4.84 (2.5) | 5.35 (2.6) | 6.16 (2.1) |

According to the descriptive statistics, only minor differences in mean values across all cognitive indicators are observed between groups of children with one and two languages of communication both in the family and in kindergarten. Thus, with respect to basic cognitive indicators, children who command two languages were, on average, slightly slower but demonstrated somewhat higher levels of working memory. On the verbal tasks, the group of preschool children with two languages showed slightly lower performance in vocabulary size and the ability to classify and generalize, but outperformed their peers who were educated in one language in the ability to construct analogical inferences based on given logical relations.

### *Analysis of group differences in the level of development of cognitive domain indicators*

To assess the statistical significance of differences between groups of preschool children with different sociocultural conditions shaped by bilingualism, as well as the effect size of these differences on cognitive domain indicators, a one-way analysis of variance was conducted. As a categorical factor, the following groupings were considered sequentially: groups with one or two languages of family communication, groups with one or two languages of instruction in kindergarten, and the coincidence, partial coincidence, or non-coincidence of the language(s) of family communication with the language(s) of education. The dependent variables included information processing speed, visuospatial working memory, general knowledge and vocabulary, the ability to classify and generalize, and the ability to draw inferences. Assessment of the distributions of all dependent variables for the compared groups using Levene's test indicated equality of variances ($p > 0.05$).

The results of the analysis of variance showed no differences across all cognitive domain indicators between groups of older preschool children who were communicated with at home in one or two languages ($p > 0.05$), as well as between preschool children attending preparatory groups in kindergartens where upbringing and education were conducted exclusively in the state language or using both the state and native languages ($p > 0.05$).

At the same time, the results of the analysis of variance in which the categorical factor was the coincidence, non-coincidence, or partial coincidence of the language(s) of family communication with the child and the language(s) of instruction and upbringing in kindergarten revealed statistically significant differences between groups of preschool children on certain cognitive domain indicators. Groups of older preschool children were formed on the basis of data on the language(s) of communication in the family and education in kindergarten.

The group of preschool children in whom the language(s) of family communication coincided with the language(s) of instruction and upbringing in kindergarten included 431 children (52.7% of the total sample). This group comprised preschool children who (a) communicated in their families in Russian (as a state or native language) and received education in kindergarten in Russian, and (b) communicated in their families in two languages (the state Russian language and a native language) and were educated in kindergarten in two languages as well (Russian and a native language).

The group of preschool children in whom the language(s) of family communication did not coincide with the language(s) of instruction in kindergarten included 153 children (18.8%). This group comprised children who were communicated with in the family exclusively in a native language from among the languages of the peoples of the Russian Federation, while attending kindergartens whose educational programs did not include a regional component in the native language.

The group with a partial coincidence between the language(s) of family communication and instruction in kindergarten included 234 children (28.5%). This group comprised children who (a) communicated in their families in two languages (the state Russian language and a native language) and were educated in kindergarten exclusively in Russian, and (b) communicated in their families exclusively in Russian (as a rule, as the state language) or exclusively in native language and were educated in kindergarten in two languages (the state Russian language and a native language) through the implementation of a regional educational component in a native language from among the languages of the peoples of the Russian Federation.

Table 2 presents the descriptive statistics of cognitive domain indicators in older preschool children depending on the degree of coincidence between the language(s) used in the family and those used in kindergarten.

**Table 2**

*Descriptive statistics of the level of development of cognitive domain indicators in older preschool children depending on the degree of coincidence between the language(s) used in the family and in kindergarten*

| | Coincides (n = 431) 52.7% | Doesn't coincide (n =153) 18.8% | Partially coincides (n=234) 28.5% |
|---|---|---|---|
| "Choice reaction time" | 1394.2 (309.1 ) | 1614.4 (360.1) | 1410.8 (395.5) |
| "Corsi Block-tapping" | 1.46 (1.2 ) | 1.45 (1.3) | 1.53 (1.6) |
| "General knowledge and vocabulary" | 6.39 (1.8) | 5.04 (1.8) | 5.97 (2.7) |
| "Classification and generalization" | 5.51 (2.1) | 3.70 (2.1) | 5.26 (2.7) |
| "Analogical reasoning" | 5.48 (2.3) | 5.53 (2.2) | 4.94 (2.7) |

According to Table 2, the analysis of mean values revealed significant group differences in information processing speed, as well as in general knowledge and vocabulary, classification and generalization. Specifically, an advantage on these cognitive indicators was observed in the group of older preschool children in whom the language(s) of family communication fully coincided with the language(s) of instruction in kindergarten. At the same time, test results in the groups of preschool children with full coincidence and partial coincidence of the language(s) of family communication and kindergarten

instruction differed slightly; in particular, on the "Classification and Generalization" task the mean values were 5.51 and 5.26, respectively.

Notably, a wider range of variability across all analyzed cognitive domain indicators was observed in older preschool children in whom the language(s) of family communication and kindergarten instruction only partially coincided.

The results of the analysis of variance of group differences among older preschool children depending on the coincidence, non-coincidence, or partial coincidence of the language(s) of family communication and education in kindergarten are presented in Table 3.

**Table 3**

*Results of the analysis of group differences in cognitive domain indicators*

| Indicator | Sum of squares (SS) | F statistic (F) | Significance level (p) | Effect size ($\eta^2$) |
|---|---|---|---|---|
| "Choice reaction time" | 1977539.6 | 10.89 | 0.000 | 0.05 |
| "Corsi Block-tapping" | 7.39 | 2.17 | 0.115 | 0.01 |
| "General knowledge and vocabulary" | 80.88 | 10.76 | 0.000 | 0.05 |
| "Classification and generalization" | 133.45 | 14.31 | 0.000 | 0.07 |
| "Analogical reasoning" | 31.16 | 2.49 | 0.084 | 0.01 |

According to Table 3, statistically significant differences between the analyzed groups of older preschool children were identified for three cognitive domain indicators—information processing speed, vocabulary and general knowledge, and the ability to classify concepts and generalize them on the basis of common features ($p = 0.000$). Specifically, group differences with an effect size of 5% were found for the "Choice reaction time" and "General knowledge and vocabulary" tasks, and with an effect size of 7% for the "Classification and generalization" task.

Multiple comparisons with Bonferroni correction revealed task-specific patterns of group differences. In particular, with regard to information processing speed, all three groups of preschool children—those with full coincidence, non-coincidence, and partial coincidence between the language(s) of family communication and the language(s) of education in kindergarten—differed from one another ($p < 0.05$). For the tasks related to vocabulary, classification of concepts, and their generalization, statistically significant differences were identified only between two groups—preschool children with full coincidence and those with non-coincidence of the languages used in the family and in kindergarten ($p < 0.001$).

## *Analysis of the structural organization of the cognitive domain*

To assess the structure of the cognitive domain in older preschool children depending on sociocultural conditions of development and education influenced by bilingualism, a correlation analysis was conducted.

The results of the correlation analysis revealed no differences in the structure of the cognitive domain between older preschool children attending preschool educational organizations where instruction was provided exclusively in the state Russian language and their peers from kindergartens implementing both the state Russian language and a native language within the framework of a regional educational component in a native language from among the languages of the peoples of the Russian Federation ($0.22 < r < 0.53$ at $p < 0.05$ in kindergartens with one language; $0.20 < r < 0.54$ at $p < 0.05$ in kindergartens with two languages).

The correlation analysis also revealed no differences in the structure of the cognitive domain between older preschool children who communicated in their families exclusively in one language and their peers from families where two languages were used ($0.14 < r < 0.53$ at $p < 0.05$ in one-language families; $0.18 < r < 0.58$ at $p < 0.05$ in two-language families).

In contrast, the correlation analysis identified differences in the structure of the cognitive domain among three groups of older preschool children for whom the language(s) of family communication and the language(s) of instruction in kindergarten coincided, did not coincide, or partially coincided. Table 4 presents Spearman's correlation coefficients for the three analyzed groups of older preschool children (*$p < 0.05$; **$p < 0.01$).

**Table 4**

*Results of the analysis of the structure of the cognitive domain in older preschool children depending on the degree of coincidence between the language(s) of family communication and instruction in kindergarten*

| Indicator | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| "Choice reaction time" (1) | Coincides | | | | | |
| | Doesn't coincide | | | | | |
| | Partially coincides | 1 | | | | |
| "Corsi Block-tapping" (2) | Coincides | -0.18** | | | | |
| | Doesn't coincide | -0.36** | | | | |
| | Partially coincides | -0.47** | 1 | | | |
| "General knowledge and vocabulary" (3) | Coincides | -0.15* | 0.19** | | | |
| | Doesn't Coincide | -0.21* | 0.24** | | | |
| | Partially coincides | -0.35** | 0.36** | 1 | | |
| "Classification and generalization" (4) | Coincides | -0.17* | 0.04 | 0.48** | | |
| | Doesn't coincide | -0.22** | 0.25** | 0.39** | | |
| | Partially coincides | -0.41** | 0.36** | 0.49** | 1 | |
| "Analogical reasoning" (5) | Coincides | -0.02 | 0.17** | 0.40** | 0.46** | |
| | Doesn't coincide | -0.19** | 0.20** | 0.42** | 0.39** | |
| | Partially coincides | -0.27** | 0.29** | 0.45** | 0.47** | 1 |

As shown in Table 4, the correlation coefficients between the analyzed cognitive indicators range from |0.15| to |0.49|, indicating statistically significant relationships of varying strength—from weak to moderate. The correlation analysis revealed two main patterns.

The first pattern was observed in the analysis of the relationships between basic cognitive functions ("Choice reaction time" and "Corsi Block-tapping" tasks) and cognitive indicators characterizing language comprehension and use ("General knowledge and vocabulary", "Classification and generalization", and "Analogical reasoning" tasks). Specifically, differences were identified in both the number and strength of interrelations across groups of older preschool children in whom the language(s) of family communication and kindergarten instruction coincided, did not coincide, or partially coincided. The cognitive domain of the group of preschool children with full coincidence of the languages used in the family and kindergarten was characterized by a smaller number of interrelations (5 out of 7 possible) compared with the other groups (7 out of 7 possible). At the same time, the strongest relationships were observed in the group with partial coincidence of the languages used in the family and kindergarten ($0.27 < r < 0.47$ at $p < 0.05$), whereas the weakest relationships were found in the group with full coincidence of the languages used in the family and kindergarten ($0.15 < r < 0.19$ at $p < 0.05$).

The second pattern was observed in the analysis of relationships exclusively among cognitive indicators characterizing language comprehension and use in interaction with the surrounding world ("General knowledge and vocabulary", "Classification and generalization", and "Analogical reasoning" tasks). In this case, similarity was observed across all three groups of preschool children—with coincidence, non-coincidence, and partial coincidence of the language(s) of family communication and kindergarten instruction. Specifically, in all groups of preschool children, the coefficients between test indicators reflecting the level of development of mental operations ranged from 0.39 to 0.49 at $p < 0.01$.

## Discussion

In the present study, conducted on a sample of older preschool children from eight subjects of the Russian Federation, characteristics of cognitive functioning were analyzed depending on sociocultural conditions influenced by bilingualism. The analysis addressed not only the level of development of individual cognitive functions but also the structure of their interrelations in groups of older preschool children under conditions of full coincidence, non-coincidence, or partial coincidence between the language(s) of family communication and the language(s) of instruction in preschool educational organizations. This research approach made it possible to assess the capacity of cognitive resources in older preschool children across differing family and educational conditions associated with bilingualism in a multinational state.

The results of the present study did not reveal statistically significant differences between older preschool children who command one or two languages, either in basic cognitive functions ("Choice reaction time" and "Corsi Block-tapping" tasks) or in indicators characterizing language comprehension and use ("General knowledge and vocabulary", "Classification and generalization", and "Analogical reasoning" tasks). These findings are consistent with the conclusions of meta-analyses and systematic reviews, which, while acknowledging extremely small effects of bilingualism on certain cognitive functions in respondents of specific age groups, generally report an absence of cognitive advantages of bilingualism (Gunnerud et al., 2020; Dick et al., 2019; Bialystok, 2017). Moreover, in most studies where minor effects of bilingualism on cognitive development—primarily executive functions—are observed, an urgent need is emphasized to identify sociocultural conditions, particularly educational ones, that may facilitate the manifestation of differences between children who command one or two languages (Ortiz & Rodríguez, 2025; Ali, 2023; Papastergiou, Pappas, & Sanoudaki, 2021; Bialystok, 2021; Hartanto et al., 2019).

Such a sociocultural condition, characteristic not only of the Russian Federation but also of "well over half of the countries of the world" (Bialystok, 2017, p. 233), was found to be the degree of coincidence between the language(s) of family communication and the language(s) of instruction in preschool educational organizations. Intergroup differences were demonstrated in the level of development of information processing speed, with an effect size of 5%, as well as in vocabulary size (5%) and the ability to classify and generalize (7%). With regard to information processing speed, all three groups of older preschool children differed from one another, with an advantage observed in children for whom the language(s) of family communication fully coincided with the language(s) of instruction in kindergarten. For indicators related to language comprehension and use, differences were identified only between groups with full coincidence and non-coincidence of the language(s) used in the family and in kindergarten, again favoring the former. These findings are consistent with results obtained in studies involving older school-age children, which report higher processing speed in high school students educated in their native language—Russian or Kyrgyz (Verbitskaya et al., 2017), and Russian, Kyrgyz, or Moldovan (Zinchenko et al., 2022).

It should be noted that more pronounced individual differences across all cognitive indicators were observed in the group of older preschool children with partial coincidence between the language(s) used in the family and in kindergarten. This group included children who communicated in two languages in the family but attended kindergartens with instruction exclusively in the state Russian language, as well as children who communicated in only one language in the family but were educated in kindergartens using two languages. The greater individual variability observed in this group may be associated with the degree of mastery and frequency of use of each language and, consequently, with individual differences in the use of each language—whether in home

communication, kindergarten instruction, or their constant mixing (Green & Abutalebi, 2023; Frederiksen & Kroll, 2022; Calabria et al., 2018).

Analysis of the structural organization of the cognitive domain revealed specificity in interrelations depending on the degree of coincidence between the language(s) of family communication and kindergarten instruction, but only with respect to relationships between basic cognitive functions and indicators of language comprehension, analysis, and use. The smallest number and weakest strength of interrelations among individual indicators were observed in the group of older preschool children with full coincidence between the language(s) used in the family and in kindergarten. In contrast, the maximum possible number of interrelations and their highest strength were characteristic of the group with partial coincidence of the language(s) used in the family and in kindergarten. Conversely, analysis of interrelations exclusively among indicators of language comprehension, analysis, and use—vocabulary, general knowledge, ability to classify and generalize, and analogical reasoning—revealed uniformity of structure across all groups of older preschool children, namely, a maximum number of interrelations of moderate strength. This structural "division" may be related to age-specific features of development in older preschool children, particularly the uneven developmental trajectories of individual elements of the cognitive domain—basic cognitive functions with their rapid dynamics (Tikhomirova et al., 2023; Kuzmina et al., 2020) and the more gradual formation of thinking operations (Zaporozhets, Zinchenko, & Elkonin, 1964).

The structural specificity of the cognitive domain and differences in the level of development of individual indicators depending on sociocultural conditions influenced by bilingualism made it possible to assess the complexity of the cognitive domain in preschool children at different degrees of coincidence between the language(s) of family communication and kindergarten instruction. Within the framework of cognitive resource theory, it is precisely the complexity of the cognitive domain that reflects the capacity of an individual's cognitive resources, which in turn is characterized by varying degrees of differentiation (Druzhinin, 2007; Goryunova & Druzhinin, 2000). The highest degree of differentiation, with the possibility of autonomous activation of high-level indicators of information processing speed, general knowledge and vocabulary, and the ability to classify and generalize—and, consequently, the greatest cognitive resource capacity—was characteristic of the group of older preschool children for whom the language(s) used in the family and in kindergarten fully coincided. This group included children who communicated at home exclusively in Russian (as a native or state language) and attended kindergartens with instruction exclusively in the state Russian language, as well as children who communicated at home in two languages (native and state) and attended kindergartens where, alongside the state Russian language, a regional educational component in the native language was implemented. According to language control theory, full coincidence of the language(s) used in the family and in preschool educational organizations eliminates the need for substantial cognitive "costs" associated with language switching across contexts, thereby enabling high performance in task

completion, particularly on measures of processing speed, vocabulary, classification, and generalization (Green & Abutalebi, 2023; Bialystok & Craik, 2022; Frederiksen & Kroll, 2022; Calabria et al., 2018).

In contrast, the cognitive domain of older preschool children for whom the language(s) used in the family and in kindergarten did not coincide was characterized by the lowest degree of differentiation and a low level of development of individual cognitive functions, resulting in reduced cognitive resource capacity when performing test tasks. This group included children who communicated at home in a native language from among the languages of the peoples of the Russian Federation and attended kindergartens where upbringing and education were conducted exclusively in the state Russian language. The need to acquire knowledge in a non-native language activates a "mixed" context of language use, with a subsequent transition to a monolingual context involving a division between languages used "only at home" and "only in education." At the initial stage of language acquisition, this requires maximal cognitive resources, leaving limited capacity for effective performance of learning tasks (Gallo & Abutalebi, 2024; Green & Abutalebi, 2023; Bialystok & Craik, 2022). Indeed, a number of studies have shown that mastering an educational program in a non-native language engages substantial cognitive resources even after eleven years of schooling (e.g., Zinchenko et al., 2022). Information processing speed appears to be the most "sensitive" to conditions of bilingualism and has specific importance for learning in Russian regardless of the native language group (Zinchenko et al., 2022).

Under conditions of partial coincidence between the language(s) used in the family and in kindergarten, the cognitive domain of older preschool children, according to the obtained data, is characterized by low differentiation but a high level of development of individual cognitive functions, which allows for partial compensation of limited individual resources. This group included children who communicated in two languages in the family (state Russian and a native language) and attended kindergartens with instruction exclusively in Russian, as well as children who communicated exclusively in Russian at home and attended kindergartens implementing a regional educational component in a native language. Under such sociocultural conditions, the "mixed" context of language use is also primarily activated, with maximal cognitive "costs" and a subsequent transition to monolingual or bilingual contexts (Green, 2024; Green & Abutalebi, 2023; Bialystok & Craik, 2022). However, partial coincidence of languages—knowledge of one of them—provides an opportunity to cope more effectively with task performance due to a high level of development of individual cognitive functions, primarily information processing speed, sufficient vocabulary size, and others.

Thus, the results of the present study demonstrate intergroup variation in the efficiency of cognitive functioning at the older preschool stage depending on sociocultural conditions of development and education associated with bilingualism. Scientific data on the specific features of cognitive resources in older preschool children, obtained through consideration of the "language-related" characteristics of the family and preschool

educational organization, open up opportunities for the development of psychological and pedagogical support programs for children, including those implemented within the framework of regional educational components in a multinational state environment.

## Conclusions

Sociocultural conditions of development and education associated with bilingualism in a multinational state—namely, full coincidence, non-coincidence, or partial coincidence between the language(s) of family communication and the language(s) of instruction in preschool educational organizations—contribute to the manifestation of specific features of the cognitive domain in older preschool children, leading to changes in the capacity of their cognitive resources when performing everyday and learning-related tasks.

Under conditions of full coincidence between the language(s) used in the family and in kindergarten, the cognitive domain is characterized by a high degree of differentiation and high-level development of individual cognitive functions, and, consequently, by greater cognitive resource capacity in this group of older preschool children. In contrast, when the languages do not coincide, the cognitive domain is characterized by low differentiation and a low level of development of cognitive indicators, which may result in reduced cognitive resource capacity when performing relevant tasks. In situations of partial coincidence, the cognitive domain of preschool children is characterized by low differentiation but a high level of development of individual cognitive functions, which allows for compensation of limited individual resources.

Among cognitive domain indicators, information processing speed, vocabulary size, and the ability to classify and generalize are the most "sensitive" to sociocultural conditions of development and education influenced by bilingualism, with higher levels of development observed in older preschool children under conditions of full or partial coincidence between the language(s) of family communication and instruction in preschool educational organizations.

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**Tatyana Nikolaevna Tikhomirova** – idea, concept and methodology of the study; administration of data collection; interpretation of results; text of the article.

**Artem Sergeevich Malykh** – selection of methodological tools; database administration; statistical data analysis.

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## Conflict of Interest Information

The authors have no conflict of interest to declare.

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# Meta-Analysis of Body-Related Factors of Color Sensitivity Variability

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## Abstract

**Introduction.** Color sensitivity (the ability to distinguish individual colors and to perceive differences in the spectral composition of visible radiation and object colors) in individuals with normal color vision (healthy normal trichromats) can vary significantly under the influence of various factors, both internal and external. The most significant group of factors are physiological (or body-related). This paper is the first effort to systematize the results of empirical studies similar in methodology, in which the possible influence of body-related factors on color sensitivity was assessed using the Farnsworth-Munsell 100-Hue test. **Methods.** The study was conducted using systematic review and meta-analysis. The sources were selected in accordance with PRISMA recommendations via scientometric archives (PubMed, Scopus) and web platforms (Web of Science, Semantic Scholar). The database included the results of 35 studies conducted in the period from 1963 to 2024 in 17 countries with the participation of 4,024 subjects. **Results.** Thematic clustering of the identified works enabled us to divide the body-related factors of color sensitivity into three enlarged groups. The first group includes factors related to gender differences and endocrine specificity. The second group includes the main anthropological features of the eye, primarily the color of the iris, the density of macular pigment, and the size of the pupil. The third group includes various effects of age–related changes in the process of natural aging of the body. **Discussion.** A comparison of the total error score (TES) and partial error score (PES) of the Farnsworth-Munsell 100-Hue test obtained in each of the thematic clusters showed that color sensitivity has quite significant differences in the population, which correlate with gender, age, ethnic, and racial characteristics of the eye structure. One of the main limitations of the measurements is the involvement of participants from Europe and the United States in the studies. This is especially relevant for age-related norms. Research in this field needs to be continued and further developed.

## Keywords

color sensitivity; color vision; variability of color perception; color cognition; Farnsworth-Munsell test; FM 100-Hue test; meta-analysis; systematic review; physiological factors; body-related factors

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# Introduction

### *Variability of color sensitivity*

The description and measurement of the variability of human color sensitivity is one of the relevant fields of modern interdisciplinary research into cognitive processes (see the research overview in: Bosten, 2022; Maule et al., 2023). In this case, color sensitivity is understood as the ability of the visual system to distinguish individual colors and perceive differences in the spectral composition of visible radiation and the color of objects (Izmailov et al., 1989), and its variability is understood as measurable individual differences in these sensations arising under the influence of various factors (Muraya et al., 2023).

The starting point for the beginning of a scientific discussion on individual differences in color sensitivity is considered to be the report of J. Dalton, delivered by him in 1794 and published four years later in the Proceedings of the Manchester Literary and Philosophical Society (Dalton, 1798). While studying botany, J. Dalton observed that he had considerable difficulties identifying plants by color. He found similar features of color vision in his brother, while most other people he knew saw colors differently.

Until then, the fact that color sensitivity can vary considerably from person to person has not been given much importance in science. Possible discrepancies in color recognition were mainly discussed in the context of philosophy, and there they were considered only as interesting curiosity (see: Osborn, 2012). Almost the same is the case today in the study of taste. Few people care whether all people are equally good at distinguishing the salinity or sweetness of the same product, and how these individual sensations correspond to the established standard (see for example: Spence, 2022).

The catalyst for studying color sensitivity was the development of rail transport and commercial shipping. In these new areas of activity, color began to be used as a sign of movement regulation, and an erroneous perception of color led to several major disasters, with many victims (the most famous occurred in Sweden in 1875) (Osborn, 2012, p. 324). As a result, interest in the state of color vision increased, however, greatly influenced by the practical needs of the time, the dichotomy paradigm became the main paradigm in the study of color sensitivity. From the point of view of color sensitivity, all people were simply divided into two groups – those with normal color sensitivity and those with impaired ability to distinguish between all or some shades (people with abnormal color sensitivity, or colorblind people) (see: Osborn, 2012, p. 325).

### *Farnsworth-Munsell 100-Hue Test*

An important role in the development of a modern paradigm for studying the variation of color sensitivity has been played by the development of simple and easy to use measurement tools, especially the Farnsworth–Munsell panel tests (Farnsworth-Munsell 100-Hue, FM 100-Hue, FM-100). Developed in 1943 by D. Farnsworth based on the idea of W.O.D. Pierce (Pierce, 1934; see Pokorny & Smith, 1986) and the Munsell color system (Farnsworth, 1943, 1957), the test has been actively used since the mid-20th century to evaluate color vision and is currently one of the most widespread worldwide.

The widespread popularity of the test is related to several circumstances at once. The test is mass-produced and has a reasonable price; it is portable and convenient to transport; it has no cultural specificities and does not require any prior training from both the observer and the operator. The recognition of the test by the scientific community is also explained by the fact that it allows to quantify the color discrimination of an observer (Farnsworth, 1957; Smith et al., 1985) and compare the indicators obtained with those obtained in longitudinal studies or perform a comparative analysis of generalized groups. The test is quite resistant to refractive errors (Thyagarajan et al., 2007), has a high (up to 100%) sensitivity and specificity (83%) (Seshadri et al., 2005; Fanlo Zarazaga et al., 2019).

In the early years of the scientific application of the test, largely under pressure from the established dichotomic paradigm of color sensitivity description, individual differences, often recorded in psychophysical data within the normal range, have not become the subject of detailed discussion, much less independent research (Boston, 2022). The existence of even larger discrepancies in the data sets of people with normal color vision (normal trichromates) was seen more as an error; this was a sign that something was wrong with the study, and even a reason to distrust the averages presented, which were generally used in the analysis.

However, over time, the empirical data obtained have led to a rethink of the structure of differences in color sensitivity (see notes: Muraya et al., 2023). Researchers have come to understand that the boundaries of the norm are arbitrary, and people with normal color vision also see colors fundamentally differently. Individual differences in the processing of

color-related information at different levels of the visual system affect all aspects of color perception, from color discrimination to constancy of color perception, color naming, and subjective color experience (Boston, 2022). The scientific interest thus focuses on variability, diversity in color sensitivity, research on factors that can affect it and the sociocultural consequences that this may lead to.

Throughout the long history of the Farnsworth-Munsell test, discussions of the possible influence on color sensitivity of factors that are not related to the functional capabilities of the visual system, both internal and external, have been the basis for a number of scientific publications that require systematic reflection and comprehensive analysis. Since all these papers are similar in methodology, the empirical data presented in them are suitable for comparison. Systematization and meta-analysis of the accumulated material will enable us to draw important conclusions for further research into color sensitivity and mechanisms of formation of color vision variability.

This paper **aims** to identify the physiological (body-related) factors most important for the formation of individual differences, based on a systematic review of the published results of empirical studies of the color vision of normal trichromats with the Farnsworth-Munsell test and a meta-analysis of quantitative indicators essential to the variability of color sensitivity.

# Methods

## Research methodology

The study uses systematic review and meta-analysis (see Littell et al., 2008), aimed at identifying, analyzing and synthesizing large amounts of quantitative empirical data from published studies using the Farnsworth-Munsell color sensitivity test.

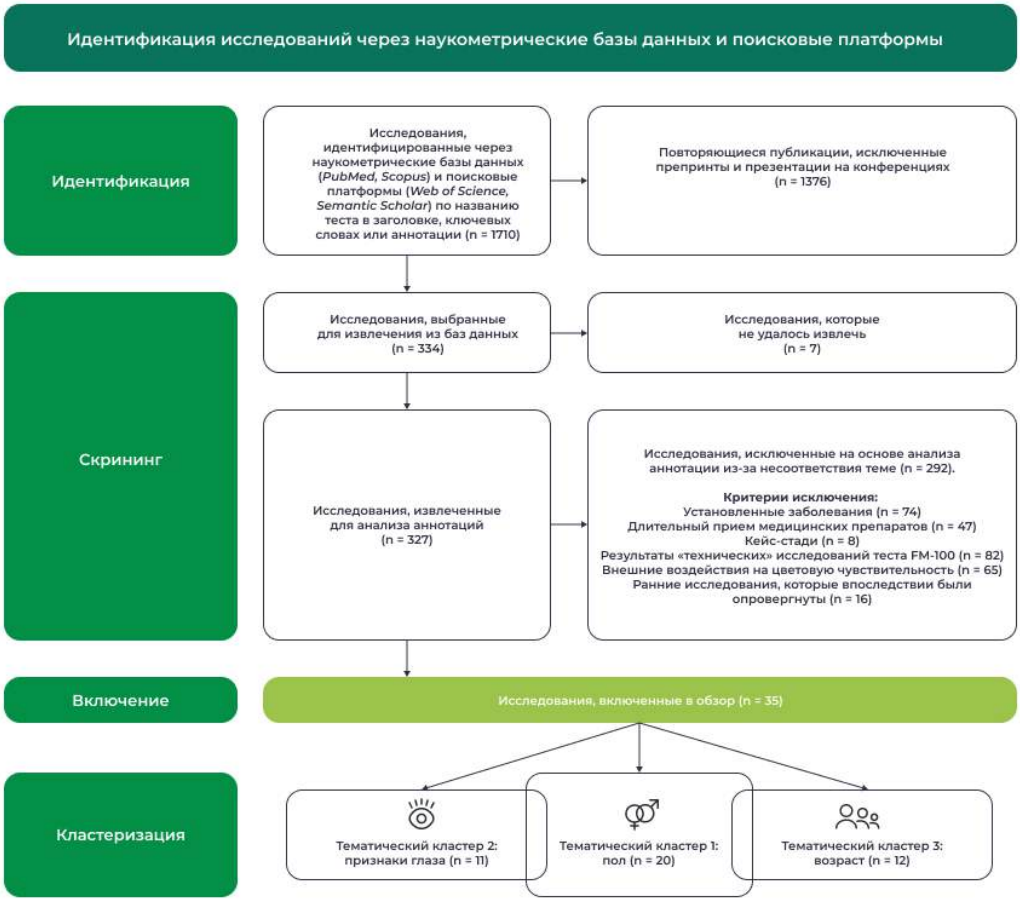
To our knowledge, this is the first systematic review of color sensitivity studies.

## Source selection and formation of the research database

The selection of sources and formation of the research database were carried out in accordance with the recommendations of PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) (Page et al., 2021) and included 4 stages (Figure 1).

**Figure 1**

*Stages of selecting sources and forming a research database*




**In the first stage**, studies were identified using scientific databases (*PubMed, Scopus*) and search platforms (*Web of Science, Semantic Scholar*). Various variants of the test name accepted in scientific publications were used as a keyword (*Farnsworth–Munsell 100 Hue Color Vision test, Farnsworth–Munsell 100-Hue test, FM 100-Hue test, FM-100 test*). A search by titles, keywords, and abstracts revealed 1,710 relevant scientific publications.

During the screening, **in the second stage** of selecting sources, 1,376 repetitive publications, preprints, and conference presentations were excluded from the list. The remaining 334 articles, which could potentially be relevant to the issue under study, were prepared for extraction from the relevant databases and 327 of them were successfully extracted.

The subsequent analysis of the full texts of the abstracts in the **third stage** of source selection enabled us to form a final list of sources for a systematic review of physiological factors and a meta-analysis of the variability of color sensitivity. When forming the list, sources containing the results of measurements of color vision in individuals with established diseases (eye diseases, diabetes, dementia, Parkinson's disease, bipolar disorder, coronavirus, etc.) or long-term users of medications (antiepileptic, antidiabetic, anti-tuberculosis, and many others) were excluded. The analysis of individual cases (case studies) presented in it, the results of "instrumental" studies of the FM-100 test (for example, its comparison with others), as well as the analysis of various external influences on color sensitivity, including economic (food quality, medical care), geographical (altitude above sea level, air composition, habitual illumination), socio-cultural (field of activity, ethnic traditions, hobbies and organization of daily life), and psychological ones (alcohol and drug addiction), were also considered as reasons for excluding the study from the database.

When selecting early studies, the main criterion for inclusion in the database was their importance for the development of modern ideas about the factors of color vision variability. We did not include in the review the results of the studies that were subsequently rechecked and refuted.

Thus, the database for a systematic review and meta-analysis of the factors of color sensitivity variability, which we conditionally called body-related, includes the published results of 35 studies conducted between 1963 and 2024 in 17 countries located on all continents. These results include data obtained from the Farnsworth-Munsell test on color vision of 4,024 people aged 5 to 81.

In the **final stage** of the database formation, all the documents selected for the study were divided into three thematic clusters. The first cluster consisted of studies of gender differences and endocrine specificity of color sensitivity (n = 20). The second cluster included papers that discussed the possible impact of the main anthropological features of the eye on color sensitivity variability, including the color of the iris, the density of macular pigment, and pupil size (n = 11). The third cluster included papers on age-related changes in color sensitivity during the natural aging of the body (n = 12). The studies analyzing factors from two clusters simultaneously were included in the two corresponding groups (n = 8).

The texts of all articles selected for the review were thoroughly examined and analyzed.

# Results

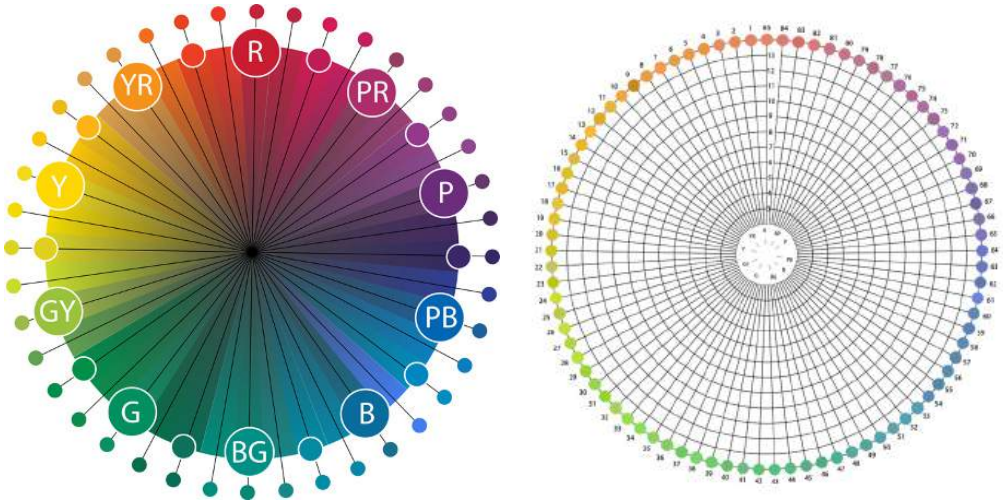
## Quantitative indicators of color sensitivity variability

## *Test structure*

The FM 100 Hue test (X-Rite, Grand Rapids, Michigan, USA) contains 85 caps, the shades of which together form a complete color wheel (Figure 2 on the left). The shades are divided into approximately equal steps of perception. In the conventions of the Munsell system (see: Griber, 2018), all shades have the same lightness and saturation values (Value = Chroma = 6) and differ only in tone (Figure 2 on the right).

**Figure 2**

*Munsell color wheel (left) and template for presenting the results of the Farnsworth-Munsell 100 Hue test (right)*




The caps are arranged in 4 trays, which are often indicated by the Latin letters A, B, C, and D. Tray A contains 22 caps, while the other three contain 21 caps. In each of the four trays, the caps represent a specific sector of the color wheel – from red to red-orange (tray A, caps 85–21), from yellow to yellow-green (tray B, caps 22–42), from green to green-violet (tray C, caps 43–63), and from indigo to magenta (tray D, caps 64–84).

The outermost caps in each tray are fixed, while the others are movable. To measure color sensitivity, the caps are mixed up and the observer is asked to rearrange the sequence in each tray so that the transition from one color to another is as smooth as possible.

Despite this seemingly simple task, only 1–2% of people with normal color vision can correctly place all caps (Pokorny & Smith, 1986). The average color difference (delta E) between the shades is only about 2.2 units, which allows for the detection of the smallest differences in color sensitivity. However, the values of this indicator vary among different color trays. Tray A is the least challenging, while tray C is the most challenging (Lakowski, 1966). The shades of the caps from 85 to 8 and from 35 to 65 are the most similar. As a result, placing these caps in the correct order is more difficult for the observer (Dain et al., 1991).

### *Total Error Score (TES)*

The traditional analysis method first includes the calculation of the Total Error Score, TES. This indicator reflects the chromatic sensitivity in general and is calculated as the sum of the scores for the caps in the four trays. The score for a single cap is calculated as the sum of the absolute difference between the number of errors for a particular color and the number of errors for the caps adjacent to it minus 2 (Farnsworth, 1957):

$$Total\ Error\ Score\ (TES)=\sum_{i=1}^{4} iES=\sum_{i=1}^{4}\left(\left(\sum_{j=1}^{n+2} CE_j\right)-((n+2)*2)\right) \quad (1)$$

where $CEj = |Cj\text{-}Cj\text{-}1|+|Cj\text{-}Cj+1|$; i – tray (i=1 indicates tray A, 2 – B, 3 – C, 4 – D); Cj – cap number j; CEj – cap error j; n is the number of movable caps in the tray corresponding to i (n = 22 for tray A, and n = 21 for trays B–D). For the formula to work correctly, the terms |Cj-Cj+1| and |Cj-Cj-1| must be equal to 1 when the caps are placed correctly. Since the first free cap in tray A is cap 85, not 1, a dummy array is required to calculate the value of the cap, which assigns the value 1 to cap 85, the value 2 to cap 1, and so on. The cap error (CE) is calculated for the outermost caps of the tray, otherwise the scoring would be incorrect; this requires (n + 2) terms in formula (1), where 2 accounts for the outermost caps (Esposito, 2019).

The errors made in each of the trays are denoted by AES, BES, CES, and DES, respectively (Esposito, 2019). If all the caps are placed in the correct order, the total error value, TES, is 0; the more caps are misplaced, the higher the TES value. Since TES has an asymmetric distribution, modern calculations often use the square root of the total error (√TES) to obtain a distribution that is closer to normal (Kinnear, 1970).

A special computer program (X-Rite, V.3.0, USA) is commonly used for quick estimation of the total error under laboratory and field conditions.

Depending on the magnitude of the total error score (TES), observers are traditionally divided into three groups: those with superior color discrimination (TES between 0 and 16), those with average discrimination (TES between 20 and 100), and those with low discrimination (TES>100). Most normal trichromats in the population (approximately 68%) have average discrimination, while approximately one-sixth have low discrimination and one-sixth have superior sensitivity (16% each) (Farnsworth, 1957).

### *Partial error scores (PES)*

To determine the color sensitivity variability, partial error scores are used, which are calculated (1) separately for each cap (*IES, Individual Error Score*) (Verriest, 1963) or (2) for individual ranges of colors (*PES, Partial Error Score*).

For individual color categories (*HPES, Hue Partial Error Score*), the Total Error Score is usually divided into 10 segments (Griber & Paramei, 2024; Trukša et al., 2024):

(1) from red to yellow-red (R-YR), caps 1–9; from the long-wave region of the color spectrum to 590 nm;

(2) from yellow-red to yellow (YR-Y), caps 10–17; 590-580 nm;

(3) from yellow to green-yellow (Y-GY), caps 18–26; 580-560 nm;

(4) from green-yellow to green (GY-G), caps 27–35; 560-500 nm;

(5) from green to blue-green (G-BG), caps 36–45; 500-490 nm;

(6) from blue-green to blue (BG-B), caps 46–53; 490-470 nm;

(7) from blue to purple-blue (B-PB), caps 54–60; 470-450 nm;

(8) from purple-blue to purple (PB-P), caps 61–70; 450 nm to the short-wave end;

(9) from purple to red-purple (P-RP), caps 71–77; 560*–500* nm;

(10) from red-purple to red (RP-R), caps 78–85 (complementary to shades from green-yellow to green).

To assess the number of errors along the main axes of the perceptual color space – blue-yellow and red-green – the total error score is divided into two parts: the B-Y axis (*BY-PES, Blue-Yellow Partial Error Score*) (caps 1–12, 34–54, and 76–85) and the R-G axis (*RG-PES, Red-Green Partial Error Score*) (caps 13–33 and 55–75 (Smith et al., 1985).

As with the Total Error Score (TES), square roots of all the scores required for discussion are usually used in the analysis to obtain a distribution that is close-to-normal.

## *Index of change dynamics*

To assess the dynamics of color sensitivity in longitudinal studies, the index of change is used, which is calculated by the formula (2):

$$\sqrt{TES_1} - 0{,}25 - \sqrt{TES_2} \quad (2)$$

where $TES_1$ is the total error score at the first survey, $TES_2$ is the total error score at the second survey.

The use of this formula allows the learning effect to be taken into account in calculations when repeating FM 100-Hue test (Verriest et al., 1982).

## *Age standardization of test results*

Age standardization (AS) of test results can be performed based on the normative values for the age group according to the formula (3):

the individual TES – average score in the age group

the standard deviation (SD) from the average score in the age group.

The score obtained in this case shows by how many magnitudes of the standard

deviation (SD) the individual TES differs from the normal average score corresponding to age (Mäntyjärvi, 2001).

## Calculations using Vingrys and King-Smith method

In some studies, additional calculations are performed using the Vingrys and King-Smith method (Vingrys & King-Smith, 1988). This analysis method is based on D. Farnsworth's idea that the measurements of color sensitivity obtained using the FM 100-Hue test can be "transferred" to the color space and the difference in chroma for caps located nearby can be calculated (Farnsworth, 1943). The calculations proposed by the authors transform the cap scores from CIE 1931 into a single chromaticity space CIELUV 1976 to determine the vectors of color differences between adjacent caps in the analyzed sequence. The direction of the vectors obtained shows the type of violation of the observer's color perception, and its length shows the degree of displacement of adjacent caps.

Calculations using Vingrys and King-Smith method traditionally include the determination of five main indicators, including the confusion angle, the minor radius, the major radius, the scatter index (S-index = major radius / minor radius) and the confusion index, C-index (see Griber & Paramei, 2024). In modern research, Vingrys and King-Smith analysis is usually performed using specialized WEB-based programs (see for example: http://www.torok.info/fm100/).

## Interpretation of color sensitivity variability indicators

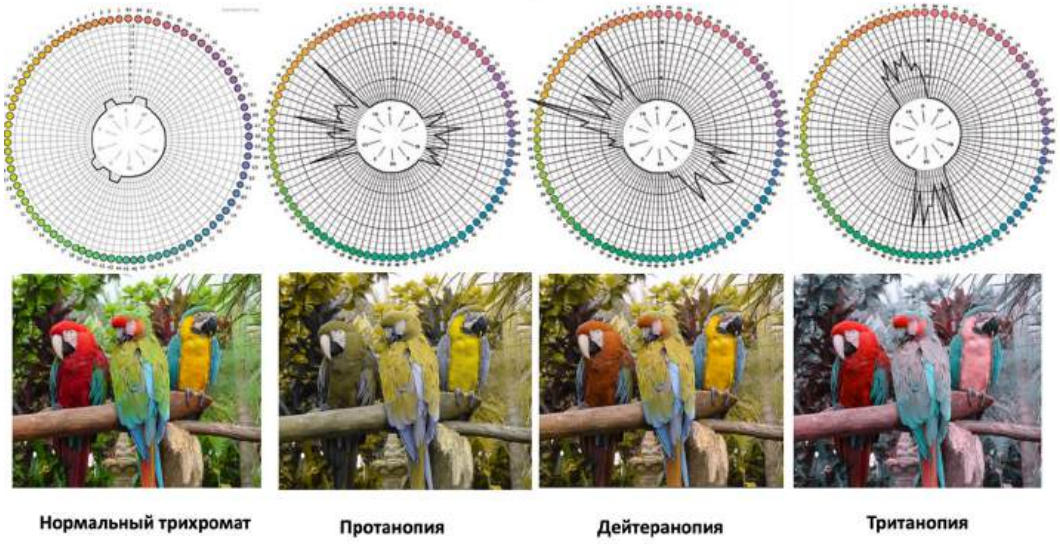
To interpret the variability of color sensitivity, the terminology of congenital color vision abnormalities is usually used, although congenital disorders of color sensitivity and its variability within the normal range most often have a fundamentally different nature and different scale. In the case of color sensitivity variability, we are not talking about pronounced defects, but only about weakness of color vision. However, in both cases, errors made during the test on the color wheel contribute to a characteristic pattern (see, for example, Birch, 1989).

Deutane defects is caused by pigment changes in the M-type cones, and protane defects – in the L-type cones. People with both types of color disorders do not distinguish well between the same colors (for example, orange, yellow and green; dark green, brown and red), therefore such disorders are also called red-green color vision deficiency. The two main differences between these two types of disorders are that people with deutane defects retain normal brightness sensitivity to red light, while people with protane defects have decreased brightness sensitivity, resulting in poor discrimination between red and gray. People with tritan defects usually confuse purple, gray and yellow-green; blue and blue-green; blue-green and bluish-white; dark blue and black. As a result, this disorder is also called blue-yellow color vision deficiency (Lankford & Hovis, 2023). By analogy with color vision anomalies, color vision variability is also described depending on the

predominant axis (as blue-yellow or red-green changes) or compared with a specific type of color anomaly (deutane-, protane-, or tritane-like deficiency) (Figure 3).

**Figure 3**

*The characteristic location of error zones for various color vision abnormalities in the results of the Farnsworth-Munsell test (above) (reconstruction based on diagrams in the sources (Lakowski, 1969; Kinnear, 1970; Knoblauch, 1987)) and modeling the color perception of a complex scene with each type of violation (below) using a simulator (Coblis, 2025)*




## Meta-analysis of body-related factors of color sensitivity variability

The thematic clustering of factors that can be conventionally referred to as body-related allows us to combine them into three extended groups: (1) gender and endocrine specificity, (2) the main anthropological characteristics of the eye (iris color, macular pigment density, pupil size), and (3) age-related changes in the process of natural aging of the body. Each of these groups is considered separately in the following review.

### *Gender and endocrine specificity*

A comparative analysis using the Farnsworth-Munsell test on color sensitivity in men and women has not yet yielded clear results (Table 1). In most of the studies conducted, no statistically significant differences between men and women were found (Verriest, 1963; Knoblauch et al., 1987; Rigby et al., 1991; Mäntyjärvi, 2001; Karaca et al., 2005; McCusker et al., 2012; Koçtekin et al., 2013; Oji et al. al., 2014; Simionato et al., 2021). A number of studies have found that young women are better able to distinguish shades than men of

the same age (Fine, 1973; Fine & Kobrick, 1980 vs. Fine, 1983; Panchal et al., 2013; Imbery et al., 2018, 2020, 2022; Gupta et al., 2020), and this advantage persists until about 25 years of age (Verriest, 1963). However, the opposite result was also recorded – fewer errors were recorded among young men compared to their peers (Dain et al., 2004).

The rhetoric of the publications included in the review indicates that, in general, possible differences in color sensitivity between men and women are generally expected for researchers due to gender dimorphism, pronounced hormonal, ontogenetic and environmental inconsistencies between the genders, as well as significant gender differences in the cognitive processing of color information at all levels, from color perception to color metacognition, which may be related to a wide range of social and behavioral reasons (see: Grieber, 2025).

Traditionally, women are believed to have a more developed color sensitivity than men. In many respects, this view is stereotypical, because men are statistically ten times more likely than women to have hereditary color vision disorders; 8% of men and only 0.4% of women have various color vision abnormalities worldwide (see, for example, Moreira et al., 2024). However, this factor could actually influence the result obtained: since color abnormalities screening was not carried out in most studies, men were more likely than women to have an unidentified observer with severe color vision impairments among the average results, if excluded, the gender difference would lose statistical significance.

Researchers attribute higher color sensitivity rates in men to gender differences in pupil diameter. Because men have a larger pupil diameter than women, more light enters the retina, which has a positive effect on color discrimination (Dain et al., 2004).

The differences in the obtained results may be explained by the fact that participants in some studies may have simply been motivated and more attentive to the task than participants in others (Murray et al., 2012).

Another possible cause may be unaccounted for endocrine changes, which are discussed separately in a number of published papers (Giuffre et al., 2007; Orbán & Dastur, 2012). Studies have shown that women's color vision experiences subtle but statistically significant fluctuations at different stages of the menstrual cycle under the influence of changes in estradiol levels. As a result, women are better able to distinguish color during ovulation compared to the beginning and end of the menstrual cycle (Giuffre et al., 2007).

Significant improvements in color discrimination (lower total error scores (TES) compared to non-pregnant women) are also noted in the background of pronounced hormone dynamics in pregnant women during the first trimester of pregnancy. Researchers believe that changes in color discrimination can be part of a network of perceptual and physiological defense mechanisms (including changes in the sense of smell and taste, nausea and vomiting) that perform adaptive functions. They increase the likelihood of visual signals associated with food toxicity, thereby reducing the risk of eating foods containing teratogens that can cause abnormal fetal development (Orbán & Dastur, 2012).

**Table 1**

*Mean score and standard deviation of the total errors scores (TES) for healthy normal trichromats of different genders, presented in (Verriest, 1963, Table 2), (Dain et al., 2004, Table 2), (Panchal et al., 2013, Table 1), (Gupta et al., 2020, Tables 2 and 3)*

| Gender | Healthy normal trichromats of different genders | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Verriest (1963) | | | | Dain et al. (2004) | | Panchal et al. (2013) | | Imbery et al. (2018) | | Gupta et al. (2020) | | | |
| | N | Mean TES ± SD 15–19 | N | Mean TES ± SD 20–24 | N | Mean TES ± SD 18–24 | N | Mean TES ± SD 18–22 | N | Mean TES 21–44 | N | Mean. TES ± SD 18–25 | Right eye Mean TES ± SD 18–25 | Left eye Mean TES ± SD 18–25 |
| M | 25 | 60.1 ± 29.4 | 60 | 42.3 ± 34.9 | 30 | 21.4 ± 19.1 | 50 | 43.80 ± 28.52 | 59 | 29.2 | 101 | 76.00 ± 10.61 | 89.56 ± 18.92 | 95.92 ± 22.27 |
| F | 31 | 44.5 ± 25.5 | 34 | 25.5 ± 20.6 | 32 | 30.6 ± 19.4 | 50 | 28.38 ± 22.62 | 36 | 18.6 | 69 | 48.85 ± 13.02 | 58.81 ± 16.70 | 64.35 ± 16.52 |

*Note. Binocular measurements are indicated in dark grey, monocular indicators of the right eye are light grey. The table contains only data from studies in which the differences between the indicators for men and women were statistically significant.*

### *Anthropological characteristics of the eye*

According to the published data, color sensitivity has quite noticeable differences that correlate with the anthropological characteristics of the eye – the color of the iris, the density of macular pigment, pupil size, and lens color. Moreover, the results of the measurements indicate that all these qualities seem to be interrelated (see the review of research in Garakani & Ng, 2019).

In particular, if we reduce the entire variety of existing iris color options to three main types, which correspond to the classes of the Bunak scale (Bunak, 1941) (this is exactly what some researchers did to test their hypotheses) – (1) dark type (the iris is black, dark brown, light brown, or yellow); (2) light type (the iris consists of gray, blue, light blue and gray-blue color elements) and (3) mixed type (the iris contains areas of dark and light color and it has a green, gray-green, brown-green, brown-gray shade or is colored gray or blue with a brown aureole) – then all other marked indicators will correlate with this division.

A dark eye color usually means a smaller pupil size and a denser macular layer (Hammond et al., 1996; Hammond & Caruso-Avery, 2000; Dain et al., 2004). Macular pigments, which are located in front of photoreceptors, most actively absorb waves in the blue part of the spectrum, with a length of approximately 460 nm. Thus, they are a kind of optical yellow filter for photoreceptors (Budzinskaya, 2018). Simulating an increase in the density of the macular layer using artificial filters significantly reduces color sensitivity. This leads to an increase in the total error index and causes a pronounced tritan-like polarity along the blue-yellow axis (Moreland & Dain, 1995). A natural increase in the density of the macular layer also leads to an increase in the overall error rate (Woo & Lee, 2002; Dain et al., 2004) and partial errors in the blue (caps 50-68) and blue-green (caps 36-54) parts of the color spectrum, which, however, does not reach the level of statistical significance (Davison et al., 2011; Garakani & Ng, 2019).

On the contrary, a light eye color, as a rule, correlates with a larger pupil size and a less dense macular layer (Woo & Lee, 2002; Dain et al., 2004). As a result, fair-skinned people with light iris colors (blue or green), according to the FM 100-Hue test, have higher color sensitivity than observers with dark (brown) eye color (Zlatkova et al., 2014; Garakani & Ng, 2019).

The analysis of eye anthropological characteristics also correlates with ethnicity and race (Woo & Lee, 2002; Dain et al., 2004; Garakani & Ng, 2019). In particular, pigmentation, including eye color, is crucial in racial classification, is a racial diagnosis feature and is used to characterize populations (see Loskutova, 2013).

In general, studies indicate the existence of a certain pattern. A higher rate of total error and especially so-called tritan errors (errors along the blue-yellow axis of perceptual space) is typical for people with dark skin and dark iris colors – Africans (Kaimbo Wa Kaimbo et al., 1994), Asians (Woo & Lee, 2002; Garakani & Ng, 2019), Indian reservation populations (Burdick & Chebib, 1982). The light-skinned observers with light eye color surveyed in Europe and the USA had the least number of errors. The difference between groups increases with age and is less evident among younger participants.

**Table 2**

*Mean score and standard deviation of the square root of the total error score (√TES) for healthy normal trichromats of different ages, presented in (Verriest et al., 1982, Table 1), (Roy et al. 1991, Table 1), (Mäntyjärvi, 2001, Table 1) and (Kinnear & Sahraie, 2002, Table 1)*

| Age group | Healthy normal trichromats of different age | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Verriest et al. (1982) | | | | Roy et al. (1991) | | | | Mäntyjärvi (2001) | | | | Kinnear & Sahraie (2002) | |
| | N | Mean √TES ± SD | Right eye Mean √TES ± SD | Left eye Mean √TES ± SD | N | Right eye Mean √TES ± SD | N | Left eye Mean √TES ± SD | N | Right eye Mean √TES ± SD | N | Left eye Mean √TES ± SD | N | Mean √TES |
| 5–9 | | | | | 7 | 15.6 ± 6.3 | 7 | 14.1 ± 5.5 | | | | | 72 | 15.7 |
| 10–14 | 27 | 9.13 ± 1.85 | 9.71 ± 2.54 | 9.51 ± 2.29 | 13 | 7.2 ± 3.0 | 13 | 6.3 ± 2.9 | 24 | 8.66 ± 2.29 | 24 | 8.76 ± 2.56 | 153 | 9,7 |
| 15–19 | 32 | 6.63 ± 1.91 | 7.62 ±2.04 | 7.07 ± 2.15 | | | | | | | | | 68 | 7.2 |
| 20–29 | 29 | 5.69 ± 2.07 | 6.47 ± 2.42 | 6.35 ± 2.39 | 25 | 6.0 ± 2.2 | 25 | 6.0 ± 2.5 | 30 | 7.44 ± 2.46 | 30 | 7.56 ± 2.36 | 35 | 6.7 |
| 30–39 | 29 | 6.71 ± 2.90 | 7.50 ± 2.68 | 7.45 ± 2.60 | 16 | 6.7 ± 1.9 | 17 | 5.8 ± 2.7 | 23 | 7.80 ± 3.09 | 23 | 8.13 ± 2.54 | 10 | 7.3 |
| 40–49 | 30 | 8.23 ± 2.44 | 9.28 ± 2.33 | 8.66 ± 2.34 | 13 | 5.8 ± 1.1 | 12 | 5.3 ± 2.0 | 31 | 9.34 ± 2.22 | 34 | 9.22 ± 2.38 | 10 | 8.1 |
| 50–59 | 30 | 8.68 ± 2.64 | 10.36 ± 2.43 | 10.22 ± 1.99 | 10 | 8.2 ± 2.0 | 10 | 8.0 ± 2.7 | 27 | 9.62 ± 1.59 | 23 | 9.28 ± 2.01 | 10 | 9.5 |
| 60–69 | 28 | 9.57 ± 2.44 | 10.93 ± 2.59 | 11.11 ± 2.76 | 20 | 10.1 ± 3.0 | 18 | 9.6 ± 3.0 | 21 | 10.07 ± 2.03 | 20 | 10.16 ± 2.68 | 10 | 10.7 |
| 70–80 | 27 | 11.46 ± 2.01 | 13.45 ± 2.04 | 13.30 ± 2.18 | 9 | 11.9 ± 2.1 | 9 | 12.3 ± 1.4 | | | | | 10 | 12.3 |

*Note. Binocular measurements are indicated in dark gray, monocular scores of the right eye are light gray.*

## Age

A large number of studies focus on age-related differences in color sensitivity in normal trichromats. All these studies can be roughly divided into two groups. The first group is devoted to the development of age-related limits of the norm. The second one is the study of factors explaining the age-related dynamics of color vision.

The specificity of studies aimed at determining the age-related limits of the norm of color sensitivity lies in a sufficiently large number of observers, who are grouped into five- or ten-year-old age cohorts to calculate generalized indicators. The first work of this kind was published in 1963 (Verriest, 1963). In subsequent years, updated normative scores were presented for healthy normal trichromats of mature age groups (Pinckers, 1980; Verriest et al., 1982; Roy et al., 1991; Trukša et al., 2024) from different ethnic groups (Mäntyjärvi, 2001; Karaca et al., 2005) and more detailed data on younger cohorts (Kinnear & Sahraie, 2002).

The measurements were performed monocularly or binocularly (Table 3), in various light conditions, which varies from 100 to 1000 lux, and in different populations – Belgians (Verriest, 1963; Verriest et al., 1982), British (Aspinall, 1974; Kinnear & Sahraie, 2002), Dutch (Pinckers, 1980), Americans (Roy et al., 1991), Turks (Karaca et al., 2005), and Finns (Mäntyjärvi, 2001). Nevertheless, all these studies on the age-related dynamics of color vision indicate the same trend. Chromatic sensitivity usually increases before the age of 20-30, remains relatively stable during the following years of life, and decreases after 40. The most noticeable statistically significant differences in the total error score are observed between the age groups 19-29 (M = 23.96, SD = 12.98) and the groups 40-49 (M = 39.97, SD = 25.12), 50-59 (M = 55.40, SD =12.98) (Trukša et al., 2024). At the same time, the values of the partial error along the red-green axis practically do not change throughout life. The changes mainly affect the blue-yellow B-Y axis, especially the BG-B, B-PB, G-BG and RP-R categories (Maule et al., 2023).

The mean error score in monocular and binocular testing is comparable and does not differ statistically. The normative differences between the monocular indices ($\sqrt{R} - \sqrt{L}$) for different age groups coincide and reach $0 \pm 1.16$ (Aspinall, 1974).

Studies of the age-related variability of color sensitivity of the second type are intended to test hypotheses on the influence of specific factors of different types on age-related changes in color vision. In this case, scientists develop the design of experiments to "isolate" any single factor and draw conclusions as a result of the study on its role in the processes of reducing color vision or excluding its influence.

In younger cohorts, decreased color vision is usually associated with the late completion of the formation of the blue-yellow system (Dain, 2004). Until recently, the negative dynamics of color vision recorded in the older groups were associated with age-related changes in the lens, which increase the adsorption capacity of short wavelengths of the visible spectrum, such as an increase in the density of the lens, changes in its color and transparency.

To simulate the yellowing of the lens in young observers, the researchers used special yellow filters. In early studies (Verriest, 1963), this caused a marked increase in the number of errors when performing the FM 100 Hue test. However, scientists later concluded that filters probably did not accurately reproduce age-related changes that occur in the ability of the lens to transmit light waves in reality. More recent studies have shown that the yellowing of the lens can hardly be regarded as a decisive factor in age-related changes in color vision (see the review of studies in Griber et al., 2020). The researchers also found no significant relationship between psychophysical estimates of lens density and the FM 100 Hue test results in a group of normal subjects with a limited age range (50-70 years) (Sample et al., 1988).

Today, it is considered a more reasonable strategy to take into account age-related changes in color sensitivity as a result of a complex combination of physiological changes that must be taken into account in combination (Beirne et al., 2008). The most significant are age-related decreases in pupil size and the associated decrease in retinal illumination (Knoblauch et al., 1987; Dain et al., 2004), blurred vision (Thyagarajan et al., 2007), and changes in the thickness of the macular layer (Moreland & Dain, 1995; Woo & Lee, 2002; Dain et al., 2004).

Color vision changes that are more pronounced than age-related norms occur in various diseases, including diabetes mellitus, glaucoma, cataracts and a number of others (see the review of studies in: Trukša et al., 2024).

**Table 3**

*A list of papers presenting the results of empirical studies using the FM 100 Hue test of the effects of various body-related factors on color sensitivity*

| Authors | Year | Country | N | F | Age | Factor | Method | Time limit | Light control | Indicators |
|---|---|---|---|---|---|---|---|---|---|---|
| Verriest | 1963 | Belgium | 480 | 233 | 10–64 | ⚥ 👥 | bino | no | yes | TES, IES, HPES |
| Fine | 1973 | USA | 56 | 0 | n/s (soldiers) | ⚥ | bino | 2 min | no | TES |
| Aspinall | 1974 | UK | 113 | n/s | n/s | 👥 | mono | no | yes | TES |
| Fine & Kobrick | 1980 | USA | 36 | 9 | n/s (soldiers) | ⚥ | bino | 2 min | yes | TES |
| Pinckers | 1980 | Nether-lands | 410 | n/s | 0–69 | 👥 | bino | no | yes | TES |
| Burdick & Chebib | 1982 | USA, Canada | 92 | 0 | 24–49 | 👁 | bino | no | no | TES, IES |
| Verriest et al. | 1982 | Belgium | 232 | 123 | 10–80 | 👥 | bino, mono | no | yes | TES, AES, BES, CES, DES |

| Authors | Year | Country | N | F | Age | Factor | Method | Time limit | Light control | Indicators |
|---|---|---|---|---|---|---|---|---|---|---|
| Fine | 1983 | USA | 30 | 30 | 17–62 (32.6 ± 13.5) | | bino | 2 min | yes | TES, AES, BES, CES, DES |
| Knoblauch et al. | 1987 | France | 75 | 39 | 20–78 | | bino, mono | no | yes | TES, IES |
| Rigby et al. | 1991 | UK | 30 | 7 | 20–45+ | | bino | no | yes | TES |
| Roy et al. | 1991 | USA | 115 | 63 | 5–81 | | mono | no | yes | TES |
| Kaimbo Wa Kaimbo et al. | 1994 | Zaire | 132 | n/s | 20–49 | | bino | no | no | TES |
| Moreland & Dain | 1995 | UK, Australia | 10 | n/s | n/s | | mono | no | yes | TES, IES |
| Mäntyjärvi | 2001 | Finland | 160 | 106 | 10–69 | | mono | no | yes | TES, AES, BES, CES, DES |
| Kinnear & Sahraie | 2002 | UK | 382 | 193 | 5–79 | | bino | 2 min | no | AS<br>TES, BY-PES, RG-PES |
| Woo & Lee | 2002 | Hong Kong | 100 | 49 | 30–59 (43.48 ± 7.66) | | bino | no | yes | TES, IES, BY-PES, RG-PES |

| Authors | Year | Country | N | F | Age | Factor | Method | Time limit | Light control | Indicators |
|---|---|---|---|---|---|---|---|---|---|---|
| Dain et al. | 2004 | Australia | 63 | 32 | 18–24 (21.4) | | bino | no | yes | TES, V6K-S |
| Karaca et al. | 2005 | Türkiye | 180 | 90 | 10–69 | | mono | no | yes | TES, AES, BES, CES, DES, BY-PES, RG-PES |
| Giuffrè et al. | 2007 | Italy | 15 | 15 | 21–34 (25 ± 4) | | mono | no | yes | TES, AES, BES, CES, DES |
| Thyagarajan et al. | 2007 | United Kingdom | 15 | 7 | 21–34 | | mono | no | yes | TES, IES, BY-PES, RG-PES |
| Beirne et al. | 2008 | United Kingdom | 20 | 10 | (22.2 ± 2.65)<br>(54.5 ± 2.64) | | mono | no | yes | TES, BY-PES, RG-PES |
| Davison et al. | 2011 | United Kingdom, South Africa | 102 | | 18–40<br>(29 ± 6) | | mono | no | yes | TES, IES, HPES (blue, cyan) |
| McCusker et al. | 2012 | United Kingdom | 30 | 18 | 20–61 | | mono | no | yes | TES |

| Authors | Year | Country | N | F | Age | Factor | Method | Time limit | Light control | Indicators |
|---|---|---|---|---|---|---|---|---|---|---|
| Orbán & Dastur | 2012 | Canada | 13 | 13 | 20–29 (28.35) | | bino | no | yes | TES |
| Koçtekin et al. | 2013 | Türkiye | 50 | 19 | (21.18 ± 2.52) | | mono | no | no | TES, BY-PES, RG-PES |
| Panchal et al. | 2013 | India | 100 | 50 | (19.51 ± 1.46) | | bino | no | no | TES |
| Oji et al. | 2014 | Japan | 68 | 20 | 27–69 (44.3 ± 9.1) | | bino | no | yes | TES, PES 64–78 (tongue color region) |
| Zlatkova et al. | 2014 | United Kingdom | 28 | 15 | 20–30 | | bino | no | yes | TES, BY-PES, RG-PES |
| Imbery et al. | 2018 | United States | 95 | 36 | 21–44 (25) | | bino | no | yes | TES |
| Garakani & Ng | 2019 | United States | 30 | 17 | 18–40 (25.1 ± 2.5) | | mono | no | yes | TES, BY-PES, RG-PES |

| Authors | Year | Country | N | F | Age | Factor | Method | Time limit | Light control | Indicators |
|---|---|---|---|---|---|---|---|---|---|---|
| Gupta et al. | 2020 | India | 170 | 69 | 18–25 (18.6 ± 0.91) | ⚥ | bino, mono | 2.5 min | no | TES |
| Imbery et al. | 2020 | United States | 291 | 147 | (24.9 ± 3.9) | ⚥ 👁 | bino | no | yes | TES |
| Simionato et al. | 2020 | Brazil | 120 | 67 | 20–29 (22.7) | ⚥ | bino | 2 min | yes | TES |
| Imbery et al. | 2022 | United States | 98 | 59 | 22–26 (25.5 ± 4.1) | ⚥ 👁 | bino | no | yes | TES |
| Trukša et al. | 2024 | Latvia | 146 | | 19–70 | 👥 | bino | no | yes | TES, HPES, BY-PES, RG-PES |

Note: The articles are listed in chronological order, with each year listed in alphabetical order. The age description includes a range, with minimum/maximum values, the mean score ± standard deviation in parentheses. The following symbols are used in the table: N – total number of observers; M – males; F – females; bino – binocular measurement; mono – monocular measurement; n/s – not specified; TES – total error score; AES – tray A error score; BES – tray B error score; CES – tray C error score; DES – tray D error score; IES – individual error (for each cap); HPES – partial error score for individual hues; BY-PES – partial error score along the blue-yellow axis, RG-PES – partial error score along the red-green axis; AS – age standardization of test results; V&K-S – Vingrys and King-Smith calculations. Thematic groups of body-related factors are indicated graphically: ⚥ – factors related to gender differences and endocrine specificity; 👁 – the main anthropological characteristics of the eye; 👥 – factors of age-related changes in the process of natural aging of the body.

## Discussion

The systematic review presented in this paper contains a critical analysis of the literature in the subject area, which enables us to compare the available data, identify trends and locate gaps in the study of body-related factors of color sensitivity. The review covers empirical studies over the past 60 years conducted in various countries of the world on all continents (Table 3).

The systematization of quantitative indicators and traditions of interpretation of test results shows that most studies use standard indicators for the analysis of collected data – total error score (TES) and (less often) partial error score (PES). In earlier studies partial error scores are most often calculated for individual trays (see, for example: Verriest et al., 1982; Fine, 1983; Mäntyjärvi, 2001; Karaca et al., 2005; Giuffrè et al., 2007); in later studies – along the main axes of the perceptual color space – blue-yellow and red-green (see, e.g., Kinnear & Sahraie, 2002; Woo & Lee, 2002; Karaca et al., 2005; Thyagarajan et al., 2007; Beirne et al., 2008; Koçtekin et al., 2013; Zlatkova et al., 2014; Garakani & Ng, 2019; Trukša et al., 2024). More complex calculations (for example, the calculation of partial error scores separately for each hue or by zones corresponding to the type of color vision impairment (see, for example: Verriest, 1963; Davison et al., 2011; Trukša et al., 2024), as well as the use of Vingrys and King-Smith coefficients and the interpretation of data in three-dimensional color space) (see, for example, Dain et al., 2004) are still rare.

In some cases, refusing to use certain methods is really justified. In particular, the Vingrys and King-Smith method provides the most significant results when analyzing significant color anomalies. On the contrary, in studies of color sensitivity variability that does not exceed normal limits, color vectors may have very variable angles, which makes the application of the method problematic (see, for example, Dain et al., 2004).

In the case of testing the same hypothesis, there are quite obvious differences between the indicators in different studies in some cases (Tables 1 and 2), which, however, usually indicate the presence of the same or similar trends. Researchers explain the differences between the indicators in different ways, most often by differences in the level of motivation of observers (see, for example, Murray et al., 2012), low or uncontrolled illumination (see, for example, Verriest et al., 1982; Knoblauch et al., 1987) or the possible presence in databases of unaccounted-for patients with minor color sensitivity disorders under the influence of any unaccounted-for factors, for example, endocrine ones (cf.: Giuffre et al., 2007; Orbán & Dastur, 2012).

The thematic clustering of studies confirming the possible effect on color sensitivity of internal physiological mechanisms and anthropological characteristics allows us to identify three groups of factors that can be conditionally referred to as body-related, including (1) gender and endocrine specificity, (2) the main anthropological characteristics of the eye, and (3) age-related changes in the process of natural aging of the body. A comparison of the indicators obtained in each of the thematic clusters indicates that the detected violations are moderate or even mild and, in general, manifest within the age-appropriate

norm (see, for example, Pinckers, 1980; Verriest et al., 1982; Roy et al., 1991; Mäntyjärvi, 2001; Kinnear & Sahraie, 2002; Karaca et al., 2005; Trukša et al., 2024). However, at the population level, such dynamics allow us to draw important conclusions on physiological factors that influence color perception. In particular, according to published data, color sensitivity has quite noticeable differences that correlate with ethnic and racial features of the eye structure – the color of the iris, the density of macular pigment, pupil size (see, for example: Burdick & Chebib, 1982; Kaimbo Wa Kaimbo et al., 1994; Moreland & Dain, 1995; Woo & Lee, 2002; Dain et al., 2004; Davison et al., 2011; Zlatkova et al., 2014; Garakani & Ng, 2019); with gender differences (Fine, 1973; Fine & Kobrick, 1980 vs. Fine, 1983; Dain et al., 2004; Panchal et al., 2013; Imbery et al., 2018, 2020, 2022; Gupta et al., 2020) and endocrine specificity (Giuffrè et al., 2007; Orbán & Dastur, 2012).

## Conclusion

One of the main limitations of the measurements was that European and American participants were mainly involved in the research. This is especially relevant for age-specific norms. Attempts to test the stability of age-specific norms in other ethnic and racial conditions, especially in Zaire black population, Asians and the population of American Indian reservations, are still sporadic and are usually conducted in a small sample. Research in this field needs to be continued and further developed.

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# Learning-Related Dynamics of ERP Component Amplitudes When Assessing Visual Signal Duration

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## Abstract

**Introduction.** Using a systemic-evolutionary approach, we studied the dynamics of the relationships between task performance and the amplitude characteristics of ERP components during skill learning and improvement. Learning and improvement were assessed individually for every study participant, in contrast to before–after studies or the uniform interleaving approach used in psychophysiology. A sliding window method was used to analyze covariances between performance and the amplitudes of nine ERP components identified during the signal duration assessment epoch. **Methods.** A psychophysical task of discriminating short time intervals was used. Study participants (N=28) were divided into groups of those who had not acquired the skill, those who had acquired the skill, those who had not improved the skill, and those who had improved the skill. Task performance was recorded as well as unipolar EEG recordings in 11 leads. **Results.** The relationship between ERP component amplitudes and task performance varied for different ERP components. Components with peaks corresponding to intervals before the presentation of the assessed signal, the early positive component, and the component

before the end of the assessed signal were shown to be most closely associated with learning. Despite the greater amplitude of the components identified in the middle of the presentation of the assessed signal, the relationship between performance and the amplitudes of these components did not differ across the aforementioned groups of study participants. **Discussion.** The results are discussed in the context of how positive and negative ERP components are interpreted as markers of changes in stages (substages) of a behavioral act. It has been shown that different subjective methods for determining the substages of a behavior act can lead to the acquisition of a new skill with a certain degree of probability.

## Keywords

systemic-evolutionary approach, learning, skill improvement, EEG, psychophysics, learning dynamics, Yes/No Test, event-related potentials (ERPs)

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# Introduction

Learning issues and their relationship to the dynamics of brain activity during these processes are relevant in psychophysiology (Alexandrov, 2014). An important aspect is that in literature, the term "learning" often refers to different processes (Aleksandrov, 2006).

According to the systemic-evolutionary approach (Shvyrkov, 1995), the complex of individual experience elements (systems of a behavioral act) represents a systemic structure reflecting the history of an individual's interaction with the environment. The formation of a system in the systemogenesis process ensures increasing differentiation in the individual's interaction with the environment. The implementation of behavior, during which it can be changed, is associated with changes in inter-systemic relationships that, from the point of view of an external observer, as well as during learning, may appear as "an improvement in the implementation of behavior". Thus, from the perspective

of the systemic-evolutionary approach, it is possible to distinguish two processes: systemogenesis (more associated with the learning process) and changes in inter-systemic relationships (more associated with the process of improving an existing skill).

Some studies have used neural recording and examined the structure of individual experience, demonstrating that the processes of systemogenesis and changes in inter-systemic relationships are distinct (Gorkin, 2021). The structure of individual experience can also be studied using EEG. Positive EEG oscillations are associated with an increase in the number of simultaneously actualizing individual experience systems (Gavrilov, 1987) and with an increase in the degree of concretization of the subject of behavior (Maksimova & Aleksandrov, 1987); negative oscillations are associated with a decrease in the number of simultaneously actualizing systems (Gavrilov, 1987) and with a decrease in the degree of concretization of the subject of behavior (Maksimova & Aleksandrov, 1987).

The problem of dynamic examination of learning processes and skill improvement with electroencephalographic methods has been raised relatively rarely. Although there are many classical studies on brain mechanisms subserving learning processes, most of them are based on experiments constructed with the "before and after" comparison principle (see, e.g., Poon, 1974; Stuss & Picton, 1978; Verleger et al., 1985, etc.) or on the arbitrary selection of uniform epochs of analysis (McAdam, 1966; Peters et al., 1977; Taylor, 1978; Donald, 1980; Rosler, 1981; Kecei et al., 2006; Jongsma et al., 2006). Moreover, the literature describes conflicting conclusions about the increase/decrease in component amplitudes during the learning process. In our opinion, this approach is not informative enough, since it does not take into account the procedural component of learning.

To study the dynamics of learning and improvement processes, we used the psychophysical task of discriminating short time intervals using the Yes/No Test. This is due to its ability to carry out a continuous (non-dichotomic) assessment of the learning results (Apanovich et al., 2022; 2024), which is relatively free of decision-making factors (Zabrodin et al., 1984), and to the fact that this task is characterized by a learning process that is pronounced in its effect (Skotnikova, 2003). Another advantage of the task of discriminating short time intervals is, apparently, the relatively weak representation of experience with this behavior in the structure of individual experience.

The *objective* of this study is to evaluate the dynamics of the amplitude characteristics of the ERP components that manifest themselves during learning the skill of discriminating the duration of visual signals.

## Methods

### *Study participants*

A total of 28 participants (7 males, 21 females) participated in the study. The subjects ranged from 18 to 45 years of age (mean age — 23.1 years; median age — 19 years;

standard deviation — 8.66 years). The age of the respondents was controlled because the literature suggests that the 18 to 45-year-old age group shows the greatest stability in performance in tasks involving estimation/reproduction/discrimination of time intervals (Lisenkova & Shpagonova, 2021).

Based on the performance indicators developed and described in our previous studies (see Apanovich et al., 2022; Apanovich et al., 2024), participants in the study were divided into the following four groups:

1. Those who had not acquired the skill — a group in which the study participants initially did not perform the task (their performance was not statistically different from 0) and did not acquire the skill during the experiment (they did not overcome the threshold of a non-random solution d' = 0.546).
2. Those who had acquired the skill — a group in which the study participants acquired the skill of task performance during the experiment (at the beginning of the experiment, their performance was not statistically different from 0, but then they exceeded the threshold of a non-random solution d' = 0.546).
3. Those who had not improved the skill — a group in which the study participants initially had high levels of task performance (non-random, i.e., above the level of a non-random solution d' = 0.546), but did not improve the skill during the experiment (they did not statistically significantly improve their initial result).
4. Those who had improved the skill — a group in which study participants initially had high levels of task performance (non-random, i.e., above the non-random solution level d' = 0.546) and improved their skill during the experiment (statistically significantly improved their initial score).

## *Procedure and study design*

The experiment consisted of three tasks, but this article only examines the results of the main series (the third one). The first task involved distinguishing vertical and horizontal lines. After being presented with these lines, the participant had to press the corresponding keys on the keyboard with the index or ring finger of their dominant hand. This task was used to control the participant's response time. The second task, which we termed "sensitizing" (by "sensitizing" we mean the onset and cessation of neural activity, correlated with existing systems (Apanovich et al., 2022)) was used to distinguish this process from de novo learning. The parameters of this series replicated those of the main experimental task, but the participants had to discriminate not the duration of signal presentation, but their absolute sizes.

The third and main experimental task was a modified psychophysical Yes/No Test (Gusev et al., 1998; Zabrodin et al., 1984). The presentation was conducted using a special software, Visual Yes/No Test (developed by S. A. Karpov). Short time intervals were used as the assessed parameter (see below a description of one trial). This method, in our version of the experiment, consisted of 10 series, each containing 50 trials (the participant was

not informed in advance of the number of series and trials to avoid anticipation). The break between the series was 1 minute, during which the participant was asked to sit with his eyes closed to reduce eye fatigue. The total time to complete this task was about 40 minutes.

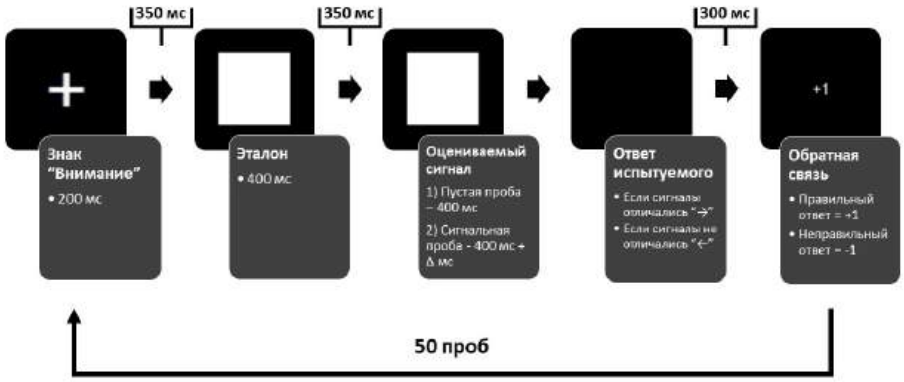
The first and second experimental tasks are control tasks for this experiment, and their results are not presented in this paper.

## *One trial description*

Each trial began with the presentation of the Attention signal (white cross, presentation duration — 200 ms, 1x1 cm dimensions, RGB color combination: 183, 183, 183). After a 350 ms break (dark background, RGB: 0, 0, 0), a reference signal was displayed for 400 ms: a white square of 3x3 cm dimensions, RGB color combination – 183, 183, 183. Then, after a 350 ms break (dark background, RGB: 0, 0, 0), the signal to be assessed was shown. Its duration, with a 50% probability, coincided with the duration of the reference signal or exceeded the duration of the reference signal by a value predetermined by the scenario (either 66 ms or 92 ms longer, depending on the scenario selected for a particular study participant). Participants in the study were asked to press the "⊠" key with their index finger if they believed that the signal lasted longer than the reference signal, and the "⊠" key if they believed that the assessed signal lasted the same time as the reference signal. After responding, the participant received feedback on the accuracy of their answer ("+1" if the answer was correct and "-1" if the answer was incorrect). Figure 1 shows graphical representation of a trial.

**Figure 1**

*Graphical representation of a trial (Apanovich et al., 2022).*



### *EEG recording method*

Recordings were made using non-polarizable silver chloride electrodes unipolarly in 11 leads: F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, O1, and O2. Electrodes were placed according to the international 10–20 system. Two neutral electrodes were placed on the mastoids behind the ears. Two EOG electrodes for artifact detection were placed 1 cm from the outer corner of the right eye along the palpebral fissure axis and in the middle of the lower eyelid contour of the left eye. Contact resistance did not exceed 10 kOhm. The sampling rate was 250 Hz, the high pass filter was 70 Hz, the low pass filter was 0.1 Hz, and the notch filter was 50 Hz. The electroencephalograph-recorder model was Encephalan-EEGR-19/26. Rejection of oculomotor, muscular, technical, and other artifacts was performed manually using our proprietary EEGAnalyzer software (developed by S. A. Karpov).

### *Analysis epoch*

The averaging epoch was defined as the interval from the end of the reference signal (350 ms before the onset of the assessed signal presentation) to the end of the assessed signal presentation (400 ms after the onset of the assessed signal presentation). The zero point was the onset of the assessed signal presentation. Thus, values from -350 ms to 0 ms corresponded to the interval between the reference and evaluation signals; 0 ms to 400 ms corresponded to the presentation interval of the assessed signal. This epoch was chosen because at that time the participant in the study estimated the duration of the signal presentation, i.e. performed the behavior that learning was studied in our study.

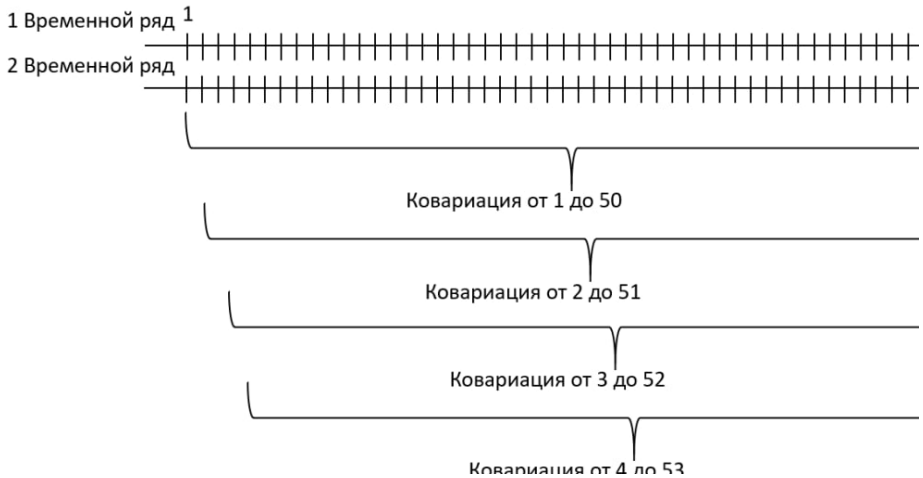
### *Variables analyzed and methods for obtaining them using the sliding window technique*

To compare the learning process with brain mechanisms subserving the behavior of discriminating short-term intervals, we analyzed the decision indicator and amplitude (peak-to-peak) characteristics of the isolated ERP components (see the next section for the criteria for including components in the analysis).

To assess the *dynamics* of the relationships between performance and the amplitudes of event-related potentials (ERPs), a sliding window technique was used. For every participant, the d' indicator was calculated in intervals lasting 50 trials, and this window was then shifted in 1 trial (see Figure 2). Using the method described above, the amplitudes of the identified ERP components were averaged. Thus, after completing 500 trials, every participant had 451 d' values and 451 amplitude values for each of the identified components. These time series of 451 values showed the dynamics of the indicators during the series.

**Figure 2**

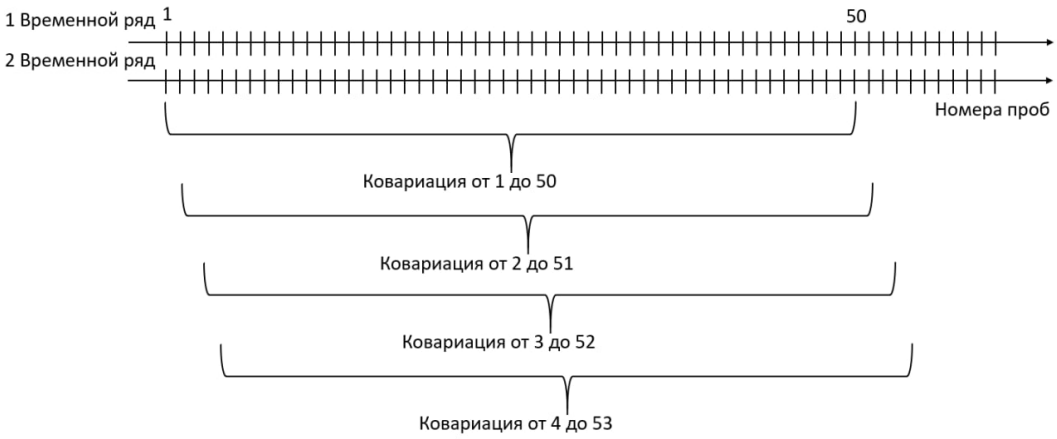
*Illustration of the sliding window principle with a window size of 50 samples and a step size of 1 trial*




The covariances between the two time series were calculated in a similar manner: The covariances were calculated over a window of 50 points obtained in the previous stage, also with a step size of 1 point (see Figure 3). Thus, two time series of 451 points yield a dynamic series of 402 covariances.

**Figure 3**

*Illustration of the sliding window principle with a window size of 50 samples and a step size of 1 trial*



For our analysis, we used the components described in the previous stage of the study (Yudakov et al., 2025). For the described epoch, the components presented in Table 1 were identified. Figure 4 shows an illustration of the model potential to describe the identified components. The moment of presentation of the assessed signal was considered as the zero point.

*Table 1*

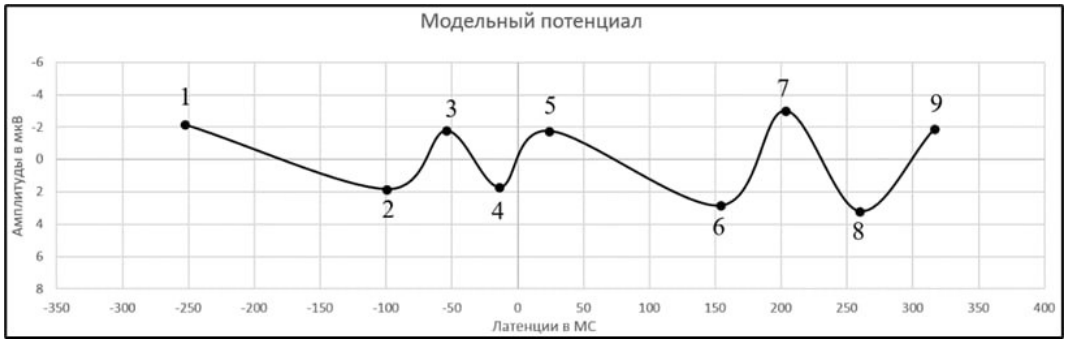
*Amplitude-temporal characteristics of the identified ERP components in the analyzed epoch*

| Component | Average latent period, ms | Average amplitude, μV | Peak-to-peak amplitude, μV |
|---|---|---|---|
| 1 | -258 | -2.13 | – |
| 2 | -99 | 1.83 | 3.96 |
| 3 | -55 | -1.65 | 3.48 |
| 4 | -15 | 1.78 | 3.43 |
| 5 | 22 | -2.03 | 3.81 |
| 6 | 154 | 2.73 | 4.76 |
| 7 | 203 | -3.06 | 5.79 |
| 8 | 259 | 3.21 | 6.27 |
| 9 | 313 | -1.87 | 5.08 |

***Note**: The peak-to-peak amplitude is presented in each row relative to the previous component. Therefore, calculating the peak-to-peak amplitude for 1 component is not possible.*

**Figure 4**

*Model potential of the identified ERP components in the analyzed epoch (Yudakov et al., 2025)*



### *Identified intervals of covariance estimation for the groups of study participants*

For every study participant, the relationship between the performance indicator d' and the amplitude of each identified component was estimated at each of the 451 points of the sliding window using the sliding covariance method. We divided the sequence of 451 averaging windows into the following epochs.

For the group of those who had acquired the skill:

- The epoch before crossing the non-random decision point d' = 0.546 ("before learning").
- The epoch corresponding to the performance increase during which the transition through the non-random decision point occurred – the interval between the local minimum preceding the increase and the local maximum after crossing the non-random decision point ("learning front").
- The epoch after crossing the non-random decision point ("after learning").

For the group of those who had improved the skill:

- The epoch before crossing the point reliably exceeding the initial performance ("before improvement").
- The epoch corresponding to the performance increase that crossed the point of reliable difference from the initial performance – the interval between the local minimum preceding the increase and the local maximum after crossing the point of non-random decision ("improvement front").
- The epoch after crossing the point of reliable difference from the initial performance ("after improvement").

For the groups of those who had not acquired and had not improved the skill, two epochs were identified to allow comparison with the groups in which the learning/improvement process was observed:

- The first half of the experiment.
- The second half of the experiment.

The values given in parentheses and quotation marks will be used hereinafter to denote the intervals described above.

### *Statistical methods for data processing*

In the first stage, we sought to reduce the dimensionality of the leads. We also analyzed the consistency of the results obtained between the leads. Our previous studies demonstrated that brain mechanisms subserving the task of discriminating short time intervals are similar in the frontocentral and parietooccipital leads (Gladilin et al., 2025). However, this result was obtained without taking into account the dynamics and assessments of the relationships. To assess the consistency of the leads based on the relationship between

performance and the amplitude characteristics of the analyzed components, we analyzed the standardized alpha coefficient.

To assess the dynamics of the relationship between performance and the amplitude characteristics of the ERP components, we conducted the following analysis, which included three stages:

(1) Evaluation of the difference between the average identified covariance and zero using a one-sample Student t-test (comparison of the average covariance value with a constant equal to zero). A covariance array was used for each of the selected intervals, and then a comparison was made to determine whether the distribution of covariances within each interval differed from zero. The analysis was conducted for every study participant separately.

(2) Comparison of covariances across intervals within the same group. For this, the covariances included in each array were used and compared with each other using the Student t-test. Thus, three pairwise comparisons were conducted for study participants from the groups of those who had acquired and had improved the skill (due to the selection of three intervals), and one pairwise comparison was conducted for the groups of those who had not acquired and had not improved the skill (comparison of the first and second halves of the experiment). The analysis was also conducted for every study participant separately.

(3) Comparison of the identified intervals between study participants from different groups. A matrix was formed that included the distributions of covariances across one of the intervals for all study participants from one group with all study participants in the other group. Similarly, pairwise comparisons were conducted between study participants from the selected groups.

The results obtained at the level of intra-individual comparisons were summarized in the context of their reproducibility and representativeness relative to the group as a whole, rather than to individual study participants. Due to the use of intra-individual comparisons, each result that characterizes groups and/or learning/improvement processes is associated with a distribution of importance levels, whose presentation would unnecessarily expand the scope of the article. Therefore, the results are presented in a generalized form.

Results were considered significant at a significance level of $p \leq 0.05$. We did not analyze the statistical trends.

## Results

Based on the criteria described above, four groups of study participants were identified: those who had not acquired the skill (3 individuals), those who had acquired the skill (15 individuals), those who had not improved the skill (6 individuals), and those who had improved the skill (2 individuals). Two study participants were not assigned to any group

because their performance indicators did not allow a final conclusion on their membership in one of the groups, i.e. they were in a "border position" and their assignment to a group could have been arbitrary. Participants whose EEG recordings contained artifacts were also excluded from the groups.

When comparing lead consistency, the similarity of mean covariance values was analyzed in the following three situations: identifying the fronto-central cluster, the parieto-occipital cluster, and combining all leads into a single cluster. Higher values of the standardized alpha coefficient indicate higher consistency among the leads included in a particular cluster. The analysis was conducted separately for each identified ERP component. Table 2 shows the results.

**Table 2**

*Lead consistency indices when combined into different clusters using the standardized alpha coefficient*

| Component | Fronto-central cluster | Parieto-occipital cluster | Combining all leads into one cluster |
|---|---|---|---|
| 1–2 | 0.91 | 0.94 | 0.96 |
| 2–3 | 0.90 | 0.88 | 0.94 |
| 3–4 | 0.90 | 0.88 | 0.94 |
| 4–5 | 0.89 | 0.81 | 0.92 |
| 5–6 | 0.88 | 0.77 | 0.92 |
| 6–7 | 0.83 | 0.92 | 0.94 |
| 7–8 | 0.90 | 0.92 | 0.95 |
| 8–9 | 0.89 | 0.92 | 0.95 |

***Note**: The maximum scores in the row are marked in bold.*

As can be seen from the table, the maximum consistency coefficients were obtained for all the extracted components when combining all leads into a single cluster. Therefore, the covariance indices across all leads were averaged and calculated as an integrated index. Unlike classical EEG averaging methods, such as General Potential, which average the EEG before preprocessing, our averaging was calculated from the covariance indices of the extracted peaks with the performance at each EEG lead. This avoids the typical shortcomings of traditional EEG averaging methods (e.g., the formation of "false" peaks that appear only when leads are combined, but do not appear at each lead individually).

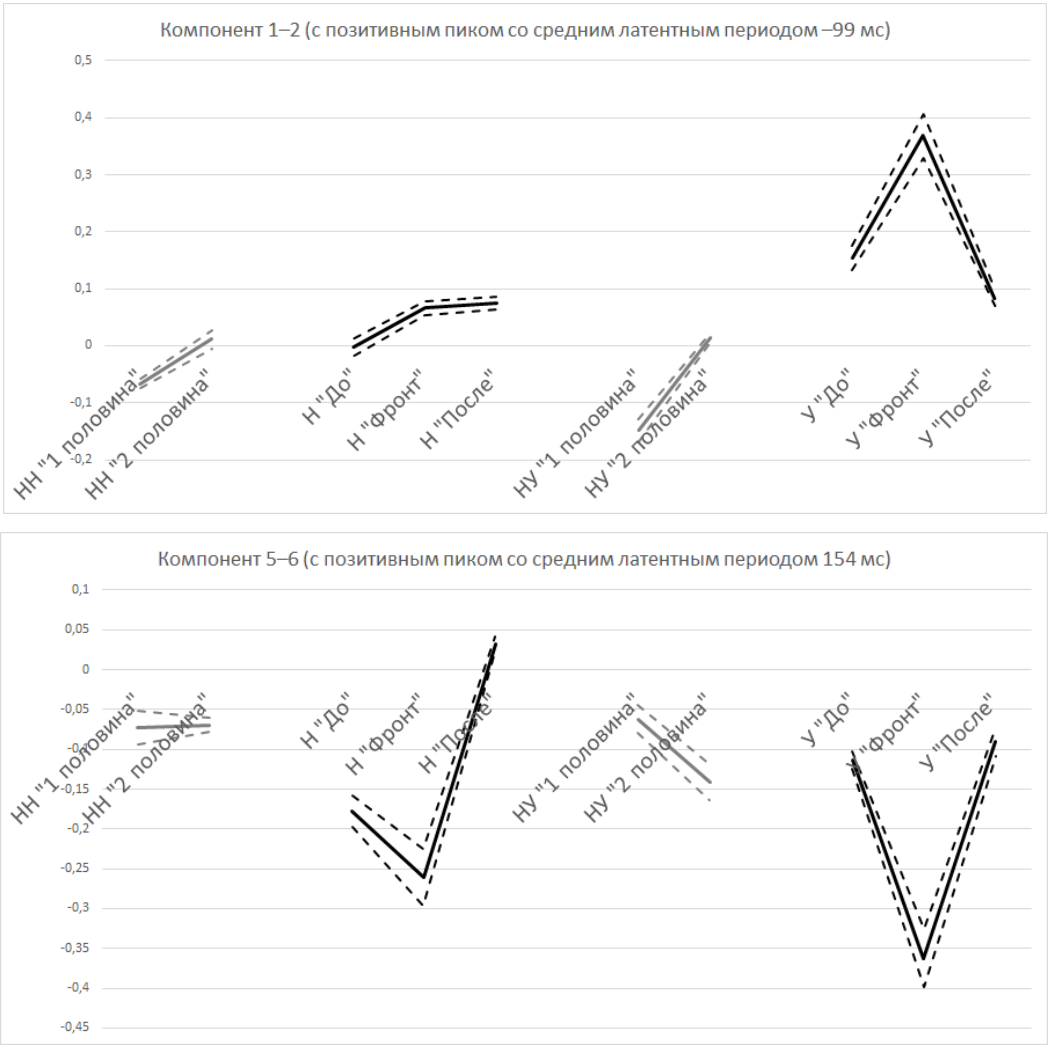
### *Analysis of the relationship between the ERP component amplitudes and performance for the identified components*

It was shown that the amplitudes of different components have different dynamics of their relationship with performance indicators in different groups of study participants. The fragmentation of a behavioral act at a point in time coinciding with the positive/negative component is a marker of the systemic organization of the substages of the behavioral act in a particular participant, in which learning occurs with a higher/lower probability. Analysis of the relationship between the amplitudes of the identified components and performance allows us to divide the identified components into three conditional groups: "+" components — reflecting the occurrence of systemic processes that contribute to the effectiveness of learning; "-" components — reflecting the occurrence of systemic processes that do not contribute to effective learning; "0" components — the severity of which is not associated with learning.

The "+" group of components includes positive components 1–2 (with an average latency of -99 ms) and 5–6 (with an average latency of 154 ms). For a graphical representation of the relationships among individual study participants, see Figure 5. Participants in groups of those who had acquired the skill were characterized by a transition from an absent (component 1–2) or inverse (component 5–6) relationship between amplitudes and performance during the learning process; in this case, maximum scores are observed either during the learning process or after passing the non-random decision point. Participants in groups of those who had not acquired and had not improved the skill were characterized by either an inverse or absent relationship throughout the experiment. In other words, as performance increases, the amplitudes of these components begin to decrease (a tendency toward component reduction is noted). With respect to component 1–2, we should also note that the group of those who had improved the skill had higher covariance values in all three epochs than all the epochs of all the other groups. For an illustration of the dynamics of amplitudes and performance in the group of those who had acquired the skill, see Figure 6, which shows the maximum synchrony in increasing performance and component amplitudes during the learning period.

**Figure 5**

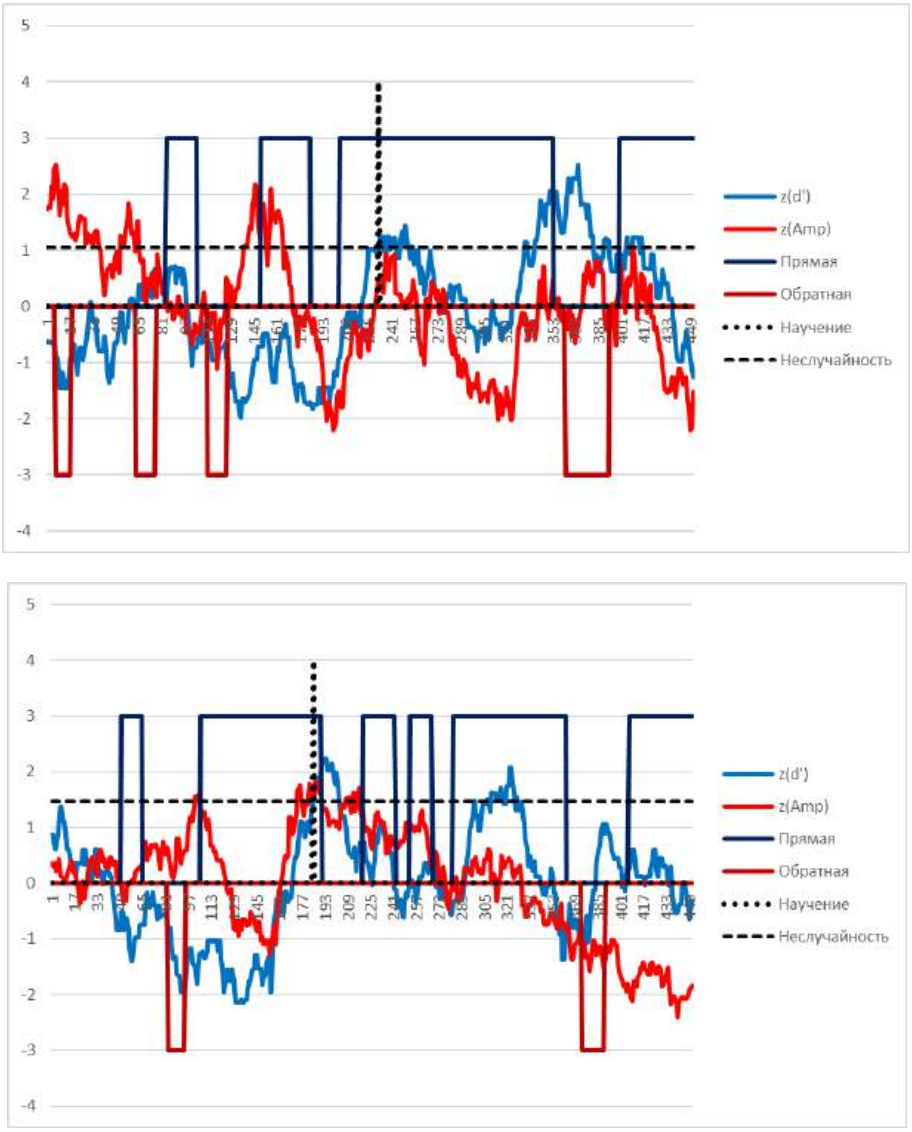
*Dynamics of covariances between the amplitudes of the "+" group components and performance*




***Note**: Data for individual study participants from 4 groups are shown (NA – those who had* **not** *acquired the skill; A – those who had acquired the skill; NI – those who had* **not** *improved the skill; I – those who had improved the skill). The solid line represents the mean covariance value within an epoch, and the dotted line represents the standard error of the mean. Values on the ordinate are given in μV.*

**Figure 6**

*Dynamics of the relationship between the amplitudes of components 1–2 and 5–6 and performance*



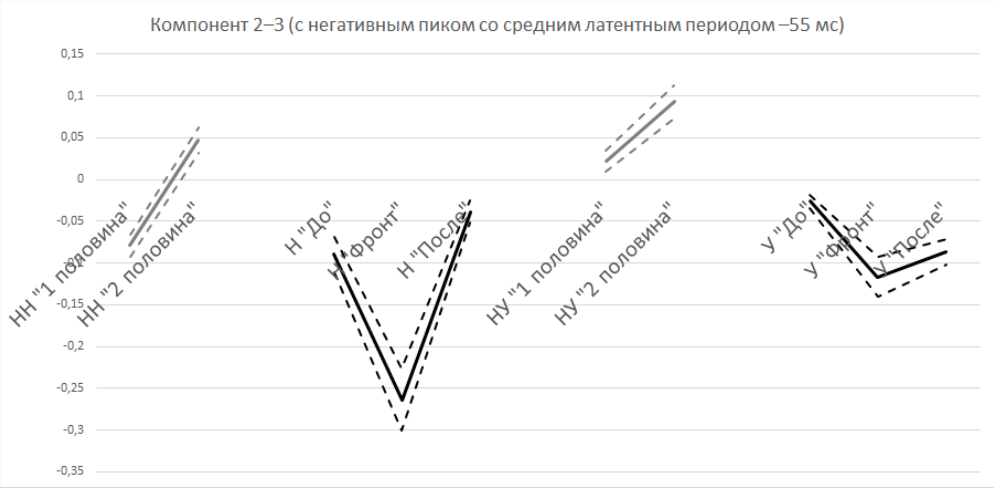

***Note:*** *Performance dynamics are shown in blue, and amplitude dynamics are shown in red. Values are converted to z-coordinates to enable direct comparison. The vertical line indicates the moment the non-random decision point is crossed. Rectangular distributions indicate reliable direct (blue) or inverse (red) relationships. Data for individual study participants from the group of those who had acquired the skill are shown.*

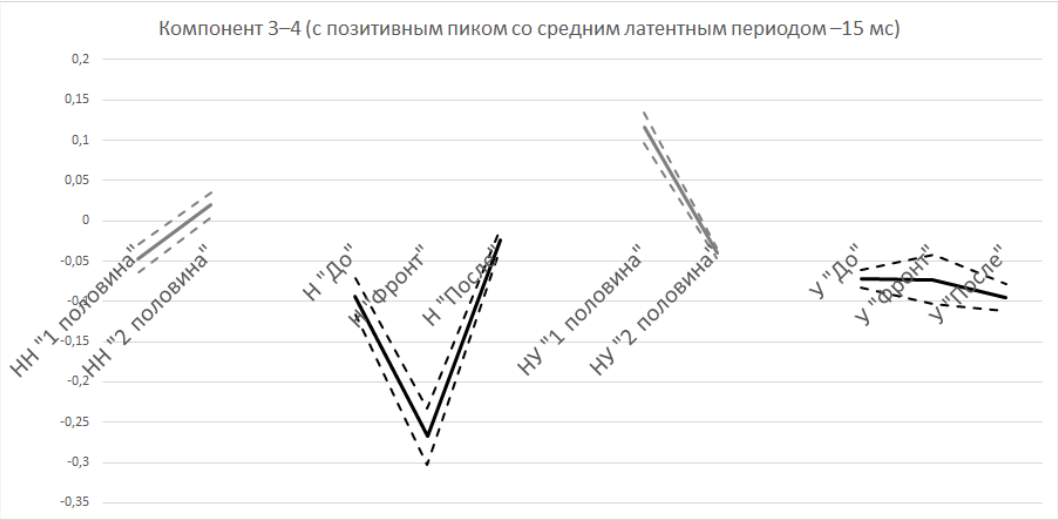
The "-" group components include lower-amplitude components: 2-3 (negative, with an average latency of -55 ms), 3-4 (positive, with an average latency of -15 ms);

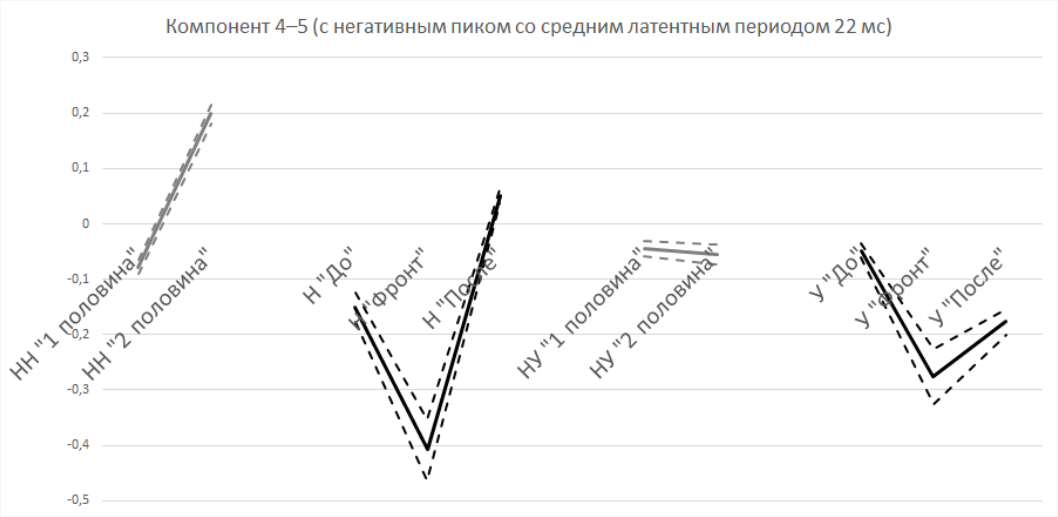
4-5 (negative, with an average latency of 22 ms). A graphical representation of the relationships for individual study participants is shown in Figure 7. It was shown that the group of those who had acquired the skill is characterized by an inverse relationship, which tends to be absent during the After Learning epoch. The strongest inverse relationship is observed in this group during the Learning Front epoch, i.e., during the active phase of increasing performance, these components are reduced. The groups of those who had not acquired the skill are characterized by a direct relationship in the second half of the experiment (negative components 2-3 and 4-5), while those who had not improved the skill are characterized by a direct relationship in the first half of the experiment (positive component 3-4) and generally higher covariances across all epochs compared to the group of those who had acquired the skill. Regarding component 4-5, we should also note that when comparing groups, there is a tendency for covariances to be higher in the groups of those who had not acquired and had not improved the skill compared to the group of those who acquired the skill. Thus, it can be concluded that the increase in amplitudes due to localized performance increases leads to the fact that, at the end of the experiment, the participants in these groups do not demonstrate reliable dynamics (learning/improvement).

**Figure 7**

*Dynamics of covariances between the amplitudes of the "-" group components and performance*






***Note**: Data for individual study participants from 4 groups are shown (NA – those who had* **not** *acquired the skill; A – those who had acquired the skill; NI – those who had* **not** *improved the skill; I – those who had improved the skill). The solid line represents the mean covariance value within an epoch, and the dotted line represents the standard error of the mean. Values on the ordinate are given in μV.*

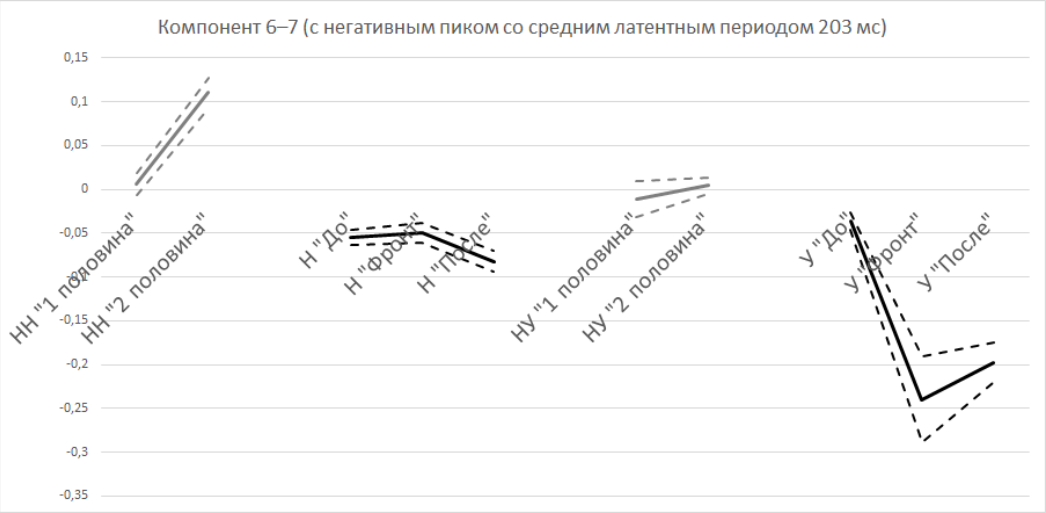
Group "0" includes the following components: 6-7 (negative, with a mean latency of 203 ms), 7-8 (positive, with a mean latency of 259 ms), and the later negative component 8-9 (with a mean latency of 313 ms). A graphical representation of the relationships for

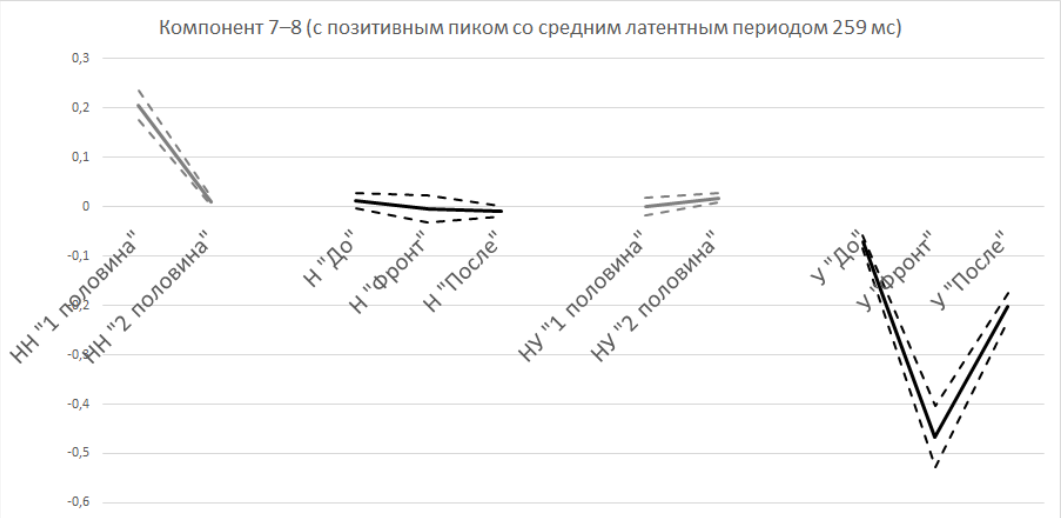
individual study participants is shown in Figure 8. Components 6-7 and 7-8 are the most stable and have the highest amplitudes, as shown in Figure 9.

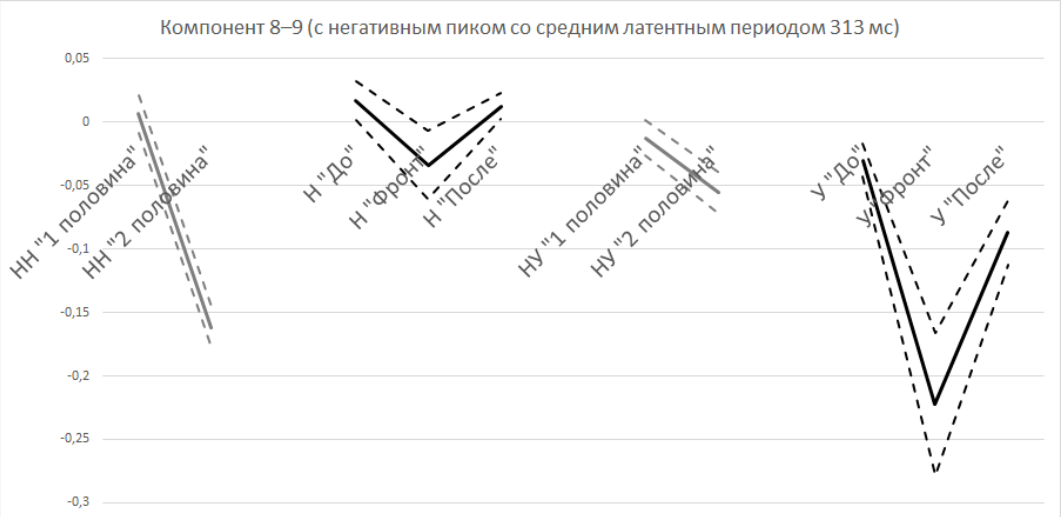
It was shown that the group of those who had not acquired the skill was characterized by a direct relationship between the amplitude of component 6-7 and performance in the second half of the experiment, and a similar direct relationship between the amplitude of component 7-8 and performance in the first half of the experiment. The group of those who had not acquired the skill exhibited the most pronounced covariances, while the group of those who improved the skill exhibited minimal covariances. The group of those who had acquired the skill exhibited no relationship between the amplitudes of these components and performance, suggesting that these components are expressed regardless of performance, and the presence of relationships is a marker of a systemic organization that is not conducive to learning.

**Figure 8**

*Dynamics of covariances between the amplitudes of the "0" group components and performance*



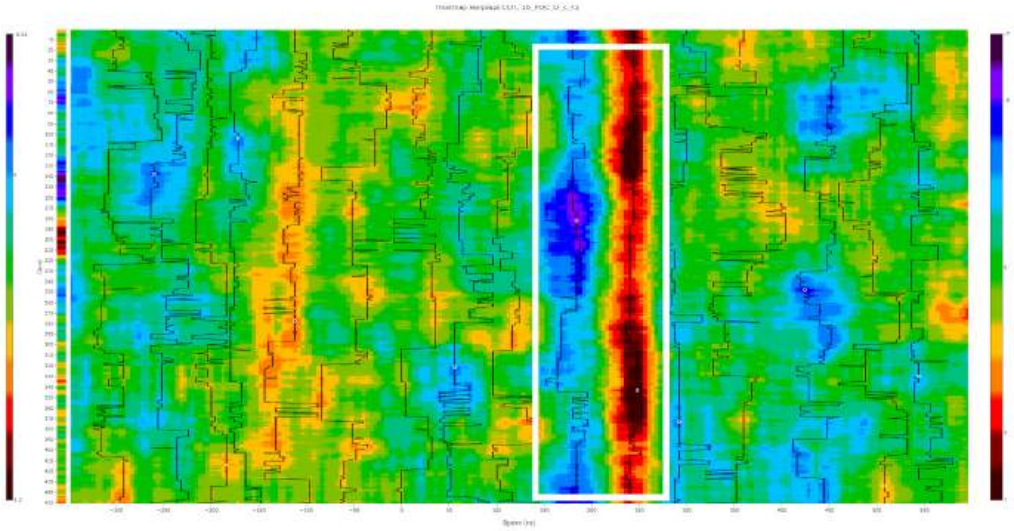



***Note**: Data for individual study participants from 4 groups are shown (NA – those who had* **not** *acquired the skill; A – those who had acquired the skill; NI – those who had* **not** *improved the skill; I – those who had improved the skill). The solid line represents the mean covariance value within an epoch, and the dotted line represents the standard error of the mean. Values on the ordinate are given in μV.*

**Figure 9**

*Heat map illustrating the severity of components 6–7 and 7–8 (indicated in a white frame)*



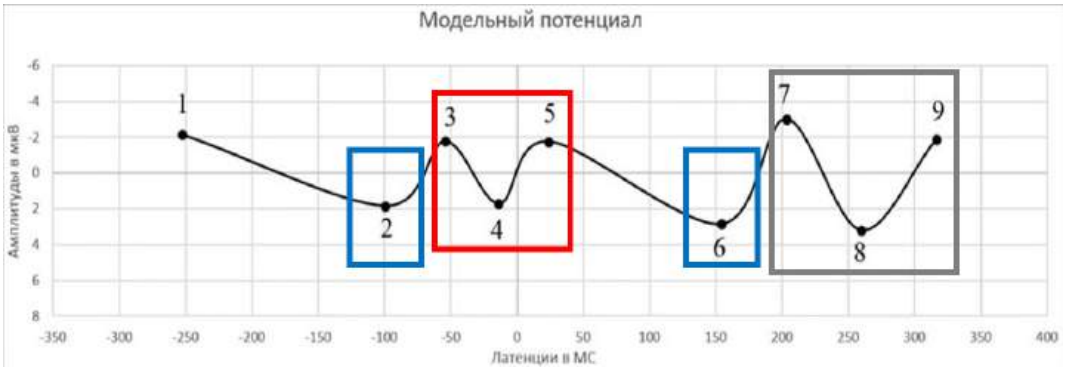
***Note**: The abscissa represents time (0 is the start time of presentation of the assessed signal) and the ordinate, from top to bottom, represents the averaging window number from 1 to 451. Negative oscillations are marked in blue, and positive oscillations are marked in red. High color intensity indicates high component amplitude.*

Negative component 8–9 in the group of those who had acquired the skill is also characterized by a lack of correlation between its amplitude and performance; however, in the groups of those who had not acquired and had not improved the skill, a phenomenon mirroring that of the previous two components is observed. In the second half of the experiment, the relationships become inverse. That is, with localized performance increases, this component begins to decline. In the group of those who had acquired the skill, the severity of this component is independent of performance and remains evident throughout the experiment. When comparing the groups, the following can be observed: In the First Half epoch the group of those who had not acquired the skill has higher covariances compared to the group of those who had acquired the skill. However, in the Second Half epoch the group of those who had not acquired the skill has less pronounced covariances compared to the group of those who had acquired the skill. Therefore, we can observe an inverse relationship in the covariance values between the groups of those who had not acquired and those who acquired the skill. A similar phenomenon is observed when comparing the groups of those who had not acquired and had not improved the skill with those who had improved the skill. The group of those who had improved the skill exhibits higher covariances than the aforementioned groups in the Post Improvement epoch.

It was thus demonstrated that the characteristics of the components identified at different intervals of time are associated with the learning process differently. Figure 10 shows a summary of the results.

**Figure 10**

*Model potential with component labels*




***Note:*** *Components in the "+" group are highlighted in blue, components in the "-" group are highlighted in red, and components in the "0" group are highlighted in gray.*

## Discussion

It was shown that the relationships between performance and the amplitude characteristics of the identified components varied across the different components. Given that ERP components can reflect the degree of actualization of experience systems (the number of simultaneously actualized experience systems) associated with different behaviors (Gavrilov, 1987), the differences can be interpreted as follows: The behaviors performed in response to interactions with the task differed among study participants from different groups. Since the components are characterized by different relationships between their amplitude and performance, we can conclude that the actualization of experience systems at different points in time can either "facilitate" the learning/improvement process or, conversely, "hinder" it.

Component 1-2 (with a positive peak with an average latency of -99 ms) was shown to belong to the "+" component group (reflecting the occurrence of systemic processes that facilitate learning effectiveness). According to the literature, a negative CNV wave might be expected to appear before the onset of the assessed signal, which is also correlated with time estimation (Macar & Vidal, 2004; Kononowicz & Van Rijn, 2011). However, in our study, a positive peak was observed. From the perspective of the systemic-evolutionary approach, this component can be interpreted as the actualization of experience systems that enable the behavior of observing the onset of the presented signal. This suggests

that the actualization of experience systems before the onset of the assessed signal is a more productive way of implementing the behavioral act and that the individual is more likely to undergo learning/improvement processes.

In those who had not acquired and had not improved the skill this component is reduced as performance increased. However, the following three low-amplitude components with average latencies of -55 ms, -15 ms, and 22 ms were more pronounced. These trends apparently indicate that the activation of experience systems and the implementation of corresponding behavior during the initial presentation of the assessed signal hinders performance improvement.

Component 5-6 (with a positive peak and an average latency of 154 ms) is characterized by the fact that, when analyzed, the establishment of a direct relationship can be detected after the non-random decision point has been passed. We can assume that, after the acquisition of a new skill, systems are formed that are activated at this point in time during the presentation of the assessed signal. Comparing this component with those described in the literature, based on its latency, it can be considered either a late P100 (Odom et al., 2004) or an early P300 (Polich, 2007). Assuming that the study participant needed to track the onset of signal presentation to assess its duration, the data can be interpreted, in terms of the existing literature, both as activity reorganizations associated with changes in the physical parameters of the environment (Odom et al., 2004) and as a "cognitive" process of initiating the assessment of signal duration (Polich, 2007).

If this component is considered an early positive component associated with changes in the physical parameters of the environment (Odom et al., 2004), it can be argued that a larger number of systems associated with changes in the physical parameters of the environment can be a predictor of learning.

The next two components — negative (with an average latency of 203 ms) and positive (with an average latency of 259 ms) — were the most pronounced. However, no correlations were found in the group of those who had acquired the skill. The direct relationships that are established in the groups of those who had not acquired and had not improved the skill apparently indicate that the presence of variability in this component does not contribute to effective learning, in contrast to its stable manifestation in the group of those who had acquired the skill.

Interpreting these components, we can say that a change in the stage (substage) of the behavioral act is currently occurring (Maksimova, Aleksandrov, 1987). Several hypotheses can be put forward that reveal the substantive aspect of this change in the systems of the behavioral act: This change in the complex of systems may be associated with the maximum duration of one stage (substage) of the behavioral act (Bezdeneshnykh, 1988), or it may mark a subjective “midpoint” in the duration of signal presentation, which allows for a more accurate assessment of the overall signal duration (Yudakov et al., 2023).

Component 8–9 (with a negative peak with an average latency of 313 ms) indicates that, by the second half of the experiment, higher covariance values are observed in the

groups of those who had acquired and had improved the skill compared to the groups of those who had not acquired and had not improved the skill. Interpreting the negative wave as an expectation of a change in the relationship with the environment (Kononowicz & Van Rijn, 2011), we can it can assert that in the groups of those who had acquired and had improved the skill, improved performance is associated with a more pronounced expectation of the end of the signal and a more precise assessment of the time interval.

The literature presents conflicting data regarding how the amplitudes of the identified components change during learning. Some studies claim an increase in the components — primarily the negative wave (Poon, 1974; Stuss & Picton, 1978), a decrease in the amplitudes of various components (Peters et al., 1977), a sequential increase in P300 amplitude followed by a decrease (McAdam, 1966; Macar & Vitton, 2004), and a sequential decrease in amplitude followed by an increase (Kecei et al., 2006). We have shown that during the learning process, amplitudes change in accordance with the identification of stages (substages) of the behavioral act. Based on this, we can assume that the different results obtained regarding the relationships between the amplitudes of ERP components and performance are explained by the fact that the authors in the aforementioned studies do not distinguish between the processes of learning and skill improvement. They also fail to take into account the complexity and specificity of the tasks.

## Conclusion

Summarizing the analysis of the described components, we can conclude that the identified components, their latent periods and amplitudes depend significantly on the specificity of the proposed task. Based on an analysis of the literature and a comparison of its results with our data, we can conclude that universal patterns of increase/decrease in amplitude are absent and can only be observed when using standardized methods (e.g., a simple choice task). Amplitudes increase or decrease during the learning process depending on the stage (substage) of the behavioral act associated with the functional systems being activated at a given moment in time, manifesting as negative or positive EEG oscillations.

We have shown that positive components with average latencies of -99 ms and 154 ms belong to the "+" component group, reflecting the systemic processes that facilitate learning effectiveness. Negative and positive oscillations with average latencies of -55 ms, -15 ms, and 22 ms belong to the "-" component group, reflecting the systemic processes that do not facilitate learning effectiveness. Oscillations with latent periods of 203 ms, 259 ms, and 313 ms belong to the "0" component group, the intensity of which is not related to learning, which can be interpreted as the necessity of their manifestation regardless of the performance dynamics.

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## Author Contribution

**Erik Aramovich Aramyan** carried out experiments, performed data preprocessing and processing.

**Dmitrii Leonidovich Gladilin** carried out experiments and performed data preprocessing.

**Konstantin Sergeevich Yudakov** carried out experiments and performed data preprocessing.

**Vladimir Viktorovich Gavrilov** analyzed data and interpreted the results.

**Viktor Vladimirovich Znakov** interpreted the results.

**Vladimir Viktorovich Apanovich** developed the research program and contributed to the study design.

**Yurii Iosifovich Alexandrov** worked with sources and critically revised the content of the manuscript.

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## Conflict of Interest Information

The authors have no conflicts of interest to declare.

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# Neurobiological Bases of Digital Behavior: Associations of DRD2, COMT, and BDNF Polymorphisms with Constructive and Destructive Internet Use Strategies among Young People

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## Abstract

**Introduction.** In the context of the rapid development of digital technologies, the study of both psychological aspects of constructive and destructive forms of digital behavior and their neurobiological underpinnings has become increasingly relevant. These underpinnings include genetic factors that determine individual differences in motivation for Internet use. Objective. To analyze the frequency of allelic variants of genes of the dopaminergic system (DRD2, COMT) and the neurotrophic factor gene (BDNF) in young people with different digital behavior strategies. **Methods.** The study involved 193 respondents aged 18–25 years (M = 19.37; SD = 2.1; 85% female), students enrolled in humanities programs. Digital behavior was assessed using the Digital Behavior Strategies questionnaire (Abakumova et al., 2021). Genotyping was performed using allele-specific real-time PCR for the BDNF (rs6265), COMT (rs4680), and DRD2 (rs1800497) genes. Statistical analysis included k-means cluster analysis, the Kruskal–Wallis nonparametric test and Dunn's post hoc pairwise comparisons. **Results.** Carriers of different genotypes demonstrated significant differences in the expression of specific motives for Internet use. The BDNF Val/Val genotype was associated with higher

scores on information-seeking motives; the COMT Val/Val genotype was linked to increased expression of radical ideas; and carriers of the DRD2 CT variant showed higher levels of self-presentation and community participation. Cluster analysis identified three behavioral profiles—passive users, constructively engaged users, and destructively engaged users—which differed in the frequency of allelic variants of the studied genes. **Discussion.** The findings confirm the presence of associations between polymorphisms of dopaminergic system genes and BDNF and different strategies of digital behavior among young people, indicating the important role of genetic factors in the formation of constructive and destructive patterns of Internet use.

## Keywords

digital behavior, internet addiction, psychological predictors, genetic predictors, gene polymorphisms, COMT, DRD2, BDNF

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# Introduction

In the context of the rapid development of digital technologies leading to increased Internet use, a number of advantages (such as access to information and communication opportunities) coexist with several negative consequences, including the risk of developing Internet addiction. Research indicates that the number of digital devices used and the frequency of Internet use are associated with the level of digital health literacy, which may play a key role in the effective and safe use of online resources (Zhao et al., 2024). At the same time, the risk of developing destructive forms of digital behavior may be linked not only to psychosocial factors (Gaidamashko, Lenkov, & Rubtsova, 2024), but also to biological determinants, including brain functioning characteristics and genetic predisposition (Long et al., 2016).

Internet addiction represents a global problem and is structurally similar to both substance-related and non-substance-related addictions (Kolesnikov, Melnik, & Teplova, 2019). Problematic Internet use in adolescents may be characterized by loss of control, compulsive behavior, irritability, and depressive symptoms (Singh, Kumar, & Reddy, 2025; Sun, Wang, & Liu, 2025). Among the significant risk factors for Internet gaming disorder, low self-regulation and anxiety have been identified (Rho et al., 2018), while depression is considered a key mediator in the development of addictive gaming behavior (Kircaburun et al., 2019; Cimino & Cerniglia, 2025).

Molecular genetic studies indicate that the development of Internet addiction involves a genetic component. In particular, most authors focus on genes involved in the regulation of neurotransmitter and neuropeptide systems (Sindermann et al., 2021; Annunzi et al., 2023). Recent review studies suggest that the risk of addictive behaviors is most likely associated with polymorphisms in the DRD2/ANKK1 (rs1800497, Taq1A), COMT (rs4680, Val158Met), DAT1 (rs28364027), 5-HTT (SLC6A4, rs25531), CHRNA4 (rs1044396), OPRM1 (rs1799971), BDNF (rs6265), HTR2A (rs6313), GRIN2B (rs2268498), and other genes (Tereshchenko & Smolnikova, 2020; Tereshchenko, 2023). For example, individuals demonstrating problematic or risky online behavior show a higher frequency of the minor A1 (T) allele in the polymorphic locus (C2137T) of the ANKK1 gene, which is associated with reduced expression of dopamine D2 receptors and altered levels of behavior-regulating hormones (Ryt et al., 2024). In addition, the Val66Met polymorphism (rs6265) of the BDNF gene is known to be associated with reduced brain-derived neurotrophic factor activity, leading to impaired synaptic plasticity in the prefrontal cortex and hippocampus, which may increase vulnerability to compulsive behaviors and addictions through dysfunctions in cognitive control (Demirci et al., 2023). Another polymorphic locus, rs6313 in the HTR2A gene encoding the serotonin 2A receptor, has been associated with increased impulsivity and emotional lability, which, in turn, correlates with Internet addiction and maladaptive social media use (Dai et al., 2024).

Furthermore, evidence suggests that epigenetic mechanisms—particularly differential DNA methylation in genes regulating neurotransmitter systems—may modulate behavioral phenotypes associated with excessive use of digital technologies. Annunzi et al. (2023) demonstrated that individuals with subclinical manifestations of Internet addiction (Internet Addiction Test scores of 30–49) exhibit significant alterations in methylation levels in the promoter regions of the OXTR gene, encoding the oxytocin receptor, as well as in dopamine and serotonin transporter genes (SLC6A4 and SLC6A3).

Thus, despite the evident benefits of contemporary digital technologies, their development is accompanied by substantial risks, among which Internet addiction and destructive Internet use strategies occupy a prominent place. This phenomenon has a complex etiology involving both psychosocial and biological factors. However, despite the growing body of research on the genetic foundations of Internet addiction, data for Russian populations on how polymorphisms in genes of neurotransmitter and neuropeptide systems (including DRD2, BDNF, COMT, among others) are associated with

Internet use strategies remain scarce. In this context, the aim of the present study is to conduct a comparative analysis of the frequencies of allelic variants of genes involved in the regulation of the dopaminergic system and neurotrophic factors in individuals exhibiting different digital behavior strategies within a Russian sample.

## Methods

The sample consisted of 193 participants aged 18–25 years (mean age = 19.37; 85% female), all students enrolled in humanities-related academic programs. To assess features of digital behavior, the Digital Behavior Strategies questionnaire was employed (Abakumova et al., 2021).

To examine genetic predictors, a molecular genetic analysis was conducted. The following candidate genes were selected for analysis: the dopamine receptor gene DRD2 (rs1800497), the catechol-O-methyltransferase gene COMT (rs4680), and the brain-derived neurotrophic factor gene BDNF (rs6265).

Participants were surveyed in person using an electronic testing format. Collection of genetic material (buccal epithelial cells) for genomic DNA extraction was performed immediately after completion of the psychological assessment, predominantly during the first half of the day. DNA analysis was carried out using allele-specific polymerase chain reaction (PCR) with real-time detection.

Statistical analyses included the Shapiro–Wilk test to assess the normality of empirical distributions. Cluster analysis (k-means method) was used to divide the sample into groups according to digital behavior characteristics. Differences between the identified subgroups were examined using the nonparametric Kruskal–Wallis test, followed by Dunn's pairwise post hoc comparisons.

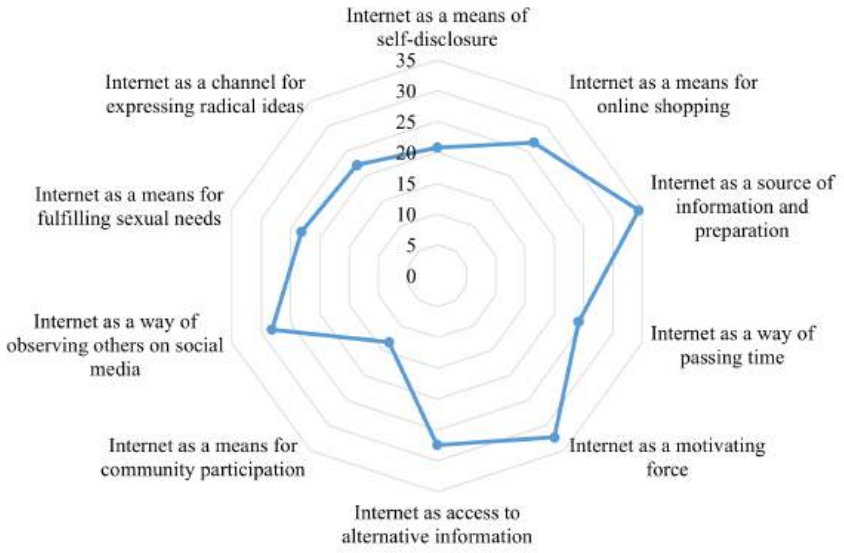
All statistical analyses were performed using the JASP software package (version 0.16)

## Results

The analysis of digital behavior revealed that the most strongly expressed motives for Internet use were Internet as an informational resource (mean score = 34.34 out of a possible 50) and Internet as a motivating force (mean score = 32.35) (Figure 1). The lowest scores were observed on the Internet for community participation scale (mean = 13.31).

**Figure1**

*Results of the assessment of digital behavior characteristics in the sample (mean values)*




A quantitative analysis of the questionnaire results for all digital behavior scales was conducted for each participant to identify the predominant motives for Internet use, determined by the highest score (Table 1). The number and percentage of individuals exhibiting predominant constructive strategies (according to the questionnaire key, corresponding to the first five scales) and destructive strategies (scales 6–10) were calculated. Additionally, comparisons were made based on participants' total scores for constructive versus destructive strategies. Overall, the analysis confirmed that constructive digital behavior strategies were predominant in the sample. The most frequently identified leading motives were Internet as a source of information and preparation and Internet as a motivating force.

**Table1**

*Results of the analysis of predominant motives and strategies of Internet use*

| Motives and Strategies of Internet Use | Number of Participants | % of the Sample |
|---|---|---|
| Internet as a means of self-disclosure | 7 | 3,63 |
| Internet as a means for online shopping | 8 | 4,15 |

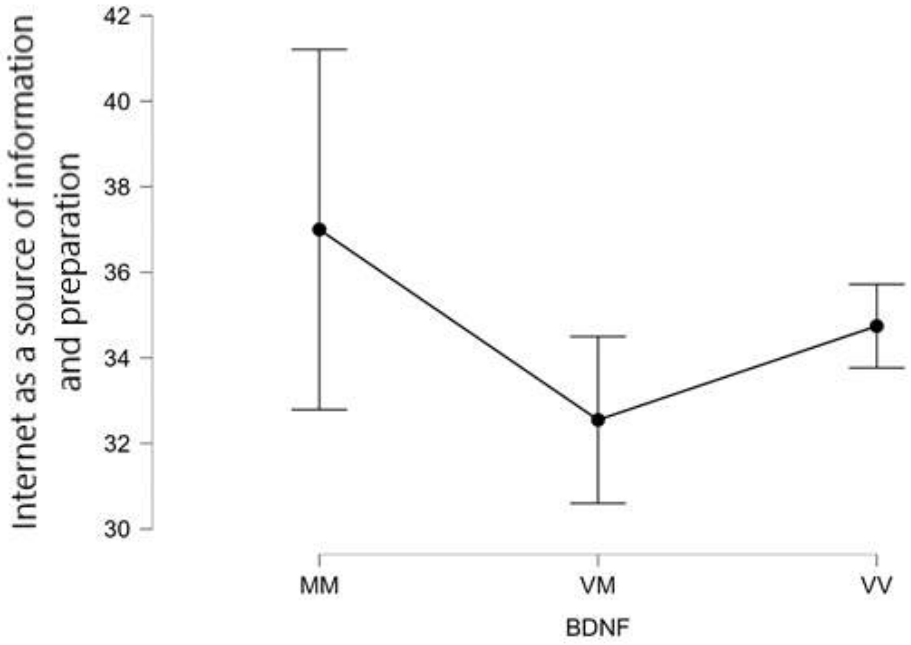
| Motives and Strategies of Internet Use | Number of Participants | % of the Sample |
|---|---|---|
| Internet as a source of information and preparation | 56 | 29,02 |
| Internet as a way of passing time | 4 | 2,07 |
| Internet as a motivating force | 36 | 18,65 |
| Internet as access to alternative information | 13 | 6,74 |
| Internet as a means for community participation | 0 | 0,00 |
| Internet as a way of observing others on social media | 22 | 11,40 |
| Internet as a means for fulfilling sexual needs | 4 | 2,07 |
| Internet as a channel for expressing radical ideas | 1 | 0,52 |
| Mixed motives | 42 | 21,76 |
| Total with predominant constructive strategy | 147 | 76,17 |
| Total with predominant destructive strategy | 46 | 23,83 |
| Constructive strategies predominate (by total score) | 166 | 86,01 |
| Destructive strategies predominate (by total score) | 27 | 13,99 |

To test the hypothesis that carriers of different genotypes in the studied genes may exhibit differences in the expression of digital behavior strategies, a comparative analysis was conducted. The significance of differences was assessed using the Kruskal–Wallis test, with Dunn's post hoc pairwise comparisons applied for post hoc analysis (Appendix 1).

Regarding genotypes of the brain-derived neurotrophic factor gene BDNF (rs6265), it was found that carriers of the Val/Val (VV) allele variant had significantly higher scores on the scale measuring Internet use for information seeking, including academic purposes, compared to Val/Met (VM) carriers (Dunn post hoc test, VV vs. VM, p = 0.034; Figure 2). Met/Met (MM) carriers showed the highest mean scores compared to the other groups, but also exhibited a substantial variability in this scale (as well as across most other scales) within the subgroup.

**Figure2**

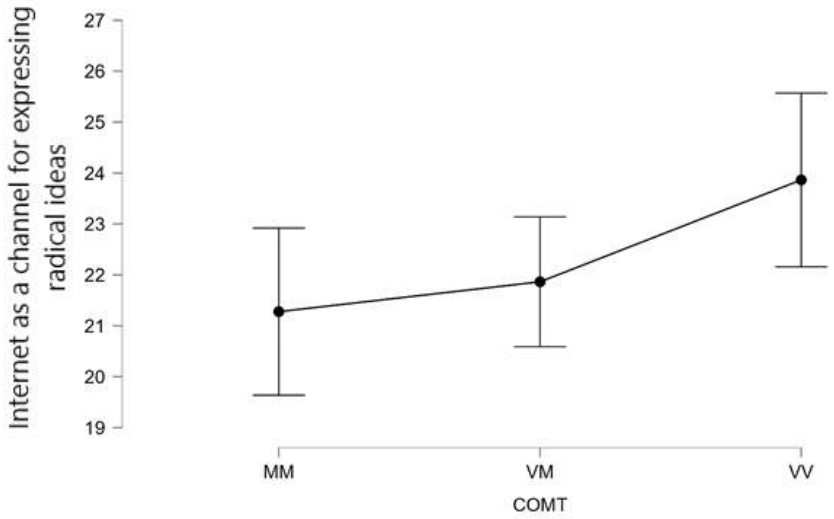
*Differences in the expression of specific Internet use motives among carriers of different BDNF (rs6265) genotypes*




Regarding the catechol-O-methyltransferase gene COMT (rs4680), carriers of the Val/Val (VV) allele exhibited significantly higher scores on the scale measuring Internet use for expressing radical ideas compared to carriers of other genotypes (Dunn post hoc test, VV vs. VM, p = 0.046; VV vs. MM, p = 0.046; Figure 3).

**Figure 3**

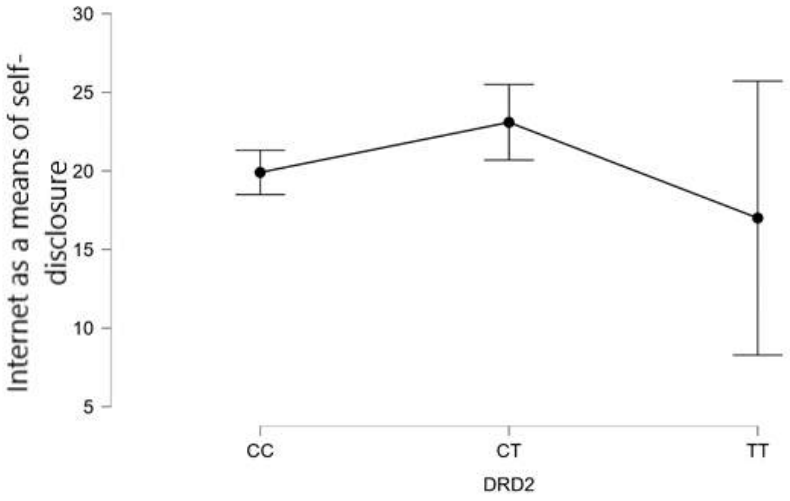
*Differences in the expression of specific Internet use motives among carriers of different COMT (rs4680) genotypes*

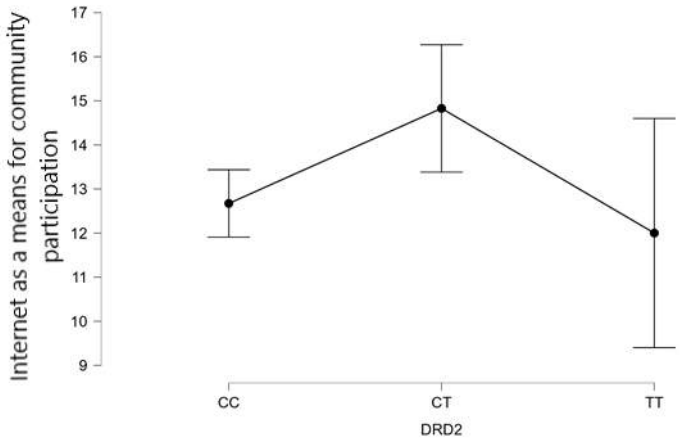



For the dopamine receptor gene DRD2 (rs1800497), it was shown that carriers of the CT allele variant scored significantly higher than CC carriers on the scales measuring Internet use for self-disclosure (Dunn post hoc test, CC vs. CT, p = 0.018) and community participation (Dunn post hoc test, CC vs. CT, p = 0.001; Figure 4). TT carriers had the lowest mean scores compared to the other groups, but also exhibited substantial variability on these scales (as well as most other scales) within the subgroup.

**Figure 4**

*Differences in the expression of specific Internet use motives among carriers of different DRD2 (rs1800497) genotypes*

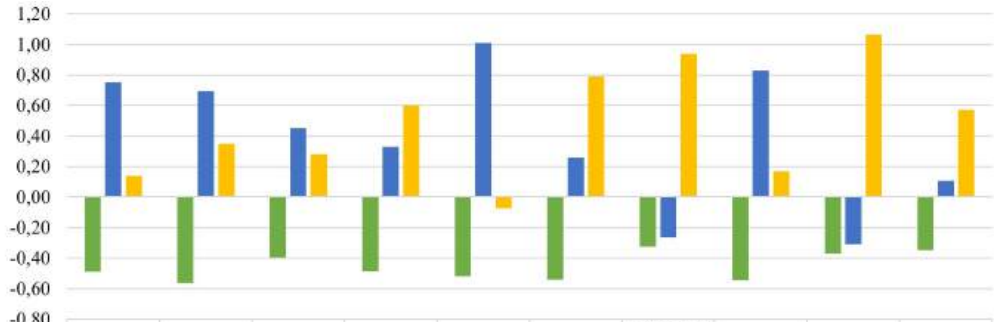





The mean total scores for constructive and destructive strategies did not significantly differ among carriers of the studied genotypes. However, analysis of the structure of Internet use motives, both in the current sample and in our previous studies (Abakumova et al., 2021; Ermakov et al., 2022), revealed substantial within-group variability, indicating heterogeneity in behavioral profiles. To identify latent patterns beyond the initially proposed dichotomy of constructive and destructive strategies, cluster analysis (k-means) was applied. Based on sample size, preliminary calculations, and inter-cluster differences, three clusters were identified (Figure 5, Table 2).

**Рисунок 5**

*Results of cluster analysis of the sample based on digital behavior strategy scores (z-scores)*




| | Internet as a means of self-disclosure | Internet as a means for online shopping | Internet as a source of information and preparation | Internet as a way of passing time | Internet as a motivating force | Internet as access to alternative information | Internet as a means for community participation | Internet as a way of observing others on social media | Internet as a means for fulfilling sexual needs | Internet as a channel for expressing radical ideas |
|---|---|---|---|---|---|---|---|---|---|---|
| Cluster 1 | -0,49 | -0,56 | -0,39 | -0,49 | -0,52 | -0,54 | -0,33 | -0,54 | -0,37 | -0,35 |
| Cluster 2 | 0,75 | 0,70 | 0,45 | 0,33 | 1,01 | 0,26 | -0,26 | 0,83 | -0,31 | 0,11 |
| Cluster 3 | 0,14 | 0,35 | 0,28 | 0,60 | -0,08 | 0,79 | 0,94 | 0,17 | 1,07 | 0,57 |

To assess differences in Internet use strategies between the identified clusters, a one-way analysis of variance (ANOVA) was conducted. The results revealed statistically significant intergroup differences across all examined measures ($p < 0.001$). The largest effect size was observed for the motive Internet as a motivating force (examples of others) ($F = 132.26$), while the smallest was for Internet for expressing radical ideas ($F = 31.87$).

**Table 2**

*Results of the ANOVA assessing the significance of differences between identified clusters*

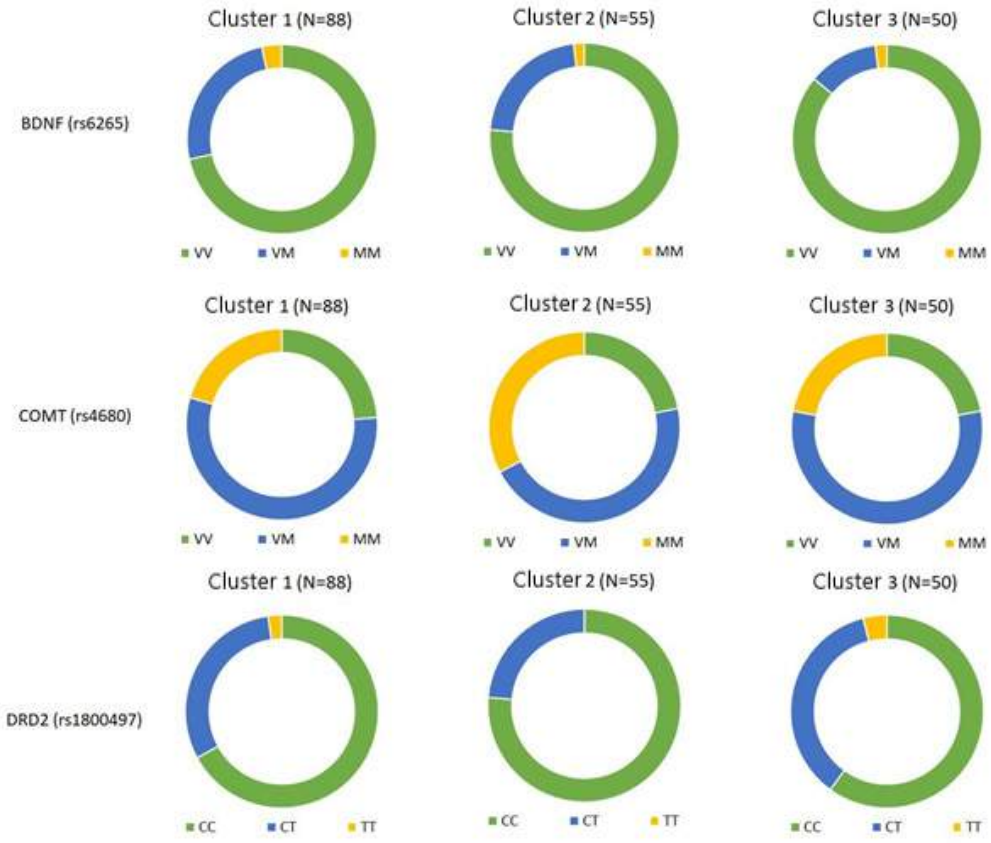
| | Between-group variance | Within-group variance | F-value (Fisher's F) | Significance level (p-value) |
|---|---|---|---|---|
| Internet as a means of self-disclosure | 105,42 | 280,58 | 72,14 | < 0,001 |
| Internet as a means for online shopping | 121,12 | 264,88 | 87,79 | < 0,001 |
| Internet as a source of information and preparation | 58,01 | 327,99 | 33,96 | < 0,001 |
| Internet as a way of passing time | 89,81 | 296,19 | 58,22 | < 0,001 |
| Internet as a motivating force | 157,44 | 228,56 | 132,26 | < 0,001 |
| Internet as access to alternative information | 121,61 | 264,39 | 88,32 | < 0,001 |
| Internet as a means for community participation | 110,90 | 275,10 | 77,40 | < 0,001 |
| Internet as a way of observing others on social media | 129,63 | 256,37 | 97,08 | < 0,001 |
| Internet as a means for fulfilling sexual needs | 143,37 | 242,63 | 113,45 | < 0,001 |
| Internet as a channel for expressing radical ideas | 54,96 | 331,04 | 31,87 | < 0,001 |

Participants in the first cluster exhibited the lowest mean scores across all scales and can be characterized as the least engaged or relatively passive users. The second cluster was characterized by the predominance of constructive and social motives (self-presentation and observing others) and can be described as users oriented toward building online identity and gaining social approval. The third cluster primarily included participants with predominant destructive motives, although these were combined with certain constructive (pragmatic) motives.

Subsequently, to analyze the frequencies of allelic variants in genes associated with regulation of the dopaminergic system and neurotrophic factors among individuals with different digital behavior strategies, absolute numbers and percentages of carriers for each allelic variant were calculated within each cluster (Figure 6, Appendix 2).

**Figure 6**

*Frequencies of different genotypes for BDNF (rs6265), COMT (rs4680), and DRD2 (rs1800497) across identified clusters*



The analysis showed that the frequency of the VV variant of BDNF (rs6265) was higher in Cluster 3. For COMT, there was a relative decrease in the frequency of the VM variant and an increase in MM carriers in Cluster 2. Cluster 2 also demonstrated an increased proportion of CC carriers for DRD2 (rs1800497).

## Discussion

This study demonstrated that carriers of different genotypes in the investigated genes show distinct patterns in specific motives for digital behavior. Val/Val (VV) carriers of the BDNF gene (rs6265) scored higher on the scale measuring Internet use as a source of information, including for academic purposes, compared with Val/Met (VM) carriers. This may reflect higher neurotrophic activity and enhanced neuroplasticity. Previous studies have linked the Val (G) allele with more efficient secretion of mature BDNF, which supports cognitive functions, synaptic plasticity, and learning (Egan et al., 2003; Demirci et al., 2023). Such neurobiological characteristics may facilitate engagement in structured learning and information-seeking online. At the same time, increased neuroplasticity in Val carriers may heighten sensitivity to external stimuli, including social and informational cues. This could explain their tendency to actively use the Internet as a source of information not only for learning but also as a means of regulating emotions and maintaining a sense of control. In this way, educational and informational digital content may serve both practical and compensatory-regulatory functions, helping reduce stress through predictability and perceived efficacy.

For the COMT gene (rs4680), carriers of the Val/Val (VV) allele scored significantly higher on the scale measuring Internet use for expressing radical ideas compared to carriers of other genotypes. The COMT gene encodes an enzyme responsible for dopamine degradation, and Val/Val carriers exhibit the highest enzymatic activity, resulting in faster dopamine breakdown in the prefrontal cortex. Studies on the functional significance of the Val158Met polymorphism have produced somewhat mixed findings. Within the "warrior/worrier" framework (Madsen et al., 2024; Serrano et al., 2019), Val/Val is associated with greater stress resilience due to lower emotional reactivity, whereas Met carriers tend to show increased anxiety and physiological sensitivity to stressors. Under moderate stress, Val/Val carriers demonstrate better executive functioning compared to baseline, whereas VM and MM carriers show a decline in performance under stress (Zareyan et al., 2021). At the same time, data on cognitive efficiency often follow an inverted-U pattern, in which homozygous carriers—whether with the highest or lowest enzymatic activity—exhibit lower cognitive performance compared with VM carriers; moreover, when interactions with other genes are taken into account, this relationship is not always consistently observed (Pizzonia et al., 2023). In the context of our findings, the elevated expression of radical ideas in Val/Val carriers may reflect particular features of emotional reactivity. Individuals with lower prefrontal dopamine levels are likely to respond less intensely to negative environmental cues, including social criticism. In this

case, reduced emotional reactivity may not only confer greater calmness and resilience but also influence emotional and cognitive processing in a way that allows these individuals to express their opinions more directly or promptly, without hesitation or fear of negative evaluation.

It was also found that carriers of the CT genotype of the DRD2 gene (rs1800497) scored significantly higher than CC carriers on scales measuring Internet use for self-disclosure and participation in online communities. The rs1800497 polymorphism involves a single nucleotide substitution (thymine to cytosine), which does not directly alter the protein structure but may affect the expression levels of dopamine D2 receptors. T allele carriers are thought to have reduced D2 receptor density. Psychologically, this variant has been associated with increased impulsivity, lower self-control, and heightened vulnerability to stress (Zhang et al., 2012). In the context of our findings, the lower density of D2 receptors in T allele carriers appears to correspond with greater sensitivity to external sources of reward, including social approval, likes, comments, and engagement in group-based online interactions.

Regarding the cluster analysis results, this study was able to refine the initially proposed dichotomy of constructive and destructive strategies. The sample naturally divided into three groups: minimally engaged users (passive-constructive strategy), constructively engaged users (active-constructive strategy), and destructively engaged users (active-destructive strategy). Consistent with previous research (Abakumova et al., 2021; Ermakov et al., 2022), no passive-destructive type emerged, indicating the need for both sample expansion and potential refinement of the measurement instrument.

Differences in genotype distribution indicate that the second cluster, characterized by self-presentation and social approval motives, showed an increased frequency of MM carriers for COMT and CC carriers for DRD2. These genetic features may contribute to enhanced prefrontal dopamine activity, both through reduced dopamine degradation (MM carriers) and higher D2 receptor density (CC carriers). This dopaminergic profile may support improved executive functioning, planning, self-regulation, and social-cognitive sensitivity, collectively promoting behavior oriented toward social interaction, impression management, and approval-seeking. Such individuals are likely to manage their digital presence more effectively, adjusting it finely to social context and audience feedback.

The third cluster, representing a destructive-pragmatic profile, included a higher proportion of VV carriers of BDNF, suggesting increased neuroplasticity and heightened sensitivity to external stimuli, including social and digital cues. When combined with adverse environmental conditions (e.g., digital overload or stress), this heightened sensitivity may promote reactive and potentially maladaptive behavioral patterns, including the expression of destructive motives.

Internet addiction is influenced by multiple polymorphisms in dopaminergic and serotonergic genes, which modulate the relationship between environmental factors and addictive behaviors (Cerniglia et al., 2020). For example, the T allele of rs6277 in DRD2 is

associated with reduced D2 receptor density in extrastriatal regions and represents a risk factor for video game addiction in adolescents (Tereshchenko et al., 2024; He et al., 2020). At the psychological level, genetic variations regulate impulsivity and decision-making tendencies: homozygous Met carriers of COMT exhibit higher risk-related impulsivity, increasing vulnerability to addictive behaviors (Malloy-Diniz et al., 2013; Wu et al., 2024).

Overall, these results support the view that individual differences in digital behavior motivation may be partly explained by neurobiological mechanisms and align with findings from contemporary behavioral genetics research. However, these effects should be interpreted cautiously, as this study did not examine potential environmental or psychological moderators, representing a key limitation. Furthermore, the differentiation between constructive and destructive strategies requires further theoretical and methodological refinement, including potential adjustments to the measurement instrument.

## Conclusions

The present study aimed to analyze the frequency of allele variants in genes associated with the regulation of the dopaminergic system and neurotrophic factors among individuals with different digital behavior strategies in a Russian sample. The results indicate that polymorphisms in DRD2, COMT, and BDNF are associated both with the intensity of specific motives and, more broadly, with constructive and destructive strategies of digital behavior.

The Val/Val genotype of BDNF (rs6265) is associated with more pronounced pragmatic Internet use, including for educational purposes, but may also relate to destructive strategies. The Val/Val genotype of COMT (rs4680) is linked to more frequent expression of radical ideas, which may reflect reduced emotional sensitivity and a more direct, straightforward approach in social behavior, whereas Met/Met carriers tend to demonstrate more constructive engagement. Carriers of the CT genotype of DRD2 (rs1800497) scored significantly higher than CC carriers on scales measuring Internet use for self-disclosure and participation in communities. Notably, the CT allele was also more frequent among individuals with predominating destructive-pragmatic motives.

Future research directions include refining the methodology for assessing digital behavior strategies, incorporating additional socio-psychological factors that shape digital behavior, and comparing identified behavioral profiles with the concept of Reward Deficiency Syndrome (Blum et al., 2022), particularly regarding reduced reward sensitivity and increased need for external stimulation, which may explain certain forms of excessive or maladaptive online activity.

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## Appendix 1

***Results of the comparative analysis of the intensity of specific motives for Internet use among carriers of different genotypes of BDNF (rs6265), COMT (rs4680), and DRD2 (rs1800497)***

| | | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | |
| | | | | | H | p-value | comparisons | z | p-value |
| Internet as a means of self-disclosure | BDNF | VV | VM | MM | 0,137 | 0,934 | MM - VM | 0,224 | 0,823 |
| | | 21 | 20,825 | 20,784 | | | MM - VV | 0,318 | 0,751 |
| | | | | | | | VM - VV | 0,215 | 0,83 |
| | COMT | VV | VM | MM | 0,568 | 0,753 | MM - VM | 0,629 | 0,529 |
| | | 21,702 | 20,52 | 20,477 | | | MM - VV | 0,702 | 0,483 |
| | | | | | | | VM - VV | 0,201 | 0,841 |
| | DRD2 | CC | CT | TT | 6,319 | 0,042 | CC - CT | -2,368 | 0,018 |
| | | 19,901 | 23,086 | 17 | | | CC - TT | 0,613 | 0,54 |
| | | | | | | | CT - TT | 1,324 | 0,185 |

| | | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | | |
| | | | | | H | p-value | comparisons | z | p-value |
| Internet as a means for online shopping | BDNF | VV | VM | MM | 3,58 | 0,167 | MM - VM | -0,625 | 0,532 |
| | | 23,6 | 25,65 | 27,054 | | | MM - VV | -1,248 | 0,212 |
| | | | | | | | VM - VV | -1,521 | 0,128 |
| | COMT | VV | VM | MM | 1,002 | 0,606 | MM - VM | 0,049 | 0,961 |
| | | 26,83 | 27 | 25,75 | | | MM - VV | 0,846 | 0,398 |
| | | | | | | | VM - VV | 0,936 | 0,349 |
| | DRD2 | CC | CT | TT | 1,715 | 0,424 | CC - CT | 0,245 | 0,807 |
| | | 26,824 | 26,586 | 23 | | | CC - TT | 1,304 | 0,192 |
| | | | | | | | CT - TT | 1,206 | 0,228 |

| | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | | |
| | | | | H | p-value | comparisons | z | p-value |
| Internet as a source of information and preparation | VV | VM | MM | | | MM - VM | 1,742 | 0,081 |
| | 37 | 32,55 | 34,743 | 5,874 | 0,053 | | | |
| | | | | | | MM - VV | 0,985 | 0,325 |
| | | | | | | VM - VV | -2,125 | 0,034 |
| | VV | VM | MM | | | MM - VM | 1,27 | 0,204 |
| | 35,255 | 34,167 | 33,795 | 2,24 | 0,326 | | | |
| | | | | | | MM - VV | 1,379 | 0,168 |
| | | | | | | VM - VV | 0,362 | 0,717 |
| | CC | CT | TT | | | CC - CT | 0,023 | 0,982 |
| | 34,527 | 34,017 | 33,25 | 0,012 | 0,994 | | | |
| | | | | | | CC - TT | 0,11 | 0,912 |
| | | | | | | CT - TT | 0,101 | 0,919 |

| | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | | |
| | | | | H | p-value | comparisons | z | p-value |
| Internet as a way of passing time | BDNF | VV | VM | 0,521 | 0,771 | MM - VM | 0,573 | 0,566 |
| | | 25,2 | 23,5 | | | MM - VV | 0,368 | 0,713 |
| | | | | | | VM - VV | -0,588 | 0,557 |
| | | VV | VM | 1,348 | 0,51 | MM - VM | 0,745 | 0,456 |
| | COMT | 25 | 24,186 | | | MM - VV | 1,157 | 0,247 |
| | | | | | | VM - VV | 0,617 | 0,537 |
| | | CC | CT | 0,107 | 0,948 | CC - CT | 0,112 | 0,911 |
| | DRD2 | 24,13 | 24,052 | | | CC - TT | -0,296 | 0,767 |
| | | | | | | CT - TT | -0,325 | 0,745 |

| | MM | |
|---|---|---|
| BDNF | 24,264 | |
| COMT | 23,068 | |
| DRD2 | 25,25 | |

| Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | | | Significance of differences | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | |
| | | | | | H | p-value | comparisons | z | p-value |
| Internet as a motivating force | BDNF | VV | VM | MM | | | | | |
| | | 30,4 | 31,35 | 32,689 | 1,528 | 0,466 | MM - VM | -0,385 | 0,701 |
| | | | | | | | MM - VV | -0,796 | 0,426 |
| | | | | | | | VM - VV | -1,009 | 0,313 |
| | COMT | VV | VM | MM | | | | | |
| | | 33,213 | 31,657 | 33,045 | 2,813 | 0,245 | MM - VM | 1,557 | 0,12 |
| | | | | | | | MM - VV | 0,385 | 0,7 |
| | | | | | | | VM - VV | -1,074 | 0,283 |
| | DRD2 | CC | CT | TT | | | | | |
| | | 32,038 | 33,207 | 30,25 | 1,028 | 0,598 | CC - CT | -0,731 | 0,464 |
| | | | | | | | CC - TT | 0,629 | 0,529 |
| | | | | | | | CT - TT | 0,841 | 0,4 |

| | | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | | |
| | | VV | VM | MM | H | p-value | comparisons | z | p-value |
| Internet as access to alternative information | BDNF | 28 | 26,95 | 27,514 | 0,419 | 0,811 | MM - VM | 0,52 | 0,603 |
| | | | | | | | MM - VV | 0,338 | 0,736 |
| | | | | | | | VM - VV | -0,522 | 0,602 |
| | COMT | VV | VM | MM | 0,448 | 0,799 | MM - VM | 0,63 | 0,529 |
| | | 27,745 | 27,431 | 27 | | | MM - VV | 0,547 | 0,585 |
| | | | | | | | VM - VV | 0,02 | 0,984 |
| | DRD2 | CC | CT | TT | 0,912 | 0,634 | CC - CT | 0,887 | 0,375 |
| | | 27,679 | 26,621 | 30 | | | CC - TT | -0,268 | 0,789 |
| | | | | | | | CT - TT | -0,534 | 0,594 |
| Internet as a means for community participation | BDNF | VV | VM | MM | 1,283 | 0,527 | MM - VM | -0,625 | 0,532 |
| | | 11,2 | 13,15 | 13,419 | | | MM - VV | -0,933 | 0,351 |
| | | | | | | | VM - VV | -0,717 | 0,473 |
| | COMT | VV | VM | MM | 0,395 | 0,821 | MM - VM | -0,551 | 0,582 |
| | | 12,979 | 13,392 | 13,455 | | | MM - VV | -0,564 | 0,573 |
| | | | | | | | VM - VV | -0,118 | 0,906 |
| | DRD2 | CC | CT | TT | 11,124 | 0,004 | CC - CT | -3,334 | < ,001 |
| | | 12,672 | 14,828 | 12 | | | CC - TT | -0,409 | 0,683 |
| | | | | | | | CT - TT | 0,616 | 0,538 |

| | | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | | |
| | | VV | VM | MM | H | p-value | comparisons | z | p-value |
| Internet as a way of observing others on social media | BDNF | 25,2 | 27,15 | 28,595 | 1,602 | 0,449 | MM - VM | -0,48 | 0,631 |
| | | | | | | | MM - VV | -0,883 | 0,377 |
| | | | | | | | VM - VV | -0,977 | 0,329 |
| | COMT | VV | VM | MM | 4,013 | 0,134 | MM - VM | 1,277 | 0,202 |
| | | 28,979 | 26,961 | 30,273 | | | MM - VV | -0,528 | 0,597 |
| | | | | | | | VM - VV | -1,862 | 0,063 |
| | DRD2 | CC | CT | TT | 1,533 | 0,465 | CC - CT | -0,05 | 0,96 |
| | | 28,214 | 28,552 | 23 | | | CC - TT | 1,227 | 0,22 |
| | | | | | | | CT - TT | 1,22 | 0,223 |
| Internet as a means for fulfilling sexual needs | BDNF | VV | VM | MM | 4,419 | 0,11 | MM - VM | 1,771 | 0,076 |
| | | 26,8 | 21,2 | 23,541 | | | MM - VV | 1,219 | 0,223 |
| | | | | | | | VM - VV | -1,605 | 0,108 |
| | COMT | VV | VM | MM | 0,33 | 0,848 | MM - VM | -0,41 | 0,682 |
| | | 22,638 | 23,471 | 22,909 | | | MM - VV | 0,094 | 0,925 |
| | | | | | | | VM - VV | 0,51 | 0,61 |
| | DRD2 | CC | CT | TT | 0,39 | 0,823 | CC - CT | 0,608 | 0,543 |
| | | 23,221 | 23 | 22,5 | | | CC - TT | 0,198 | 0,843 |
| | | | | | | | CT - TT | 0,009 | 0,993 |

| | Mean scores on the "SIB" questionnaire (Abakumova et al., 2015) for carriers of different genotypes of BDNF, COMT, DRD2 | | | Significance of differences | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Kruskal–Wallis test | | Dunn's pairwise post hoc tests | | | |
| | | | | H | p-value | comparisons | z | p-value |
| Internet as a channel for expressing radical ideas | VV | VM | MM | | | | | |
| BDNF | 17,2 | 21,3 | 22,581 | 3,923 | 0,141 | MM - VM | -1,432 | 0,152 |
| | | | | | | MM - VV | -1,84 | 0,066 |
| | | | | | | VM - VV | -0,884 | 0,377 |
| COMT | VV | VM | MM | | | | | |
| | 21,277 | 21,863 | 23,864 | 5,165 | 0,076 | MM - VM | -0,424 | 0,671 |
| | | | | | | MM - VV | -2,07 | 0,038 |
| | | | | | | VM - VV | -1,993 | 0,046 |
| DRD2 | CC | CT | TT | | | | | |
| | 22,275 | 22,034 | 21 | 0,157 | 0,924 | CC - CT | 0,195 | 0,846 |
| | | | | | | CC - TT | 0,362 | 0,717 |
| | | | | | | CT - TT | 0,296 | 0,767 |

# Appendix 2

## *Results of the analysis of the frequency of different genotypes of BDNF (rs6265), COMT (rs4680), and DRD2 (rs1800497) in the identified clusters*

| Gene and allele variant | | Total sample (N=193) | Cluster 1 (N=88) | Cluster 2 (N=55) | Cluster 3 (N=50) |
|---|---|---|---|---|---|
| BDNF (rs6265) | VV | 148 | 63 | 42 | 43 |
| | | 76,68% | 71,59% | 76,36% | 86% |
| | VM | 40 | 22 | 12 | 6 |
| | | 20,72% | 25% | 21,82% | 12% |
| | MM | 5 | 3 | 1 | 1 |
| | | 2,60% | 3,41% | 1,82% | 2% |
| COMT (rs4680) | VV | 44 | 21 | 12 | 11 |
| | | 22,80% | 24% | 22% | 22% |
| | VM | 102 | 49 | 25 | 28 |
| | | 52,85% | 56% | 45% | 56% |
| | MM | 47 | 18 | 18 | 11 |
| | | 24,35% | 20% | 33% | 22% |
| DRD2 (rs1800497) | CC | 131 | 59 | 42 | 30 |
| | | 67,88% | 67% | 76% | 60% |
| | CT | 58 | 27 | 13 | 18 |
| | | 30,05% | 31% | 24% | 36% |
| | TT | 4 | 2 | 0 | 2 |
| | | 2,07% | 2% | 0% | 4% |

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**Anastasia Vasilievna Grishina** — conceptualization and planning of the empirical study, overall project supervision, manuscript drafting.

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# Violent extremism: personality characteristics and susceptibility to radical ideology among young people

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## Abstract

**Introduction.** The relevance of this study is related to the growing psychological vulnerability of young people in conditions of information overload, which increases their susceptibility to destructive influences, especially from extremist and terrorist organizations. At the same time, individual characteristics play an important role in involvement in illegal activities. The aim of the study was to investigate the propensity for violent extremism and analyze the personality characteristics of young people that determine their susceptibility to extremist ideology. **Methods.** The study involved 274 cadets aged 17 to 29 (average age 20.12). A set of psychodiagnostic techniques was used: "Methodology for Diagnosing Violent Extremist Dispositions," "Aggression Test," "Ways of Responding in Dangerous Situations" questionnaire, "Screening Method for Diagnosing the Propensity for Extremism among Students," and the "Cultural-Value Differential" test. Data were processed using descriptive statistics, as well as correlation (Spearman's coefficient) and comparative analysis (Mann-Whitney U test). **Results.** Young people with signs of social and psychological maladjustment are characterized by social pessimism, destructiveness, and cynicism. Comparative analysis revealed statistically significant differences: cadets preparing for a career in law enforcement demonstrate higher levels of mysticism, cynicism, normative nihilism, and physical aggression, which acts as an adaptive mechanism for their future profession, but at the same time increases their vulnerability to extremist ideologies. Reserve cadets demonstrate high levels of subject aggression and collectivist orientation ("towards each other"), which can be interpreted

as a psychological defense mechanism through identification with a reference group, or as a channel for involvement through a similar mechanism of solidarity. **Discussion.** The identified symptom complex (mysticism, cynicism, nihilism) in future military specialists performs a compensatory function but creates cognitive vulnerability to simplified ideological schemes. The data obtained emphasize the need for a differentiated approach in preventive work, taking into account not only obvious markers of distress, but also latent adaptation mechanisms.

## Keywords

extremist dispositions, psychological susceptibility, vulnerability, aggressiveness, extremist ideology, social orientations, conflict behavior, response patterns, young people, cadets

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# Introduction

The modern world is characterized by psychological transitivity. The rapid development of various aspects of human life places a number of social demands on young people who are in the process of personal and professional self-determination and development. In many ways, this process is determined by the information field in which each person is included. The subjective perception of information and attitude towards it is formed individually and affects the cognitive, emotional, and behavioral components of personality development. Young people who find themselves in a situation of choice may be subject to destructive informational and psychological influences. At the same time, certain personality traits and subjectivity of perception mediate the polarity of such influence. In some cases, proactive and cognitive defenses of the personality allow

the use of a kind of "information filter," while in others, on the contrary, they serve as a predictor that increases the cognitive and emotional susceptibility of young people. Meanwhile, the threat of cognitive warfare is growing. This is largely facilitated by the broad information field through which both reliable information and false meanings of destructive ideology are disseminated.

This study aims to examine certain psychological characteristics of young people, namely cadets at military training centers, which will help to understand the level of susceptibility to extremist ideology with the aim of improving existing preventive measures. Despite the successes achieved by modern scientists in this field (Orlov, 2024), ensuring the psychological security of the population is not possible without a scientific understanding of the psychological aspects of young people's susceptibility to destructive extremist ideology. A scientific explanation of the mechanisms of informational and psychological influence, taking into account the personal and behavioral characteristics of cadets at military training centers, will make it possible to develop measures to prevent the emergence of radicalization risks and to develop a comprehensive system of prevention and, in the future, counteraction based on modern socio-psychological technologies. In addition, studying the psychological susceptibility of cadets contributes to the harmonious development of young people during their training at military training centers affiliated with universities.

Today's society is characterized by the active development of digital resources and social networks. Young people make up the majority of their audience, which makes various Internet platforms an excellent channel for promoting and spreading extremist ideology among a huge number of young people who are vulnerable to the influence of radical beliefs. Recently, the internet has been actively used to spread ideas, demonstrate violence, and intimidate society. Social networks are used to create new heroes and symbols capable of attracting the attention of young people who are actively searching for their path in life and their place in society (Melnikova, 2018). Fake photos, posts with false information, and invalid statistics can all be used by extremists for manipulation and further recruitment. In this case, young people become ideal victims, and those who spread extremist ideology are seen as conscious manipulators who use all means to carry out their radical plans (Meshchaninov, 2016). According to research by B. B. Bidova (2014), an ideology can be called extremist if it meets the following criteria:

1) the exclusive truth of this particular ideology, creating a "complex of absolute truth" — the impossibility of refuting the basic postulates of the ideology;

2) aggressive intolerance towards all ideological competitors or competing, alternative ideologies;

3) a fundamental division of society into two large groups: friends and enemies;

4) a focus on immediate practical action to correct the world and people — a program of urgent transformation of the existing social reality;

5) the predominance of destructive tasks aimed at destroying the false hostile world

over constructive tasks in the program of transformative actions;

6) a practically unachievable, overly harsh and perverted code of personal conduct that requires extraordinary, extreme actions, sacrifices and fanaticism from a person (Bidova, 2014).

The reasons why young people fall under the influence of extremist ideology are diverse: social conditions, economic difficulties, cultural differences, and political conflicts. According to a number of scholars, young people who are in the " risk zone" usually do not achieve the level of socialization and adaptation in society that they expect. They lack clear life goals, values, and objectives; sometimes they feel isolated from their community, and they find it difficult to realize their personal ambitions and desires. Young people who find themselves in such circumstances look for ways out of their situations, and radical groups offer ready-made solutions, promising support, protection, and the opportunity for self-expression (Artishchev, Artishcheva, 2015).

The process of recruiting young people involves a step-by-step introduction to extremist ideology: first, contact is established and a relationship of trust is formed, then trial tasks are carried out to test loyalty, and subsequently, the stage of active participation in the activities of the extremist group begins. In order to attract young people, financial assistance, appeals to a sense of duty, pride, or spiritual unity are often used to create a strong bond with the group. It is important to note that young people are the age group most vulnerable to manipulation by those who spread extremist ideologies. It is well known that this age period is associated with emotional instability and a tendency to take risks. New experiences and thrills, as well as a sense of their own uniqueness, are often important to young people. Among the personality traits of young people who are most susceptible to destructive influences, the most common are self-doubt, a sense of social injustice, and dissatisfaction with life (Kondratiev, 2015). People who promote extremist ideology often exploit the weaknesses of young people — their need to feel important, involved, financially secure, and part of an ideology that truly values them — and appeal to them. Thus, young people become attractive targets for leaders of extremist movements and ideologies.

In the early 2000s, the field of socio-psychological analysis of extremist ideologies underwent significant development. One of the first in this field was D.V. Olshansky, who studied the textual materials of radical groups — leaflets, manifestos, and Internet resources. Using content and discourse analysis methods, he showed that radical ideologies perform a number of key functions for individuals and groups, as well as a compensatory function, transforming feelings of helplessness and social irrelevance into feelings of strength and significance. Thus, extremist ideology is not so much a system of beliefs as a psychological mechanism for relieving internal tension and finding a place in society (Olshansky, 2002).

Later, in the 2010s, the focus shifted to digital technologies and social networks, which were assigned a key role as an information channel for the dissemination of radical ideas.

Research by K.D. Khlomov and A.A. Bocharov (2018) showed that the internet creates a unique environment in terms of group dynamics and the gradual radicalization of young people. One of the key mechanisms of this process was "echo chambers": social media algorithms create an information bubble for users, where people only see messages that confirm their views. Ideological attitudes are spread not through complex manifestos, but through simple images, short videos, and music, which are quickly and easily absorbed and evoke a strong emotional response. The phenomenon of gradual radicalization is of particular interest: a young person may start out with harmless hobbies, such as historical reenactment or musical subcultures, but gradually find themselves involved in more closed and aggressive communities. In many ways, such involvement is due to the subjective perception of information and a number of personality traits of young people.

In 2015, M.Y. Kondratyev proposed a model for working with "at-risk groups," including adolescents and young people with uncertain social status, migrants, and those from disadvantaged families, with the aim of preventing young people from becoming involved in extremist ideologies. A key direction in this model is the creation of alternative communities of acceptance—sports clubs, creative studios, volunteer movements—where young people can fulfill their basic needs for belonging, respect, and identity in socially acceptable ways (Kondratiev, 2015). Therefore, an important task is to develop critical thinking and media literacy, which helps young people recognize the manipulative techniques and information distortions characteristic of extremist communities.

Foreign studies show similar results and emphasize the complex nature of psychological and socio-environmental factors that contribute to the vulnerability of young people to extremist ideology. In particular, a study was conducted in 2023 (Haghish et al., 2023) among a large sample of Norwegian adolescents (N=11,397), using machine learning methods, which identified 550 significant psychosocial and contextual variables. The key predictors of extremist attitudes were behavioral problems, level of social well-being, family environment security, and quality of relationships with parents and peers. One of the most significant predictors was age—increased vulnerability is observed in early adolescence. The sensitivity of young people as an important predictor of loyalty to extremist ideology is confirmed by other studies. For example, a 2022 study (González et al., 2022) analyzed the psychological manipulation techniques used to radicalize young people. Among other things, the emotional sensitivity of young men and women, belief in the legitimacy of violence, and manipulation of empathy and identity aimed at achieving psychological submission play an important role. Similar results are seen in other studies (Wallner, 2023), which indicate that prevention programs are based on specific factors of youth vulnerability, including impulsivity, identity search, high susceptibility to peer influence, and an existential need for significance.

In the context of our empirical study, which was conducted on cadets at a military training center, the data obtained in Serbia in 2021 (Vukčević et al., 2021) are interesting. The researchers focused on contextual and psychological predictors of militaristic extremism. The following factors contributing to excessive susceptibility were identified:

family dysfunction, a harsh school environment, feelings of loneliness, authoritarianism, and a focus on social dominance. Together, these variables explained a significant portion of the variance in the components of extremist thinking—belief in the justification of violence and trust in divine power as the ultimate arbiter. Finally, similar to domestic studies on this issue, the 2022 report "How and Why Minors and Youth are Attracted by Extremist Ideologies?" highlights a new dimension of this problem in the digital age: accelerated radicalization is carried out through echo chambers (the exploitation of the same radical ideas) on social networks and the consumption of fragmented ideologies that synthesize conspiracy theories and extremist narratives, which significantly complicates both the diagnosis of vulnerability and the development of preventive measures.

Thus, susceptibility (vulnerability) to extremism is formed at the intersection of individual psychological traits (emotional vulnerability, behavioral problems, search for identity), developmental factors, the quality of the social environment (family, peers, school) and an increasingly aggressive digital context, which is actively exploited by recruiters to manipulate these aspects of personal susceptibility. Thus, analysis of various approaches shows that young people, due to their age characteristics, socio-economic conditions, and psychological vulnerability, are the most susceptible group to extremist influence in the digital space. The internet and social networks are becoming not only a channel of communication, but also a tool for targeted manipulation, where the tenets of radical ideologies are presented in an attractive and accessible form. In these conditions, it becomes particularly important to identify predictors that increase or, conversely, decrease the susceptibility of young people to such influence.

The lack of a clear empirical link between specific personality characteristics, apart from the obvious ones such as aggressiveness or conflictiveness and a tendency towards violent extremism, makes it difficult to develop and implement special preventive programs in working with young people, and the measures taken quickly become vague, preventing the early detection of risks of individuals becoming involved in illegal activities.

The above allows us to specify the research task: it is important to understand which personality traits, psychological states, and behavioral patterns can contribute to the involvement of young people in destructive ideologies, and which, on the contrary, prevent this. This determined the formulation of the research hypotheses.

Hypothesis 1.

It is assumed that there is a significant correlation between certain personality characteristics (mysticism and cynicism) and high levels of aggression among respondents, which increases the risk of involvement in destructive ideologies.

Hypothesis 2.

It is expected that cadets studying reserve and personnel specialties will differ in terms of the level of psychological susceptibility to extremist ideologies and the degree of their exposure to destructive attitudes and ideas.

# Methods

## *Methods*

The key tool was the "Methodology for Diagnosing Dispositions to Violent Extremism" (Davydov, Khlomov, 2017), which allows identifying stable predispositions to justify violence, conflictual perception of social reality, and negative attitudes toward society, which are the basis for involvement in destructive practices.

The characteristics of the affective sphere were determined using the Aggression Test (L. G. Pochebut), which demonstrates the differentiation between various forms of aggression and hostility. High scores on the relevant scales are interpreted as indicators of the search for destructive ways of emotional release and potential recourse to extremist ideas, which increases susceptibility to destructive informational and psychological influence.

The behavioral component was analyzed using the questionnaire "Ways of Responding in Dangerous Situations" (V. G. Maralov, 2012), which identifies dominant coping strategies. In this case, a tendency toward aggressive and confrontational reactions in threatening situations is considered a risk factor for extremist involvement.

A screening method for diagnosing a tendency toward extremism among students (Kapustina et al., 2022) was included for rapid integrated assessment.

The "Cultural-Value Differential" test (G. U. Soldatova, 1998) is aimed at identifying axiological attitudes—ethnocentrism, xenophobia, rejection of cultural diversity—which form the value basis for the assimilation of radical ideas and the cultivation of hatred towards various population groups based on a number of factors.

## *Sample*

Young people aged 17 to 29 (M=20.12 years) participated in the study. Among them were 258 men and 16 women. All respondents are enrolled in military training centers at civilian universities: 123 people are enrolled in civilian training programs, after which they will be enlisted in the reserves; 151 people are enrolled in programs that will lead to subsequent appointments to positions in military organizations.

## *Statistical processing*

Statistical research methods were selected in accordance with the nature of the data obtained. At the first stage, a descriptive analysis was carried out, which made it possible to describe the sample and check the normality of the data distribution (Table 1). The results of the analysis showed that the distribution of data was different from normal, and therefore non-parametric statistical methods were used in the study. In the second stage,

correlation analysis was used to determine the relationships between the phenomena under study, using Spearman's criterion. In the third stage, a comparative analysis of two independent groups was carried out, selected in accordance with the criterion of the educational program studied by the respondents. The Mann-Whitney U test was used to identify differences.

**Table 1**

*Descriptive analysis of the variables studied among young people—cadets at military training centers*

| Variables | Minimum | Maximum | Median | Mean | Standard deviation |
|---|---|---|---|---|---|
| Age | 17 | 29 | 20 | 19.9695 | 0.2399 |
| Methodology for diagnosing violent extremist dispositions | | | | | |
| Intolerance | 9 | 30 | 17 | 16.9008 | 1.7333 |
| Conventional coercion | 8 | 30 | 19.0 | 18.3321 | 4.5359 |
| Social pessimism | 6 | 30 | 12 | 12.9084 | 3.9720 |
| Mysticism | 6 | 30 | 14 | 13.6221 | 4.5230 |
| Destructiveness and cynicism | 8 | 30 | 15.5 | 15.6107 | 3.8865 |
| Protest activity | 6 | 30 | 17 | 16.5153 | 3.8959 |
| Normative nihilism | 8 | 30 | 16 | 16.0153 | 2.7695 |
| Anti-intraception | 9 | 29 | 19.0 | 18.2748 | 3.2295 |

| Variables | Minimum | Maximum | Median | Mean | Standard deviation |
|---|---|---|---|---|---|
| Aggression test | | | | | |
| Conformity | 6 | 30 | 15 | 15.1794 | 3.9307 |
| Verbal aggression | 0 | 7 | 2 | 2.3969 | 1.5594 |
| Physical aggression | 0 | 7 | 2 | 2.4389 | 1.7491 |
| Object aggression | 0 | 7 | 1 | 1.7901 | 1.3123 |
| Emotional aggression | 0 | 7 | 1 | 1.4695 | 1.2553 |
| Self-aggression | 0 | 8 | 2 | 2.0611 | 1.7693 |
| Questionnaire "Ways of responding in dangerous situations" | | | | | |
| Adequate type | 0 | 16 | 3.0 | 3.0878 | 1.9367 |
| Anxious type | 0 | 16 | 8.0 | 7.3321 | 2.7348 |
| Ignoring type | 0 | 10 | 4.0 | 4.1832 | 2.0049 |
| Undefined type | 0 | 0 | 0 | 0.0000 | 0 |
| "Screening method for diagnosing extremist tendencies among students" | | | | | |
| Propensity for extremism | 0 | 22 | 6 | 6.4809 | 4.0878 |
| Cultural-Value Differential Test | | | | | |
| Group orientation | 3 | 12 | 7 | 6.9962 | 1.6597 |
| Orientation toward power | 3 | 12 | 7 | 7.0573 | 1.8217 |
| Orientation towards each other | 3 | 12 | 6.0 | 6.7595 | 2.2809 |
| Focus on change | 3 | 12 | 7 | 7.2748 | 1.8427 |

## Results

Based on the results of descriptive analysis, the following dispositions of violent extremism were identified as predominant in the sample . In particular, the following manifestations were identified:

1. conventional coercion, characterized by the priority of restoring justice over other humanistic values, which is achieved through stricter demands on oneself and others, as well as the introduction of censorship (M=19);
2. anti-introspection, expressed in the rejection of subjective manifestations of introspection, fantasy, and sensual experiences; emphasis is placed on physical reality, orientation toward simple ideas, and immediate actions (M=19);
3. intolerance, reflecting a desire for unambiguous perception of the world, rejection of other people's differences, denial of the possibility of dissent, and a desire to impose one's views on others by any means necessary (M=17).
4. Protest activity, in other words, maladaptive activity characterized by a desire for heroic deeds, the unknown, adventure, and transformation, a willingness to take risks and sacrifice oneself for an idea (M=17).

At the same time, the overall level of aggression was low. In dangerous situations, the most pronounced type of response was anxious, characterized by a tendency to exaggerate the threat (M=8).

The psychoterrorism indicator is at an average level (M=-5), which indicates the absence of a pronounced desire to deliberately destabilize the interlocutor. However, a tendency toward emotional manipulation may be observed, but within limited limits.

The screening diagnostic data also did not reveal a tendency toward maladaptive behavior (M=6). In addition, a hierarchy of respondents' orientations was established. The orientation towards change ( ) is more pronounced (m(avg)=7.2; M=7), followed by the orientation towards power (m(avg)=7; M=7), towards the group (m(avg)=6.9; M=7), and towards each other (m(avg)=6.7; M=6).

To continue investigating the relationship between personality characteristics and attitudes that increase the risk of involvement in destructive ideologies, as well as to test the hypothesis of the existence of relationships between these indicators, a correlation analysis was performed using Spearman's criterion. The results of the analysis are presented in Table 2.

Correlation analysis showed that the tendency toward extremism, understood as a manifestation of socio-psychological maladjustment, is closely related to a number of personality dispositions. The tendency toward extremism (maladaptive state) is positively associated with such dispositions as social pessimism (r = 0.3) and destructiveness and cynicism (r = 0.4).

**Table 2**

*Correlation analysis of violent extremist dispositions and personality characteristics explaining the susceptibility of young people to extremist ideology*

| | IN | CP | SP | DC | PA | ODD | SA |
|---|---|---|---|---|---|---|---|
| SE | 0.20 | 0.17 | 0.32 | 0.40 | 0.15 | 0.36 | 0.40 |
| BA | 0.42 | 0.22 | 0.11 | 0.19 | 0.22 | 0.10 | - |
| FA | 0.24 | 0.33 | 0.08 | 0.17 | 0.30 | -0.06 | - |

***Note**: 1. SE — tendency toward extremism; VA — verbal aggression; PA — physical aggression; IN — intolerance; CP — conventional coercion; SP — social pessimism; DC — destructiveness and cynicism; PA — protest activity; ODD — orientation toward each other; SA — self-aggression. 2. Correlation is significant at the 0.05 level. ** 3. Correlation is significant at the 0.01 level.*

It is noteworthy that the tendency toward extremism is related to orientation toward others (r = 0.3), which is explained by the desire of young people to find a support group, a community that shares their views and justifies radical actions. At the same time, it is important for individuals to "stand out" and show results that are different from others, which is easier to achieve through radical measures and illegal actions than through painstaking work on oneself. At the same time, the coldness and emotional alienation that accompany such an orientation devalue human relationships, turning social interaction into a kind of "competition." Another interesting connection was found between a tendency toward extremism and self-aggression (r = 0.4).

It is equally telling that intolerance correlates positively with verbal aggression (r = 0.4). The desire for a simplified and rigid worldview is often accompanied by aggressive defense of one's own beliefs. Young people who are intolerant of other opinions are more likely to resort to verbal abuse and confrontation. In turn, constant exposure to conflict narrows perception and further reinforces the limitations of one's worldview. Physical aggression is significantly associated with such dispositions of violent extremism as conventional coercion (r = 0.3) and protest activity (r = 0.3).

Thus, correlation analysis showed that the tendency toward extremism among young people is formed at the intersection of such indicators as internal vulnerability, frustration, and the desire for social self-identification. Social pessimism, cynicism, aggression, and intolerance not only undermine the harmony of the individual, but also create a basis for justifying radical and destructive practices in the minds of young people.

In order to verify how much the severity of these characteristics varies among representatives of different groups of respondents, we conducted a comparative analysis using the Mann-Whitney U test. The data obtained are presented in Table 3.

**Table 3**

*Comparative analysis of violent extremist dispositions and the severity of personality characteristics among cadets in different training programs (Mann-Whitney U test)*

| Variables | U | p | Average rank[1] |
|---|---|---|---|
| Mysticism | 6879.500 | 0.013 | 117.98/141.44 |
| Destructiveness and cynicism | 6277.500 | 0 | 112.55/145.43 |
| Normative nihilism | 5765.00 | 0 | 107.94/148.82 |
| Physical aggression | 7102.50 | 0.032 | 119.99/139.96 |
| Object aggression | 6640.500 | 0.002 | 147.18/119.98 |
| Orientation toward each other | 6451.500 | 0.001 | 148.88/118.73 |

***Note:*** *[1]The number before the slash is the average rank of the values of variables for cadets in reserve specialties, and after the slash is for cadets in regular specialties.*

Cadets oriented toward professional activity in military structures demonstrated statistically significantly higher scores on dispositions such as mysticism (z = 6879.5), destructiveness, cynicism (z = 6277.5), and normative nihilism (z = 5765.0) compared to cadets enrolled in the reserve program. Future military specialists are characterized by a pronounced tendency toward an external locus of control, which manifests itself in a tendency to shift responsibility to external, uncontrollable forces. This psychological mechanism can be seen as a compensatory strategy for coping with existential anxiety and high levels of uncertainty, which are objectively inherent in the professional activities of specialists in the military sphere. The use of irrational explanatory models (belief in predestination) performs a protective function for the psyche, reducing the emotional tension associated with the awareness of the risks and high responsibility of the future profession. However, this same mechanism creates cognitive vulnerability: simplified and emotionally charged explanatory schemes increase susceptibility to extremist ideologies, which are characterized by a dichotomous view of the world ("us" versus "them") and the absolutization of the image of the enemy.

The increased levels of destructiveness and cynicism among students in the military training program reflect a generalized negative attitude toward people, attributing base motives to their actions, devaluing interpersonal relationships, and diminishing the value of human life. In the context of a military specialty involving the use of violence, such cynicism can serve an adaptive function, reducing emotional stress and moral-psychological/intrapersonal conflicts. In the long term, this contributes to the dehumanization of the enemy, which not only facilitates the performance of combat tasks, but also creates an illusion to justify excessive cruelty and the acceptance of ideologies based on hatred and

exclusivity on one side. Normative nihilism is more common among cadets who plan to continue working in the military. This disposition legitimizes unlawful actions. Moral and legal restrictions begin to be perceived as conditional and applicable only to situations not related to "serving the cause."

The above dispositions constitute a symptom complex that serves as an adaptive mechanism to the high stress and moral dilemmas of the military profession, but, on the other hand, make cadets in professional training vulnerable to extremist ideology. Physical aggression, which is also more common among cadets in military specialties and represents an increased readiness to use physical force, is the behavioral embodiment of the above-mentioned dispositions, completing the picture of potential involvement in violent practices.

Cadets who will form the mobilization reserve upon completion of their training have higher scores in terms of object aggression, a tendency to express negative emotions toward inanimate objects in situations of frustration or psycho-emotional stress, compared to cadets training in personnel specialties. This form of response may indicate restraint from direct aggression against people and is considered less destructive. Cadets deliberately choose more acceptable forms of aggression—this is probably due to their future professional activities, where legitimate physical force will not be used and, accordingly, there will be no need to resort to physical aggression. This cannot be said about cadets in personnel specialties, whose professional activities may be directly related to it.

The higher indicators of "friend-oriented" behavior among reserve cadets compared to cadets in regular military specialties may reflect significant differences in their value and meaning systems. For example, reserve cadets demonstrate a more pronounced collectivist orientation, which can manifest itself in a desire for mutual assistance, cooperation, and emotional support within the group. Sometimes this is due to their temporary stay in the service environment and the lack of long-term prospects in this area, which increases the importance of horizontal ties and mutual support as a mechanism for adapting to stressful training conditions. Cadets in regular military service specialties are less oriented toward the collective. This is probably due to their desire for individual achievement and further career growth, as well as the fact that they are initially trained for leadership positions. Upon completion of the educational program, they are distributed across different regions of the country, which reduces the importance of interaction within their study group. Individualistic work makes cadets vulnerable to the influence of various ideological concepts, including radical and extremist ones.

## Discussion

The analysis of the data revealed a number of significant correlations between the psychological characteristics of young people and their susceptibility to extremist ideology. The tendency toward extremism as a maladaptive state demonstrates significant

links to a complex of specific psychological dispositions, among which the key indicators were: social pessimism, destructiveness and cynicism, orientation toward others in the context of conformity and seeking approval, self-aggression, intolerance, and physical aggression. Foreign researchers come to similar conclusions in their work , emphasizing that recruiters manipulate perception. Negative attitudes towards society are formed on the basis of distrust of another group, which is based on opposition that distinguishes the individual from others (Kruglanski et al., 2014; McCauley & Moskalenko, 2017). The results obtained provide a deeper understanding of the psychological mechanisms underlying radicalization. In particular, social pessimism, expressed in a negative, catastrophic perception of the world and the future, combined with destructiveness and cynicism, forms the cognitive-emotional basis for adopting radical views. Frustration, along with the need for security and justice, generates a demand for simplified answers and a dichotomous perception of reality, which corresponds to the provisions on "strains of terrorism." The severity of social pessimism predisposes people to a negative perception of the world around them, catastrophizing the future and expecting danger, while destructiveness and cynicism are dispositions that manifest themselves in a critical attitude towards others, suspicion, and rejection of human relationships (Davydov, Khlomov, 2017). The interdependence of these dispositions, as well as the tendency toward social and psychological maladjustment, is due to the fact that one of its criteria, identified by Kapustina T.V., is depression, which is characteristic of individuals with pronounced social pessimism and dehumanization of others, which can occur with an increased level of cynicism (Kondratiev, 2015). A frustrated sense of security, negative expectations of the present and future, and intolerance of human manifestations can be markers of the risk of involvement in extremist ideologies, as young people may be inclined to resort to radical methods of changing their environment. ' tendency to view the world through the prism of pessimism can cause feelings of hostility towards them. Intolerance towards others is already an aspect of predisposition to destructive acts against those around them. Thus, in situations of psychological vulnerability, ideas about the legitimacy and legality of using violence and other destructive means to protect oneself and one's interests may arise. An important role in the formation of this predisposition is played by orientation towards others, which manifests itself in conformity and the search for support among like-minded people. This echoes data according to which extremist groups satisfy the basic needs of belonging and recognition for individuals with impaired social connections (Doosje et al., 2016). As L.G. Pochebut notes, a person deprived of inner harmony and psychological defense mechanisms is vulnerable to an aggressive external environment. In situations of psychological vulnerability, young people may experience an acute sense of danger, which leads to a distortion of their values and meaning and contributes to the development of a tendency to make radical and destructive decisions as a mechanism for protecting their psychological integrity.

Self-aggression and intolerance emerged as key markers of internal distress closely linked to extremist attitudes. Their connection with verbal and physical aggression

highlights the role of internal conflicts and cognitive rigidity in the radicalization process (Maralov et al., 2012; Melnikova, 2018). The work of E.V. Sokolova and A.A. Grigorieva (2010) revealed important personality differences between young people observed in extremist manifestations and their peers. The study was conducted on a sample of 120 people aged 17–25. The first group of participants consisted of young people registered with law enforcement agencies for extremist actions or statements, while the second group was a control group. The results showed that the radicalized group of young people had a higher level of aggression, both physical and verbal. In addition, they had a negative self-image, expressed in a complex of "wounded pride": low self-esteem, internal conflict, and a tendency to blame themselves. The motives for involvement were predominantly non-ideological. Participants most often spoke of the need to belong (27%), protest against social injustice (23%), and the search for thrills (19%). Ideology was not the root cause, but rather a justification and a tool for unity (Sokolova, Grigorieva, 2010). However, conventional coercion is based on the desire to "restore justice" at any cost, even to the detriment of humanistic values (Davydov & Khlomov, 2017). Usually, this is achieved by imposing strict requirements on oneself and others. This logic is consistent with the well-known "frustration-aggression" model. Protest activity, on the contrary, reflects a need for novelty, a search for thrills and "forbidden experiences." In this case, aggression and violence become a form of exploration, a unique way to test oneself and the surrounding world. This is consistent with longitudinal studies, where aggression and bullying are among the most consistent predictors of antisocial behavior (Vergani et al., 2018; Victoroff, 2005). Moreover, research data show that young people, as the main users of social networks who demonstrate active constructive and destructive forms of information behavior, have significantly higher scores on all indicators of aggression and hostility and demonstrate more pronounced polene dependence (Kolenova et al., 2022). It is important to note that in the study, classic risk factors such as symptoms of depression and anxiety did not show as significant predictive power in relation to extremist attitudes as the complex of identified dispositions (Vergani et al., 2018). Consequently, a more detailed analysis of specific personality traits and cognitive styles of information processing, going beyond general diagnostic categories, is necessary to understand the phenomenon of extremism.

Susceptibility to extremism is the result of a complex interaction of maladaptive personality traits, affective states, and cognitive distortions. This conclusion is supported by foreign studies on the characterological traits of terrorists, since the identified dispositions are a direct reflection of psychological tension, which can find an outlet in radical forms of coping strategies. This confirms that higher education institutions, which bring together young people from diverse cultural, ethnic, and religious backgrounds, face a dual effect. On the one hand, this enriches the educational space, but on the other, it creates potential ground for conflict. In this process, building partnerships within the university community is of fundamental importance. It is through such interaction that a mature personality is formed, capable of self-realization and critical understanding of reality, which is the basis for resistance to destructive ideologies (Kagermaova et al., 2021).

The limitation of this study is that the emphasis is on correlations, and causal relationships are assumed exclusively between the variables under consideration. In addition, the results are based on a sample in which men are numerically predominant, which may limit the practical significance of the conclusions for women, who may also obtain military-related degrees at universities.

Prospects for further research primarily include studying the causal relationships between psychological dispositions and the propensity for extremism, which is necessary for a more detailed understanding of the mechanisms of the formation of extremist views and the constant updating of knowledge about them. An equally important area of future research is the analysis of the role of social and cultural factors influencing the radicalization of young people, as these are sometimes understudied catalysts for changes in a person's worldview. In the future, it is planned to compile patterns of personality traits in young people that are most likely to lead to the radicalization of an individual's views, which will enable early diagnosis and timely preventive intervention.

## Conclusion

The results of the study demonstrate the complex nature of young people's susceptibility to extremist ideology. Not only aggressive and intolerant attitudes play an important role, but also personality traits such as pessimism, mysticism, and cynicism. Preventive programs should take these psychological characteristics into account and be aimed at developing critical thinking, emotional stability, and tolerance among young people. This will reduce the risks of radicalization and contribute to the formation of a more harmonious society.

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**Alexandra Anatolyevna Zherdeva** – selection and description of methodological tools, collection of empirical data.

**Elena Aleksandrovna Krasnova** – theoretical review of Russian literature on the research topic.

**Ekaterina Olegovna Kuznetsova** – data processing and statistical preparation for analysis and interpretation.

**Ekaterina Petrovna Khazina** – review of international literature, discussion of results, technical formatting of the text.

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# Modelling Teachers' Readiness for Inclusive Education: A Predictive Approach

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## Abstract

**Introduction.** The article addresses the formation of teachers' inclusive culture as an integrative personal trait that determines their readiness to work in inclusive education. It presents a contemporary understanding of the construct of inclusive culture and its relationship with general culture, identifies its key components, values and social norms, and describes its external dimension (accessibility and safety of the educational environment) and internal dimension (values, norms and rules). The role of inclusive culture as a foundational condition for the development of inclusive education is emphasized. **Methods.** The study employed four standardized diagnostic instruments measuring inclusive readiness, readiness for teaching, pedagogical communication styles and emotional intelligence in a sample of 549 pre-service teachers (372 students from Chechen State Pedagogical University and 177 students from Azerbaijan University of Languages). Statistical analysis was carried out using multiple regression (backward stepwise method, 12 models). **Results.** Regression analysis demonstrated a significant contribution of the studied variables to the prediction of inclusive readiness ($F = 38.790$; $p < 0.001$). Nine key predictors were identified: emotional awareness, absence of a hyporeflexive communication style, absence of a hyperreflexive communication style, ability to recognize others' emotions, differentiated attention pattern, sociability, dictatorial communication style, self-confidence and self-motivation. **Discussion.** A predictive

model of teachers' readiness for inclusive education is proposed. The strongest predictor is emotional awareness (β = 0.278), reflecting teachers' capacity for reflection on their own emotions; the second most important predictor is the absence of a hyporeflexive behavioral pattern (β = –0.177), and the third is the absence of a hyperreflexive style (β = –0.135). Together, these components shape teachers' readiness to work effectively in an inclusive educational environment.

## Keywords

inclusive culture; inclusive readiness; regression analysis; emotional intelligence; pedagogical communication styles; predictive model of teachers' readiness for inclusive education

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# Introduction

The development of inclusive practices in society and education places new demands on the preparation of future teachers. One of the key requirements is the formation of an inclusive culture as an integrative personal characteristic that underpins future teachers' readiness to work in inclusive educational settings and to provide continuous psychological and pedagogical support to students with disabilities. Despite the long-standing experience of implementing inclusive education in Russia, teachers' attitudes towards inclusion remain ambivalent, shaped by a complex interplay of contextual and individual factors, which makes the task of fostering an inclusive culture among students in teacher education programmes particularly salient.

Contemporary research conceptualizes inclusive culture as an integral part of general culture that encompasses core cultural components such as values, social norms and mechanisms for transmitting cultural heritage (Andreeva, 2021). At the heart of an inclusive

culture lies the value of the individual, recognised in all their unique characteristics and capabilities. The social norms underpinning an inclusive culture are linked to the acceptance of others, mutual support and cooperation (Dyachkova, Tomyuk, Shutaleva, & Dudchik, 2019; Booth & Ainscow, 2002). The transmission of inclusive cultural heritage is closely tied to teachers' communicative competences, in particular their willingness and ability to interact with all participants in the educational process within an inclusive environment (Booth, 2007; Polyansky & Martirosyan, 2018).

In this perspective, inclusive education is viewed as one of the key mechanisms for building a society of equal opportunities (Kudryavtsev, Kashtanova, Olkhina, Medvedeva, & Karpushkina, 2018; Mirzayeva, 2019), and the acceptance of inclusive values in society—reflected in people's communication, language, behaviour and activity—is regarded as an important indicator of an inclusive social culture (Shemanov & Yekushevskaya, 2018). In the scientific literature, inclusive culture is described as the foundation of inclusive education, largely determining the success of inclusion, and is understood both as a specific philosophy and as a component of the overall culture of an educational organization (Segal, 2014; Ainscow & Sandill, 2010).

Recent studies distinguish between the external and internal dimensions of inclusive culture. The external dimension is associated with the accessibility and safety of the educational process (the educational component) and of the educational organization itself (the architectural component), whereas the internal dimension encompasses the values, norms and rules shared by all participants in the educational process (Alyokhina, 2014; Alyokhina & Shemanov, 2018; Makarova, 2020; Starovoit, 2022; Ainscow, 2005).

In the context of higher education, inclusive culture is defined as the basic, initial stage in the development of future teachers' readiness for professional activity in inclusive educational settings (Kashtanova, Kudryavtsev, & Krasnopevtseva, 2023; Yemelyanova, 2015; Skuratovskaya, 2020; Ilaltdinova, Filchenkova, Kudryavtsev, & Krasnopevtseva, 2022). Its formation depends on specific pedagogical conditions created at the university, including the use of a competence-based approach to organizing the educational process, the development of didactic models for cultivating inclusive culture, and the implementation of targeted programmes for enhancing students' inclusive culture through specially designed educational activities (Bogdanova, 2020; Krivodonova, 2020; Salavatulina & Reznikova, 2023; Khitryuk, 2012).

## Methods

The level of inclusive culture and readiness to work in inclusive education among students of teacher education programmes at Chechen State Pedagogical University and Azerbaijan University of Languages was assessed using the following instruments: Method for Diagnosing the Level of Inclusive Readiness of Future Teachers (V. V. Khitruk), Scale for Assessing Readiness and Adaptability of the Individual to Teaching Activity (Yu.

Dementieva), Method for Diagnosing Pedagogical Communication Styles (N. P. Fetiskin), and Emotional Intelligence Questionnaire (N. Hall). Multiple regression analysis using the backward stepwise method (12 models) was conducted to determine the contribution of psychological and socio-psychological characteristics to the manifestation of future teachers' inclusive readiness.

The study was carried out online using an electronic survey form that incorporated the stimuli of all four instruments. The sample comprised 549 students aged 17–21 years, including 372 students from Chechen State Pedagogical University and 177 students from Azerbaijan University of Languages.

## Results

To develop a predictive model, all studied variables were initially included as candidate predictors, namely: overall level of emotional intelligence, rigidity of response, productivity, hyporeflexive style, hyperreflexive style, dictatorial style, differentiated attention style, efficiency, contactless style, level of self-regulation, authoritarian style, creative capacity, adaptability, sociability, self-confidence, emotion regulation, emotional awareness, active interaction style, self-motivation and the ability to recognize other people's emotions. The indicators listed in Table 1 were selected from this set for further analysis and interpretation as the most informative predictors of teachers' inclusive readiness.

**Table 1**
*Variables Removed During Backward Stepwise Regression Analysis of Predictors of Teachers' Inclusive Readiness*

| Model | Removed Variable | Method |
|---|---|---|
| 1 | — | Backward (Criterion: Probability of F for removal ≥ .100) |
| 2 | Overall emotional intelligence level | Backward (Criterion: Probability of F for removal ≥ .100) |
| 3 | Level of self-regulation | Backward (Criterion: Probability of F for removal ≥ .100) |
| 4 | Creative capacity | Backward (Criterion: Probability of F for removal ≥ .100) |
| 5 | Task efficiency | Backward (Criterion: Probability of F for removal ≥ .100) |
| 6 | Authoritarian style | Backward (Criterion: Probability of F for removal ≥ .100) |

| Model | Removed Variable | Method |
|---|---|---|
| 7 | Adaptability | Backward (Criterion: Probability of F for removal ≥ .100) |
| 8 | Emotion regulation | Backward (Criterion: Probability of F for removal ≥ .100) |
| 9 | Work capacity | Backward (Criterion: Probability of F for removal ≥ .100) |
| 10 | Contactless (avoidant) style | Backward (Criterion: Probability of F for removal ≥ .100) |
| 11 | Active interaction style | Backward (Criterion: Probability of F for removal ≥ .100) |

As shown in Table 1, nine variables were retained for subsequent analysis: sociability, self-confidence, emotional awareness, self-motivation, the ability to recognize others' emotions, and four pedagogical communication patterns—namely, dictatorial, differentiated attention, hyporeflexive and hyperreflexive styles.

Table 2 presents the statistical parameters of the final regression model, including standardized and unstandardized coefficients, standard errors and significance levels.

**Table 2**

*Results for the Regression Model Predicting Teachers' Inclusive Readiness*

| Model | Sum of Squares | Mean Square | F | Significance (p) |
|---|---|---|---|---|
| Regression | 173.052 | 19.228 | 38.790 | < .001 |
| Residual | 212.159 | 0.496 | — | — |
| Total | 385.211 | — | — | — |

*Note. Dependent variable: Teachers' Inclusive Readiness*

As indicated in Table 2, the F-statistic ($F = 38.790$, $p < .001$) demonstrates a significant contribution of the studied variables to predicting teachers' inclusive readiness.

To assess the assumptions of multiple regression analysis, the Durbin–Watson test was conducted and variance inflation factors (VIF) were examined. The results are presented in Tables 3 and 4.

**Table 3**

*Variance Inflation Factors (VIF) and Condition Indices*

| Dimension | Eigenvalue | Condition Index | (Constant) | Sociability | Self-Confidence | Dictatorial | Differentiated Attention | Hyporeflexive | Hyperreflexive | Emotional Awareness | Self-Motivation | Emotion Recognition | Dimension |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.198 | 1.000 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | 1 |
| 2 | 2.000 | 1.897 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .04 | .04 | .03 | 2 |
| 3 | 0.209 | 5.867 | .00 | .01 | .01 | .00 | .00 | .00 | .00 | .75 | .28 | .11 | 3 |
| 4 | 0.184 | 6.263 | .00 | .05 | .05 | .06 | .00 | .06 | .00 | .16 | .03 | .00 | 4 |
| 5 | 0.169 | 6.520 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .01 | .61 | .81 | 5 |
| 6 | 0.137 | 7.241 | .00 | .03 | .04 | .00 | .12 | .07 | .05 | .01 | .00 | .02 | 6 |
| 7 | 0.044 | 12.823 | .00 | .02 | .00 | .27 | .08 | .37 | .22 | .02 | .02 | .01 | 7 |
| 8 | 0.029 | 15.738 | .00 | .44 | .47 | .11 | .17 | .19 | .13 | .00 | .00 | .00 | 8 |
| 9 | 0.024 | 17.258 | .00 | .35 | .40 | .12 | .44 | .22 | .23 | .00 | .01 | .00 | 9 |
| 10 | 0.006 | 35.474 | 1.00 | .10 | .02 | .43 | .19 | .10 | .37 | .00 | .00 | .01 | 10 |

**Table 4**

*Summary Statistics of Residuals*

| **Statistic** | | | | | |
|---|---|---|---|---|---|
| Predicted value | 0.522 | 3.753 | 2.262 | 0.629 | 438 |
| Residual | –1.852 | 2.346 | 0.000 | 0.697 | 438 |
| Standardized predicted value | –2.765 | 2.369 | 0.000 | 1.000 | 438 |
| Standardized residual | –2.630 | 3.332 | 0.000 | 0.990 | 438 |
| **Statistic** | **Minimum** | **Maximum** | **Mean** | **Std. Deviation** | **N** |

***Note. Dependent variable: Teachers' Inclusive Readiness***

The diagnostic tests presented in Tables 3 and 4 confirm that the assumptions of multiple regression were satisfied: no multicollinearity was detected (all VIF values were acceptable), and the Durbin–Watson statistic indicated no significant autocorrelation in the residuals. These findings justify proceeding with the interpretation of the regression results.

Table 5 presents the regression coefficients and model fit statistics for the final regression model predicting teachers' inclusive readiness based on the studied psychological and social-psychological characteristics.

**Table 5**

*Unstandardized and Standardized Regression Coefficients for the Final Model Predicting Teachers' Inclusive Readiness*

| Predictor | B | SE | β | t | p |
|---|---|---|---|---|---|
| (Constant) | 1.643 | 0.404 | — | 4.067 | < .001 |
| Sociability | 0.040 | 0.018 | 0.123 | 2.191 | .029 |
| Self-Confidence | 0.036 | 0.018 | 0.110 | 2.006 | .046 |
| Dictatorial Style | 0.898 | 0.383 | 0.116 | 2.344 | .020 |
| Differentiated Attention Style | 0.892 | 0.307 | 0.127 | 2.903 | .004 |
| Hyporeflexive Style | –1.179 | 0.301 | –0.177 | –3.918 | < .001 |
| Hyperreflexive Style | –1.056 | 0.351 | –0.135 | –3.009 | .003 |
| Emotional Awareness | 0.032 | 0.007 | 0.278 | 4.445 | < .001 |
| Self-Motivation | 0.014 | 0.007 | 0.123 | 1.866 | .063 |
| Emotion Recognition | 0.015 | 0.008 | 0.130 | 1.978 | .049 |

***Note.*** *B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient (beta); t = t-statistic; p = significance level. Dependent variable: Teachers' Inclusive Readiness.*

The regression analysis results illuminate the differential contributions of the studied variables to teachers' inclusive readiness. Emotional awareness emerged as the primary predictor ($\beta = 0.278$, $p < .001$), reflecting the capacity for reflection on one's own emotional states—a core component of emotional intelligence according to Hall's model. This finding underscores emotional awareness as the leading predictor of future teachers' readiness to implement inclusive practices.

The second-strongest predictor was the absence of a hyporeflexive communication style ($\beta = -0.177$, $p < .001$), characterized by teacher-centeredness, reliance on monologic discourse, and emotional insensitivity to others. The significant negative coefficient indicates that the absence of this maladaptive pattern is crucial for inclusive readiness and achieved statistical significance comparable to emotional awareness.

The absence of a hyperreflexive style ($\beta = -0.135$, $p = .003$) constituted the third-strongest predictor. This dysfunctional pattern manifests as excessive socio-psychological reactivity, preoccupation with impression management and defensive responsiveness to student feedback. Its absence similarly predicted stronger inclusive readiness.

Ranked in descending order of predictive strength, the remaining significant predictors were: emotion recognition ability ($\beta = 0.130$, $p = .049$), reflecting the capacity to identify others' emotional states; differentiated attention style ($\beta = 0.127$, $p = .004$), denoting teachers' strategic focus on students requiring additional support; sociability ($\beta = 0.123$, $p = .029$), understood as interpersonal openness and adaptability to teaching roles; dictatorial style ($\beta = 0.116$, $p = .020$), suggestive of directive classroom management; and self-confidence ($\beta = 0.110$, $p = .046$).

Self-motivation ($\beta = 0.123$, $p = .063$) was retained in the final model as a marginal predictor, indicating a pronounced but sub-threshold trend. While not meeting conventional significance criteria, this indicator's inclusion suggests the potential importance of intrinsic motivation for sustained inclusive practice, warranting further investigation.

## Discussion

The findings underscore the fundamental role of inclusive culture as an integrative personal attribute that shapes teachers' readiness to work in inclusive educational environments. The identification of emotional awareness as the strongest predictor of inclusive readiness aligns with contemporary understanding of the significance of emotional intelligence and metacognitive reflection on one's own emotional states for effective teacher practice within inclusive settings (Hall, 2006; Dunaevskaya, 2018). This suggests that emotional awareness functions as a key resource enabling teachers to embrace student diversity and adopt a humanistic pedagogical orientation (Andreeva, 2021; Alyokhina, 2014).

A noteworthy finding is that inclusive readiness is predicted not only by the presence of positive psychological characteristics, but also—and significantly—by the absence of

certain dysfunctional communication styles, particularly hyporeflexive and hyperreflexive patterns. Teachers who are predominantly self-focused, emotionally unresponsive to their students, or conversely, overly concerned with impression management contradict the foundational values of inclusive culture, which centre on acceptance, dialogue and genuine cooperation (Booth & Ainscow, 2002; Shemanov & Yekushevskaya, 2018). This finding empirically supports the theoretical proposition that cultivating an inclusive culture requires a fundamental transformation of pedagogical communication styles (Ainscow & Sandill, 2010; Polyansky & Martirosyan, 2018).

The contributions of emotional recognition, sociability and differentiated attention patterns further illuminate the relational foundations of inclusive readiness. These predictors demonstrate that inclusive culture rests on well-developed interpersonal and social-perceptual competences. This aligns with contemporary approaches that conceptualize inclusive culture not merely as an articulated system of values, but as a coherent set of sustainable interactive practices with students requiring specialized support (Kolokoltseva, 2022; Kashtanova et al., 2023). The emphasis on targeted, individualized support correlates with the notion of an inclusive educational environment as a space characterized by flexible differentiation and personalized pedagogical assistance (Morina, 2017; Stubbs, 2008).

The positive contribution of the dictatorial communication style merits particular attention. On the surface, this result appears inconsistent with inclusive principles; however, it may be interpreted as reflecting culturally situated features of university-level educational organization, where more directive group management can coexist with teachers' emotional awareness and communicative sensitivity. Contemporary literature describes such transitional or hybrid professional orientations as characteristic of educational systems undergoing institutional transformation (Kudryavtsev et al., 2018; Starovoit, 2022).

The marginal statistical significance of self-motivation suggests a potentially important but emerging role for teachers' intrinsic motivation in sustaining inclusive practice over time. Scholarship emphasizes that resilience to occupational stress and sustained commitment to supporting students with special educational needs correlate with deep personal investment and intrinsic motivation (Yemelyanova & Sinyavskaya, 2015; Skuratovskaya, 2020). These findings indicate self-motivation as a fruitful direction for future investigation within the broader predictive model.

Collectively, the predictive model presented aligns with theoretical frameworks positing that inclusive culture in higher education emerges at the intersection of ethical values, emotional-personal dispositions and pedagogical interaction patterns (Alyokhina & Shemanov, 2018; Ilaltdinova et al., 2022). The results underline the imperative to incorporate into teacher preparation programmes targeted content addressing the development of emotional intelligence, reflective practice and communicative competence within inclusive educational contexts.

The developed predictive model yields a coherent profile of teachers' inclusive readiness. Concretely, teachers will demonstrate readiness to implement inclusive practices when they possess the capacity for reflective engagement with their own emotional experiences, the ability to differentiate pedagogical attention and direct it towards students requiring additional classroom support, and an orientation towards the substantive content of their teaching rather than its superficial presentation. Additionally, such teachers will display emotional attunement to their students, accurately recognize student emotions, and demonstrate genuine sociability—capacities that enable authentic connection with learners in inclusive settings, flexible structuring of instructional materials aligned with students' cognitive abilities, and professional confidence in their pedagogical conduct.

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# Analysis of Problem Behavior in Pet Dogs Using Artificial Intelligence Technology: A Pilot Study

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## Abstract

**Introduction.** Research on problem behavior in pet dogs is underrepresented in Russian zoopsychology, primarily due to the lack of measurable metrics for objective assessment of their behavior. Drawing on international studies, this work aims to identify objective markers of problem behavior in pet dogs. **Methods.** The pilot sample included 35 dogs—15 males and 20 females. The assessment consisted of the owner questionnaire CBARQ and behavioral tests: meet and greet, interaction with owner, and interaction with a stranger. Behavioral patterns were extracted from video recordings using the YOLO neural network. Movement speed was calculated using the Euclidean distance formula, and switching frequency was determined from behavioral pattern transitions. **Results.** Based on the median value of the "Fear and Anxiety" scale from CBARQ, dogs were divided into anxious and calm groups. Anxious dogs showed higher baseline values during the stranger interaction test and greater distance from the owner during all tests. From the anxious group, excitable dogs were additionally identified. Average speed was higher in excitable dogs and anxious dogs compared to calm dogs—most pronounced in anxious dogs. Switching frequency calculations showed differences in behavioral patterns depending on the dog's psychological profile. **Discussion.** The combination of various methods made it possible to analyze possible markers of behavioral disorders, taking into account the dog's chart, visual observation (distance between frames), data on motor

activity dynamics, and behavior patterns. As spart of the pilot study, test ethograms were obtained, allowing for the objective classification of a dog's behavior type. The possibility of adding movement speed and switching frequency to the dog ethogram, as well as the results of anxiety, aggression, and excitability analysis based on owner surveys, was demonstrated. It was found that contact with humans is a manifesting factor that allows the use of selected metrics to identify problematic dog behavior.

## Keywords

pet dog, anxiety, aggression, excitability, movement speed, switching frequency, artificial intelligence, affective computing

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# Introduction

Addressing the welfare of pet dogs opens a new chapter in modern zoopsychology (MacLean et al., 2021; Farhat et al., 2024). The diversity of behavioral patterns, adaptation and adjustment of pet dogs in society, and their ability to perform specific functions underscore the importance and relevance of research aimed at properly identifying functional and dysfunctional owner-pet dyads.

Despite extensive research on the ethological characteristics of dogs during socialization and contact with humans, pet dogs remain poorly studied in contemporary Russian science. Classical cynology and zoopsychology, based primarily on analyzing working qualities of dogs, have developed test batteries that allow analysis of dogs' psychoemotional characteristics from the perspective of their application to specific tasks. Pet dogs are not identical to working and laboratory dogs due to the formation of a special type of attachment to owners, similar to child-parent relationships (Konok et al., 2015; Dodman et al., 2018; Solomon et al., 2019; Riggio et al., 2020).

Therefore, the application of objective methods for analyzing pet dog's behavior is becoming increasingly relevant. Analysis of the articles (Gähwiler et al., 2020) and the

authors' own experience reveals difficulties owners face in identifying problem behaviors in dogs without guided questions. In the owner-pet dyad, this is a key factor, and dyad dysfunction is reflected in animal behavior. Identifying signs of behavioral disturbances in animals is necessary for assessing their welfare, communication with owners in the dyad, and creating opportunities for predicting future behavior (Gähwiler et al., 2020). The importance of considering dyadic interaction is evidenced by data obtained by Ren et al. (2024) showing correlation between frontal-parietal interactions in owners and dogs during eye contact and physical touch.

The need to apply objective computational methods to solve this task—identifying temperament type, anxiety, aggression, and fear—is related, among other things, to owner subjectivity when assessing animal welfare based on questionnaire tests (Zamansky et al., 2018, 2021; Rodriguez et al., 2023). Error rates when evaluating animal behavior based solely on questionnaire tests can reach up to 50% due to the variety of diagnostic methods and interpretation approaches (Rodriguez et al., 2023). Behavioral types and characteristics of dogs' psychoemotional states that owners evaluate as preferable may actually be causes or markers of animal suffering (Serpell, 2019). Deviations in dogs' behavior and their emotional interaction with owners can also be signs of declining health. Changes in subtle behavioral signs are generally difficult to identify without using specialized computational tools due to the complexity of pattern identification (Kim et al., 2024).

In Russian, research related to applying artificial intelligence systems for analyzing dog's behavior is not represented. In contrast, this direction is new and relatively well-developed in international articles. Computational animal behavior analysis (CABA) (Zamansky et al., 2021; Farhat et al., 2024), based on automated video analysis using convolutional neural networks, eliminates observer bias and lack of necessary information about behavioral patterns of biological species. The fact that dogs' psychoemotional state and overall welfare level are reflected in motor activity indicators is undisputed (Atif et al., 2023).

Research using artificial intelligence technology can be divided into two groups: those related to algorithm development (Barnard et al., 2016; Menaker et al., 2022; Amirhosseini et al., 2024; Farhat et al., 2024) and those related to its application for identifying and solving behavioral problems (Völter et al., 2023; Schork et al., 2024). In a study by Amirhosseini et al. (2024), cluster analysis methods in four machine learning models based on owner responses to CBARQ questionnaire identified five personality and temperament types in dogs with 99% accuracy. In Schork et al. (2024), convolutional neural networks analyzed dog sleep characteristics based on posture identification with 89% accuracy. In Völter et al. (2023), a machine learning system was used as a tool to determine whether dogs could distinguish behavioral patterns in situations where humans were unwilling or unable to pass food.

Farhat N. et al. (2024), based on a meta-analysis concluded that two-dimensional visualization dominates in video data analysis, with detection and tracking tasks being key. Barnard S. et al. (2016) developed 3D software for recording and analyzing dog behavior in kennel housing (as an unnatural environment that reduces welfare). Pose analysis and body part positioning relative to the main body axis (4 positions total) were used as markers. Subsequently, this enabled identification of behavioral patterns indicating reduced welfare (for example, prolonged rest and rare decrease in active movement time percentage when dogs were in cramped kennels or housed individually). In a similar study, artificial intelligence systems enabled determination of stress levels in shelter dogs based on head position.

Menaker et al. (2022) used a promising combined approach analyzing owner survey scores and clustering video recordings of dog behavior in response to strangers to create a system for objectively differentiating anxious and calm dogs. In a similar study (Martvel et al., 2025), applying artificial intelligence to analyze the spectrum of facial emotional expressions revealed reduced mobility and expressiveness of facial expressions in brachycephalic dogs, which could potentially complicate intraspecific communication.

The capabilities of artificial intelligence methods for assessing declining dog health were demonstrated by Kim S. C. and Kim S. (2024), who, based on numerical analysis of behavioral signs (sleep, licking, swallowing, and scratching) using a trained neural network with 87.5% accuracy, developed a scoring scale where high scores correspond to adequate health and welfare levels, while values dropping below 5 warrant immediate consultation with a veterinarian and animal psychologist.

Regardless of the chosen methodology and software, the advantage of the method lies in the simplicity and low cost of collecting behavioral data through video recording (Fomina et al., 2025; King et al., 2022). At the same time, the impossibility of identifying complex behavioral patterns using only observational methods and visual analysis of recordings justifies the use of resource-intensive convolutional neural network technologies for identifying behavioral patterns and analyzing quantitative behavioral characteristics such as movement speed, switching frequency, territory coverage, etc.

Another valid method for analyzing dog behavioral activity is the use of linear and angular acceleration analysis through accelerometry (Clarke, Fraser, 2016). This method allows analysis of animal activity using a portable recording device attached to a collar or harness. Applying AI to accelerometry data analysis enables identification of recurring behavioral patterns and frequency of switching between activity types. In a study by Marcato et al. (2023), based on analysis of linear and angular accelerations from accelerometers and gyroscopes fixed on dog harnesses or collar, a pose assessment system was developed. Data patterns corresponding to static poses (standing, sitting, lying) and motor activity in dogs were identified. The method enabled classification of resting state with 0.86 accuracy and distinguishing poses with raised or lowered head with 0.9 accuracy (Ladha & Hoffman, 2023), as well as estimating and annotating dog step count and distance traveled (Ladha et al., 2018).

Video surveillance methods allow continuous recording of animal behavior in natural conditions but require resource-intensive video data coding. On the other hand, owner questionnaires are a quick and convenient way to obtain behavioral information but have high subjectivity. An integrative approach combining subjective and objective data is becoming increasingly relevant. An example of such an approach is qualitative behavior assessment (QBA), which demonstrates high reproducibility in interpreting affective states of animals (King et al., 2022).

**The aim** of this pilot study was to identify and test objective markers of problem behavior in pet dogs based on analysis of owner survey data and motor activity.

## Methods

The target group for the study consisted of pet dogs. Animals (weight from 4 to 35 kg; age from 1 to 10 years), non-neutered, not participating in professional training or dog sports were admitted to participate. The pilot sample included 35 dogs of both sexes (15 males and 20 females) of different ages and breed affiliations.

Before the examination, owners were familiarized with the purpose and protocol of the study, testing procedures, and signed informed written consent for participation and possible use of the obtained data in research and educational activities. Participation was anonymous for humans; dogs were registered according to the name provided by the owner. The examination protocol and consent form were approved by the Local Independent Ethics Committee of Don state technical university (Protocol No. 1 dated February 5, 2024).

Dogs without recent history of illness, surgery, trauma, or acute stress episodes were selected for the study. Basic description of the methodology was previously presented in Fomina et al. (2025). The testing protocol included the following behavioral tests in chronological order:

1. "Introduction"—free dog's behavior in a new territory (at least 10 minutes), aimed at reducing the novelty effect. This test showed the greatest variability in the sample and was not used for further calculations.
2. "Owner"—typical interaction of the animal with the owner without provoking stress or aggressive reactions.
3. "Unknown"—contact of the dog with an unfamiliar person in the absence of the owner. Two faculty assistants previously unfamiliar to the animals acted as unknown.
4. "Being Alone"—dog's stay on the testing ground alone.

The experiment was conducted on a specially prepared testing ground equipped in an enclosed space of 20 $m^2$. The room was equipped with a hygrometer and thermometer; temperature was maintained at 19–21 °C, humidity at 25–30%. The floor of the testing ground was marked with squares with 60 cm sides, providing the possibility of spatial assessment of movements.

Before testing, owners completed a paper version of the CBARQ (Canine Behavioral Assessment & Research Questionnaire) adapted for Russian-speaking audiences. The original version of the test was presented by the authors in an open publication (Duffy & Serpell, 2012). The test included seven scales: "Training," "Obedience," "Aggression," "Fear and Anxiety," "Separation," "Excitability," "Attachment." The test translation was pre-checked to exclude linguistic distortions. Responses were digitized in table format (R7 Office Excel); for each dog, the percentage of points scored from the maximum possible value for each scale was calculated. This approach was chosen due to possible omission of individual questions if corresponding situations had not been previously observed by the owner.

For quantitative analysis of dog motor activity, the accelerometry method was used with an autonomous sensor device based on the MPU6050 module, which includes a three-axis accelerometer and three-axis gyroscope. The 50-gram device was fixed to the animal's individual collar or harness and allowed registration of linear accelerations and angular velocities along the X, Y, and Z axes throughout the entire experiment. This approach ensured continuous recording of movements with high sensitivity without disrupting the animal's natural behavior.

**Figure 1**

*Schematic diagram of the accelerometry system components*

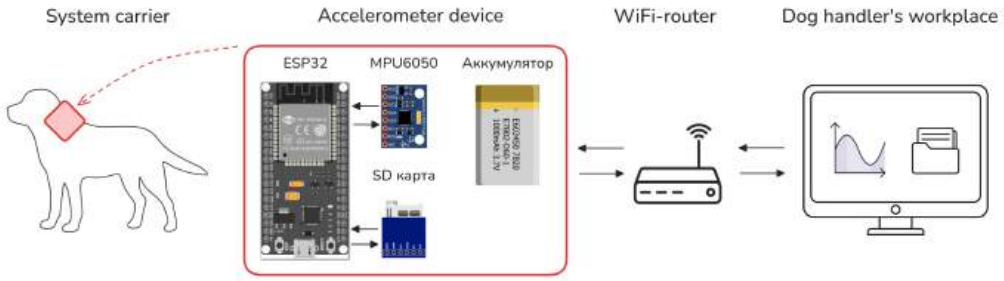



Figure 1 presents a schematic diagram of the accelerometry system components developed for monitoring dog motor activity during behavioral testing. The system includes a hardware module placed on the animal's body and remote access tools for device interaction and data retrieval. The device, fixed in the neck area, consists of an ESP32 microcontroller, MPU6050 sensor, memory card, and autonomous power source. The ESP32 microcontroller ensures data collection from the MPU6050 module, which integrates a three-axis accelerometer and gyroscope, and records this data to a microSD card in CSV format. Simultaneously, the ESP32 deploys a built-in web server that enables connection to the device from a computer via local Wi-Fi network. The web interface provides file viewing, selection, and download capabilities without requiring physical access to the device. This approach ensures autonomous and continuous collection of objective motor activity metrics with remote monitoring capability while minimizing interference with the dog's behavior during examination.

Before analysis, data preprocessing was performed, consisting of stages of correcting time stamps of records, removing duplicates and sorting data along the time axis, assessing the stability of temporal intervals based on statistical measures, signal interpolation, and setting the sampling frequency equal to 1000 Hz.

To extract hidden patterns of dog motor activity based on accelerometry data, an autoencoder was applied—a neural network algorithm trained without supervision. The model was used for automatic processing of segmented time windows of 1024 ms length, each of which included normalized values of accelerations and angular velocities. The autoencoder architecture included an encoder and decoder, trained using the mean squared error (MSE) loss function and Adam optimizer. After 80 training epochs, the loss function stabilized at a satisfactory level, indicating sufficient model convergence.

Based on the trained autoencoder model, each time segment of accelerometric data was passed through the encoder, resulting in formation of a compact vector representation of motor activity. Subsequently, transitions between different activity types were determined by analyzing differences between successive feature vectors. Thus, the autoencoder allowed transformation of raw, high-frequency data into stable behavioral features without the need for manual annotation.

Also for motor activity analysis, a video recording system was developed and implemented based on a Hikvision DS-2CD2043G2 IP camera, providing recording at 1920×1080 pixel resolution and 25 frames per second. The camera was connected to the local network and configured for continuous recording with subsequent storage of video data on external media. The device was placed stationary at a height of 10 cm from the ceiling, with an angle of inclination of approximately 60°, which allowed covering the entire area of the experimental testing ground and ensuring stable visual observation of the animal throughout the entire duration of the tests. To comply with research ethics principles, the face area of each person in the frames was subjected to blurring; the dog image was preserved in accordance with owner permissions.

The obtained video recordings were subjected to post-processing using computer vision software tools and a convolutional neural network trained on an annotated set of frames. To ensure quality behavioral analysis, recordings lasting at least 5 minutes were selected, in which the dog was present in the frame in the foreground for at least 90% of the time.

For analyzing interaction with a human in the "Owner" test, a "Contact" metric was also introduced, representing the visually assessed distance between the dog and owner in fixed frames. Frames were selected at equal time intervals (n = 10) and analyzed manually using the testing ground markings as the initial coordinate system and measurement scale. Distance was classified into the following categories: being held in arms, physical contact ("close," up to 10 cm), distance up to 50 cm, 50 to 100 cm, and 100 to 150 cm. Play behavior and active movements were excluded from assessment to increase analysis objectivity. Figure 2 shows the interface of the original software for measuring distance between owner and animal.

**Figure 2**

*Sample frame for assessing distance between owner and dog accounting for camera perspective distortions*


The system automatically outlined the dog's body, constructed movement trajectories, and calculated distances traveled. We extracted coordinates and trajectory data for each test and dog, enabling quantitative comparison of motor activity patterns across different experimental conditions.

We also generated heat maps visualizing zones of greatest activity and dog location frequency throughout the testing area. This approach allowed spatial analysis of behavior and identification of preferred and avoided zones under different test conditions.

We performed statistical data processing using R7 Office Excel, open online statistical calculators, and Python. Since the distribution of calculated data for CBARQ questionnaire scales, accelerometry metrics, and video recordings did not conform to normal distribution according to the Kolmogorov-Smirnov test ($p < 0.05$), we used nonparametric statistical methods for analysis. Intergroup differences were assessed using the Mann-Whitney U-test in pairwise comparisons. To analyze relationships between variables, we applied Spearman's correlation coefficient (two-tailed correlations). Differences were considered statistically significant at $p \leq 0.05$.

## Results

The study included 35 pet dogs, including 15 males and 20 females; this ensured a balanced sex distribution. The mean age of the dogs was $4.8 \pm 0.74$ years, with the age range varying from 1 to 10 years. Breed distribution included representatives of small, medium, and large breeds weighing from 4 to 25 kg.

Analysis of CBARQ questionnaires demonstrated the ability to obtain valid data on individual behavioral characteristics of dogs in daily life. We calculated test scales for each dog and identified key behavioral features. CBARQ scale validity was assessed using Cronbach's alpha coefficient (values of at least 0.889 for each scale).

Preliminary analysis showed no significant sex differences on this scale. For males, the mean "Fear and Anxiety" scale score was 28.05 $\pm$ 3.35%, for females 25.23 $\pm$ 2.77% ($p = 0.541$). For the "Aggression" scale, mean values were 18.03 $\pm$ 3.39% and 17.44 $\pm$ 2.15% respectively ($p = 0.87$). The absence of significant differences allowed further research without accounting for animal sex.

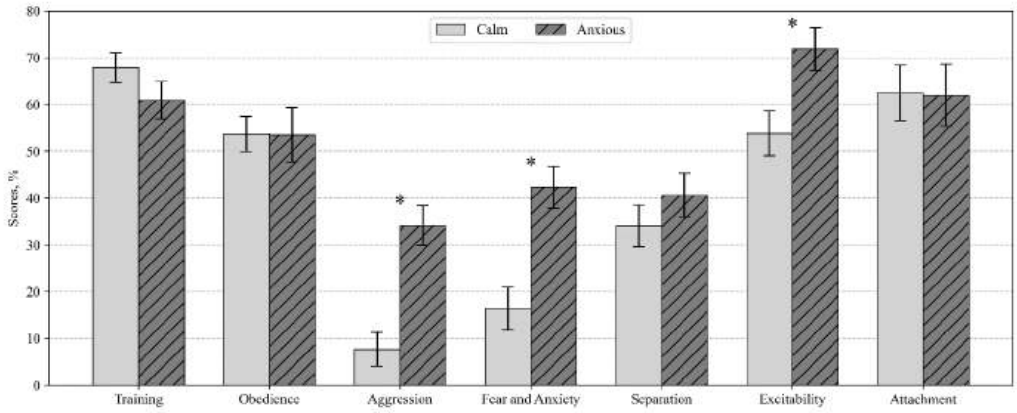
To identify dog groups, we assessed CBARQ test scale scores for 35 dogs as percentages of maximum possible scores. Dogs were sorted relative to the calculated median value on the "Fear and Anxiety" scale (29.3%). Dogs scoring below the median were classified as "Calm dogs" ($n = 16$); those above the median as "Anxious dogs" ($n = 19$). The validity and appropriateness of this division were confirmed using discriminant analysis (Wilks' Lambda = 0.063, Chi-square = 38.623, $p = 0.003$).

Based on statistical data from the CBARQ test, significant differences between "Calm dogs" and "Anxious dogs" groups were found for the following scales: "Aggression" (7.68% and 34.13%, $p < 0.001$, $U = 2.000$, $p < 0.001$), "Fear and Anxiety" (11.81% and 42.32%, $p < 0.001$, $U = 15.00$, $p < 0.001$), "Excitability" (53.82% and 71.88%, $p = 0.01$, $U = 29.00$, $p = 0.0487$).

No significant differences were found for the remaining test scales ("Training": 67.88% and 60.94%; "Obedience": 53.65% and 53.52%; "Separation": 34.04% and 40.58%; "Attachment": 62.5% and 61.98%). Figures 3 and 4 and Tables 1 and 2 below present CBARQ testing results.

**Figure 3**

*Mean CBARQ test scores (%) for "Calm dogs" and "Anxious dogs" groups (before subgroup division) (N = 35)*




*Note. The x-axis shows test scales; the y-axis shows scores as % of maximum.*

**Table 1**

*Statistical analysis results of CBARQ test scores in dog groups, as % of maximum per scale*

| Scale | Dog groups | |
|---|---|---|
| | Calm (n=18) | Anxious (n=16) |
| Training | 67.88±3.19 | 60.94±3.97 |
| Obedience | 53.65±38 | 53.5±5.78 |
| Aggression | 7.68±3.63 | 34.13±4.3<br>U=2.0, p<0.001* |
| Fear and Anxiety | 16.41±4.53 | 42.32±4.49<br>U=15.00, p<0.001* |
| Separation | 34.04±4.5 | 40.58±4.69 |
| Excitability | 53.82±4.8 | 71.88±4.6<br>U=29.00, p=0.0487* |
| Attachment | 62.5±5.9 | 61.98±6.57 |

*Note. *when comparing score values with those for the "Calm dogs" group.*

When conducting correlation analysis using the Pearson criterion for the "Calm dogs" group, no correlations of aggressive and anxious behavior features were found; a negative correlation was shown between the "Fear and Anxiety" and "Attachment" scale indicators ($r = -0.643$, $p = 0.018$). For the "Anxious dogs" group, a positive correlation was shown between the "Aggression" and "Fear and Anxiety" scale indicators ($r = 0.571$, $p < 0.001$), "Fear and Anxiety" and "Attachment" ($r = 0.60$, $p < 0.001$), and a negative correlation between the "Training" and "Obedience" scale indicators ($r = -0.727$, $p < 0.001$).

Based on the conducted analysis, the "Aggression," "Anxiety," and "Excitability" subscales were selected as most informative for determining the probability of behavioral disorders in dogs; results of the remaining subscales were not used in the study.

According to the results of visual assessment of distance between owner and dog, in the "Calm dogs" group 86.6% (11 dogs) were classified into the "Up to 50 cm" class. 6.6% of dogs sat next to the owner maintaining physical contact ("Nearby" class), 2.6% belonged to the "50 to 100 cm" class, and 4.6% to the "100 to 150 cm" class. Being held in arms by the owner was not recorded.

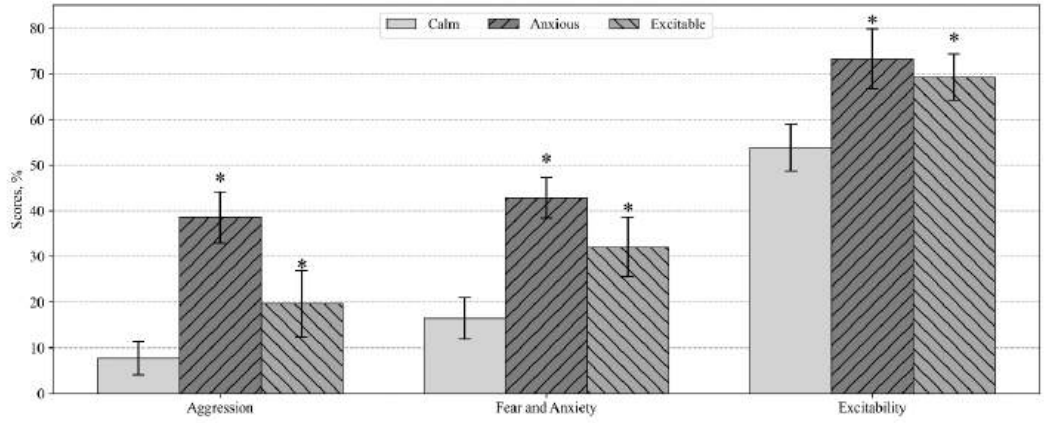
In the "Anxious dogs" group, dogs were divided into two subgroups: 47.05% of dogs were classified into the " Nearby" class, 41.17% into the "50 to 100 cm" class. 11.7% were classified into the "Up to 50 cm" class. Being held in arms was recorded in less than 1% of frames.

In connection with the identified differences in the "Contact" metric, additional analysis of the three CBARQ test scale scores in the "Anxious dogs" group also showed their heterogeneity.

For dogs whose dominant class was " Nearby," high values were shown for the "Aggression" (38.5 ± 5.57%) and "Fear and Anxiety" (42.75 ± 4.42%) scales. For dogs whose dominant class was "50 to 100 cm," significantly lower values were shown for the "Aggression" (19.64 ± 4.3%, U = 11.5, p = 0.001) and "Fear and Anxiety" (32.04 ± 6.5, U = 2, p = 0.05) scales. The high value of standard deviation is due to the small sample of dogs. It should be noted that values of the "Excitability" scale indicator did not differ between groups of anxious dogs (73.22 ± 6.6% and 69.3 ± 5.1%), but were significantly higher compared to the "Calm dogs" group (53.82 ± 5.1%, U = 20.0, p = 0.02 and U = 31.0, p = 0.035 respectively).

**Figure 4**

*Mean scores of three CBARQ test scales for groups "Calm dogs" (n = 18), "Anxious dogs" (n = 8), "Excitable dogs" (n = 7), identified based on comparison of test scores and "Contact" metric values*




*Note. The x-axis shows test scales; the y-axis shows scores as % of maximum.*

**Table 2**

*Statistical analysis results of CBARQ test scores in groups "Calm dogs," "Anxious dogs," "Excitable dogs"*

| Scale | Dog groups | | |
|---|---|---|---|
| | "Calm dogs" (n=18) | "Anxious dogs" (n=8) | "Excitable dogs" (n=7) |
| Aggression | 7.68±3.63 | 38.53±5.56<br>U=14.0, p=0.006* | 19.64±7.29 |
| Fear and Anxiety | 16.41± 4.538 | 42.75±4.42<br>U=7.00, p=0.001* | 32.041±6.49<br>U=32.0, p<0.044* |
| Excitability | 53.82±5.16 | 73.22±6.57<br>U=20.00, p=0.02* | 69.334±5.09<br>U=31.00, p=0.035* |

*Note. *when comparing score values with those obtained for the "Calm dogs" group*

In connection with this, further analysis of indicators proceeded according to three groups:

1. Combined "Calm dogs" group — 13 dogs (subdivision into subgroups was not performed).
2. "Anxious dogs" group — 8 dogs.
3. "Excitable dogs" group — 7 dogs.

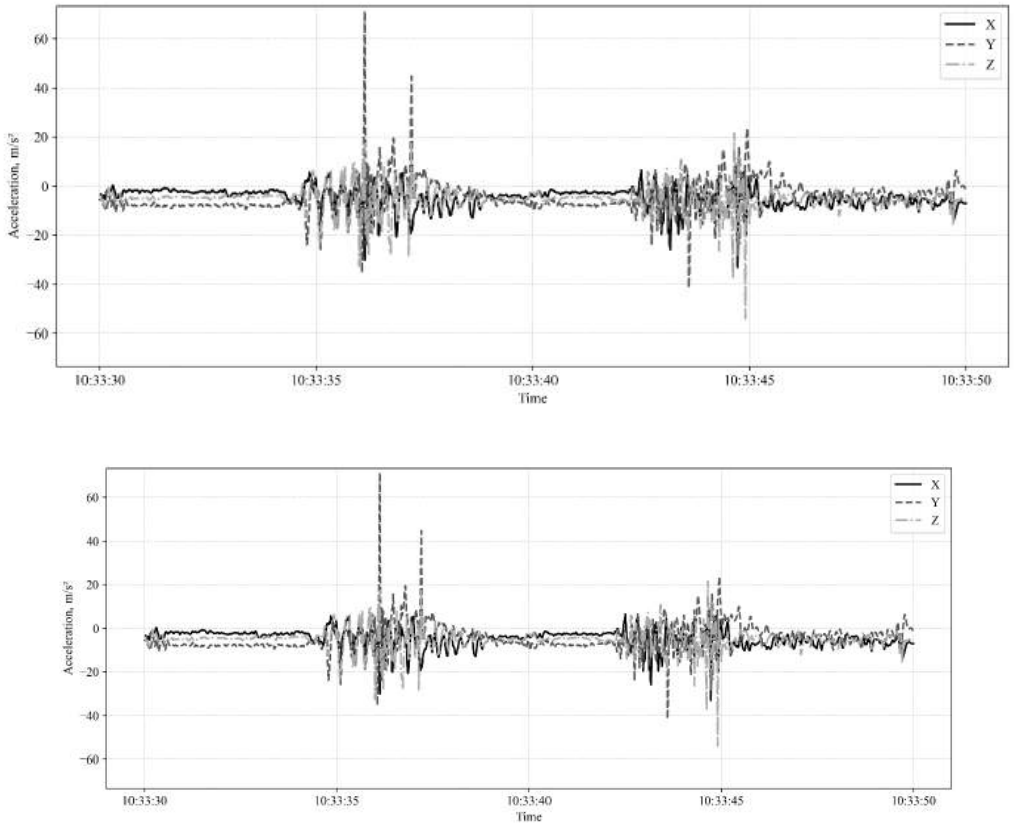
## *Motor activity assessment based on accelerometry methods*

Unprocessed data from the accelerometer were subjected to normalization in the range [0;1] and segmented into time windows of 1024 ms length. Each window was represented as a one-dimensional array of 3072 values (1024 values per axis). An autoencoder model consisting of an encoder and decoder was applied for automatic extraction of motor activity patterns. Training was conducted using the mean squared error (MSE) loss function and Adam optimizer (initial learning rate — 0.0001). The mean value of the loss function on the test sample was 0.0023, which confirms acceptable signal reconstruction accuracy and relevance of using the model for behavioral analysis.

As a result of motor activity data collection, they can be represented in the form of a graph of acceleration magnitudes and angular velocities. Figure 5 shows an example of accelerometry data with determination of dog activity type.

**Figure 5**

*Example of accelerometry data with determination of dog activity type "standing on hind legs" (top), "jumping on owner, standing on hind legs" (bottom)*




Based on the obtained time series, an integral metric was developed — the frequency of switching between activity types (act/min). The indicator reflects the number of motor pattern changes per unit of time and is a sensitive marker of excitation, anxiety, or stability of behavioral pattern in the dog.

For detailed analysis of mean speed and switching frequency indicators between four tests — "Introduction," "Owner," "Unknown," "Being Alone" in three dog groups, it was shown that for the "Switching frequency" metric in calm and excitable dog groups, no differences were revealed either between groups or between the first three tests. During transition to the " Being Alone" test, a significant decrease in switching frequency was shown in excitable dogs.

Maximum values of this metric were recorded in dogs of the "Anxious dogs" group (4.14 $\pm$ 0.08 act/min), which significantly differed from the "Calm dogs" groups (3.88 $\pm$ 0.09 act/min, $U = 12.5$, $p = 0.048$) and "Excitable dogs" (3.80 $\pm$ 0.12 act/min, $U = 10.5$, $p = 0.043$).

Additional analysis within individual tests ("Owner," "Unknown," "Being Alone") showed that in the "Anxious dogs" group, the metric reached peak values in interaction with owner and stranger, decreasing during transition to the "Being Alone" test. In excitable dogs, a significant decrease in switching frequency was observed exclusively in the "Being Alone" test, while calm dogs demonstrated stable values regardless of the situation (Table 8).

Figure 6 shows a graph of activity switching frequency for different stages of the experiment.

**Figure 6**

*Activity switching frequency during the study*

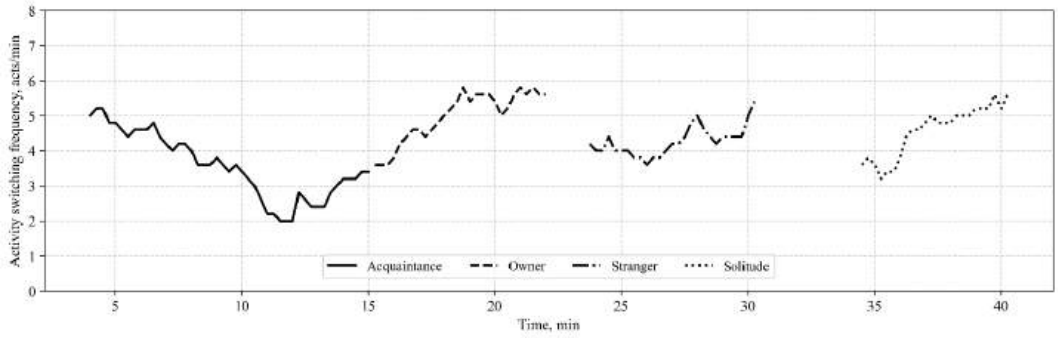
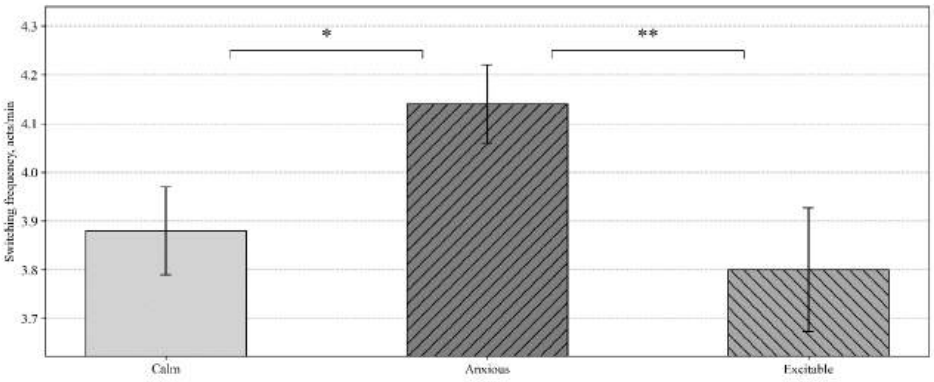



Figure 7 shows the frequency characteristics of switching between activity types for different dog groups. The table presents values of key metrics depending on the test.

**Figure 7**

*Switching frequency values between activity types in groups "Calm dogs," "Anxious dogs," "Excitable dogs," averaged over the entire examination time*




*Note. The x-axis shows dog groups; the y-axis shows switching frequency, act/min. Signs * and ** indicate significant differences in metric values between groups.*

When analyzing video recordings, the mean accuracy of the trained model on the test dataset was 92.3% at a confidence threshold of 0.5. The precision indicator reached a value of 89.7%, and recall was 91.2%. Validation set control showed loss function stabilization at a level of 0.041 by the 80th epoch, indicating that the model achieved a state of optimal training without signs of overfitting.

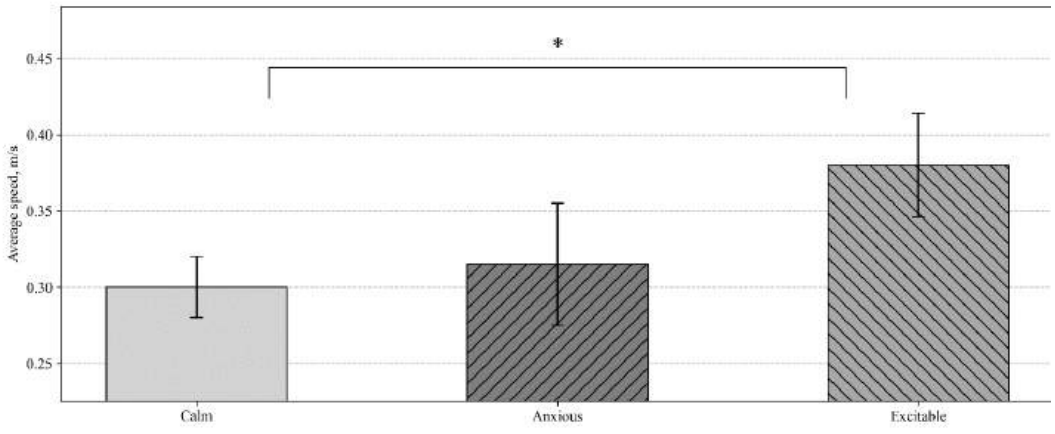
Figures 8 and 9 show motor activity metric values in different dog groups. Table 3 presents statistical characteristics of motor activity metrics. As a result of video recording processing and neural network training, the following metrics were introduced for analyzing dog motor activity:

1. Mean movement speed. When analyzing mean movement speed of dogs, maximum values of this metric were in the "Excitable dogs" group (0.38 ± 0.03 m/s) and "Anxious dogs" (0.315 ± 0.04 m/s); in the "Calm dogs" group, values were lowest (0.30 ± 0.02 m/s).

2. Distance between points as an indicator of testing ground coverage. When analyzing distance between point concentrations, maximum metric values were in the "Excitable dogs" group (2.01 ± 0.13 m/s), and minimum in the "Anxious dogs" group (1.37 ± 0.28 m/s); in the "Calm dogs" group, values were intermediate (1.94 ± 0.12 m/s). This is consistent with the "Contact" metric indicators.

**Figure 8**

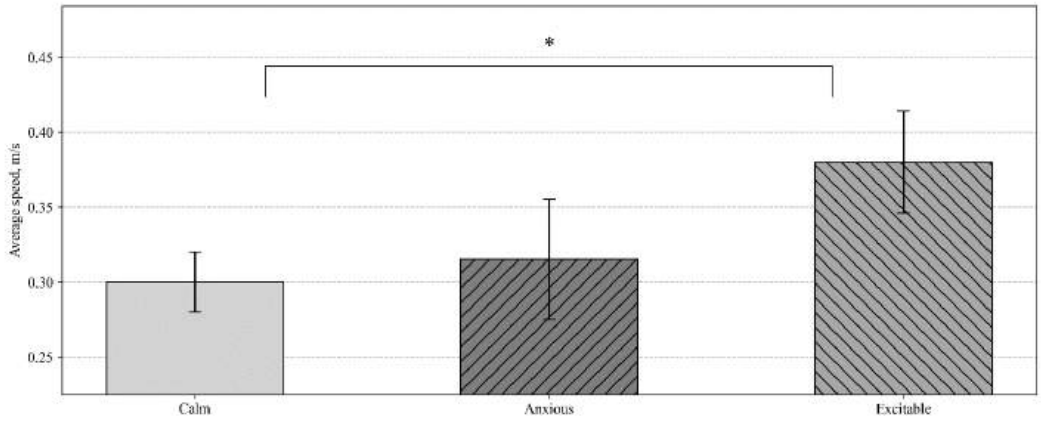
*Distance values between point concentrations in groups "Calm dogs" (n = 18), "Anxious dogs" (n = 8), "Excitable dogs" (n = 7), averaged over the entire examination time*




*Note. The x-axis shows dog groups; the y-axis shows distance, m. Signs * and ** indicate significant differences in metric values between groups.*

**Figure 9**

*Mean speed values in groups "Calm dogs" (n = 18), "Anxious dogs" (n = 8), "Excitable dogs" (n = 7), averaged over the entire examination time.*




*Note. The x-axis shows dog groups; the y-axis shows mean speed, m/s. The * sign indicates significant differences in metric values between groups.*

**Table 7**

*Results of statistical analysis of motor activity metrics in dog groups for the entire recording time*

| Metric | Dog groups "Calm dogs" (n=18) | "Anxious dogs" (n=8) | "Excitable dogs" (n=7) |
|---|---|---|---|
| Switching frequency, act/min | 3.88 ± 0.09 | 4.14 ± 0.08<br>U=12.5, p=0.048* | 3.80 ±0.127<br>U=10.5, p=0.043** |
| Distance between point concentrations, m | 1.94±0.12 | 1.37 ± 0.28<br>U=19.5, p=0.013* | 2.01 ±0.13<br>U=12, p=0.021** |
| Mean speed, m/s | 0.30 ±0.02 | 0.315 ± 0.04 | 0.38 ± 0.034<br>U=29.5, p=0.034* |

*Note. * when comparing values with those obtained for the "Calm dogs" group. ** when comparing values in the "Anxious dogs" and "Excitable dogs" groups.*

When analyzing values of the two metrics calculated separately for trials, we found that differences detected for the overall recording time were preserved (Table 8). We found no differences in the "Calm dogs" group between trials. For the "Anxious dogs" group,

we found maximum values of switching frequency in the "Owner" and "Unknown" trials. For the "Owner" and "Unknown" trials, no significant differences were found between the "Calm dogs" and "Excitable dogs" groups for both analyzed indicators. In contrast, in the "Anxious dogs" group, switching frequency and mean movement speed were higher in the "Owner" trial. In the "Unknown" trial, the situation changed: while high switching frequency was maintained, mean movement speed was significantly lower compared to both calm and excitable dogs. The "Being Alone" trial requires separate consideration, where maximum switching frequency was maintained in anxious dogs but sharply decreased, along with increased movement speed, in the "Excitable dogs" group. Based on this, this trial can be used to differentiate dogs.

**Table 8**

*Results of statistical analysis of motor activity metrics in dog groups for three trials*

| Metric | Dog groups "Calm dogs" (n=18) | "Anxious dogs" (n=8) | "Excitable dogs" (n=7) |
|---|---|---|---|
| Owner | | | |
| Switching frequency, act/min | 3.69±0.37 | 4.42±0.27<br>U=16, p=0.05 | 3.66±0.34 |
| Mean speed, m/s | 0.47±0.04 | 0.52±0.09 | 0.48±0.04 |
| Unknown | | | |
| Switching frequency, act/min | 3.65±0.34 | 4.38±0.32 | 3.86±0.29 |
| Mean speed, m/s | 0.32±0.04 | 0.24±0.03<br>U=15, p=0.46 | 0.35±0.04 |
| Being Alone | | | |
| Switching frequency, act/min | 3.00±0.51 | 3.48±0.37 | 2.74±0.35 |
| Mean speed, m/s | 0.17±0.03 | 0.17±0.03 | 0.29±0.01<br>U=23, p=0.02 |

## Motor activity assessment based on video recording and movement tracking methods

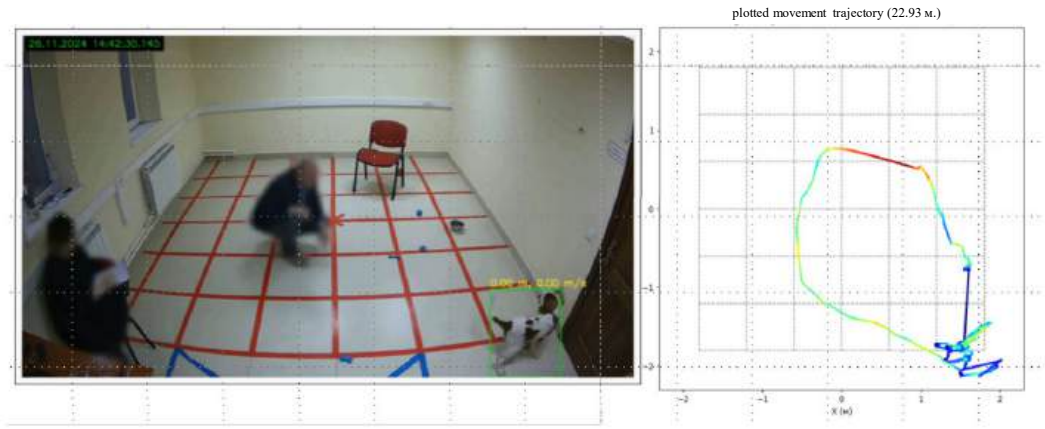
The detailed visualization and digitization of dog movement allowed us to analyze behavior in different parts of the testing ground for individual animals. Visualization was

calculated based on coordinates of the dog's position, its speed, and distance traveled. Speed characteristics were divided into quartiles and visualized on the testing ground space. We identified slow, medium, and fast movements. The proportion of medium movements is associated with exploratory behavior, the proportion of slow movements with reduced activity, and the proportion of fast movements with excitability level. Differences in speed and occupancy density can indicate different behavioral patterns. Calculation of numerical values showed that significantly higher values of the proportion of fast movements were found in the "Excitable dogs" group (26.08 +/- 1%; U = 14.0, p = 0.02) compared to the "Anxious dogs" and "Calm dogs" groups (24.22 +/- 1.1% and 22.93 +/- 1.2%).

Additionally, for data visualization, we calculated "heat maps" where line brightness corresponded to movement speed, and the number of color spots ("hot spots") corresponded to zones of maximum time spent. Visual analysis of the obtained patterns showed that the "Calm dogs" group is characterized by pattern stability and a large number of "hot spots," regardless of size, sex, and breed, whereas the "Anxious dogs" group is characterized by a small number of "hot spots" and their lability. This is consistent with the results of analyzing the "Contact" and "Distance between points" indicators. Figures 10 and 11 show the results of the tracking system based on the neural network detector.

**Figure 10**

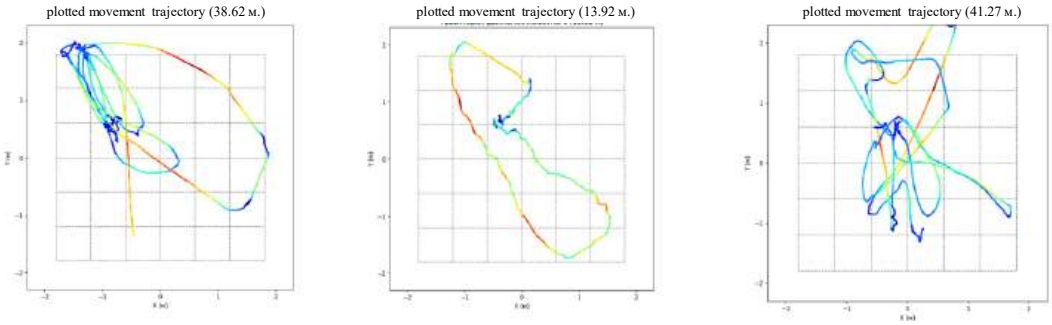
*Visual representation of tracking and speed assessment of dog movement on the testing ground*




**Note.** *On the left is an image from the video recording camera; on the right is a schematic representation of the testing ground with the plotted movement trajectory (Spaniel, male, two years old).*

**Figure 11**

*Visual representation of tracking the movement of small breed dogs. Color shows the speed of the controlled object's movement*




A - calm dog B - anxious dog C - excitable dog

Application of the approach based on a convolutional detector of dogs of different breeds in video allows us to build occupancy maps and determine density. Figure 12 shows contour plots of dog occupancy in the context of slow, medium, and fast movements.

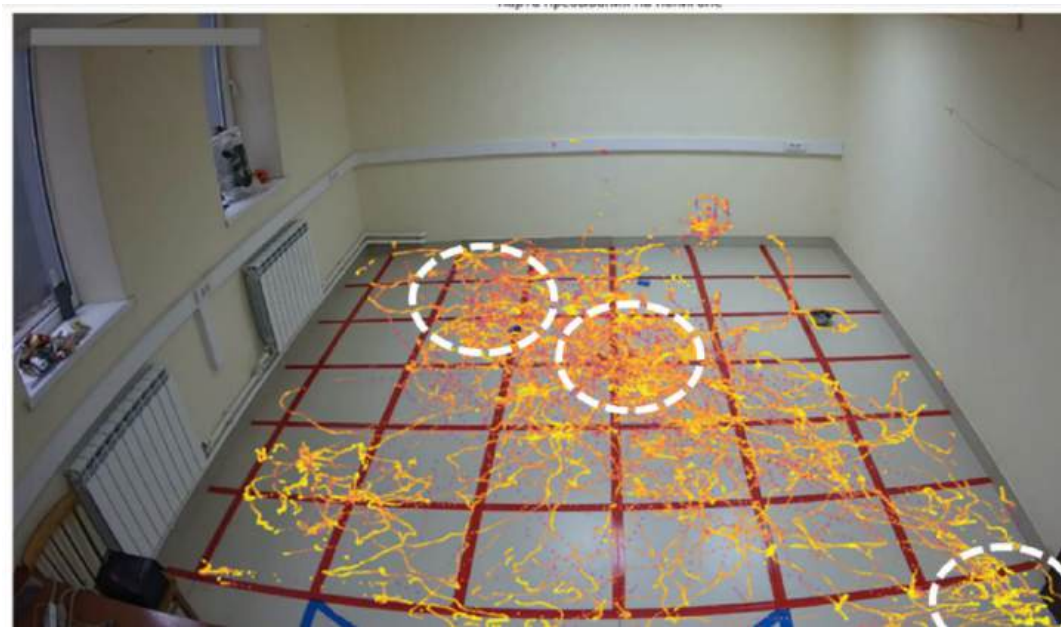
**Figure 12**

*Contour representation of dog occupancy density for slow, medium, and fast movements*


Figure 13 shows a heat map of animal occupancy throughout the entire experiment. "Warmer" colors show areas with higher occupancy density. Special markers show areas with the highest concentration of occupancy.

**Figure 13**

*Heat map of dog occupancy on the testing ground throughout the entire study*



In the "Anxious dogs" group, we found a positive correlation between mean speed and percentage of slow movements (r = 0.868, p = 0.005) and a negative correlation with medium movements (r = -0.718, p = 0.045). In the "Calm dogs" group, in contrast, we found a negative correlation between mean speed and percentage of medium movements (r = -0.753, p = 0.002) and a positive correlation with fast movements (r = 0.740, p = 0.002) and switching frequency (r = 0.668, p = 0.009). "Calm dogs" and "Excitable dogs" are characterized by pattern stability and a large number of "hot spots," while "Anxious dogs" are characterized by a small number of "hot spots" and their lability. This is consistent with the "Contact" metric and confirms the possibility of identifying a specific motor pattern for differentiating dogs.

## Discussion

Application of comprehensive methods for analyzing animal behavior includes a number of techniques that allow analysis of both physiological and behavioral indicators (Karl et al., 2020). In ethological science, the key method of analysis remains observation and analysis of behavioral aspects, including using video recordings. At the same time, visual analysis does not allow identification of certain activity patterns or calculation of movement speed and other characteristics. However, it is precisely calculation methods

that can create the possibility of objective behavior analysis and dog differentiation based on measurable metrics. This approach allows us to objectively obtain information, reduce the role of expert personal experience, and minimize the likelihood of anthropomorphism when interpreting behavioral aspects. Moreover, implementation of neural network technologies reduces the labor intensity of visual analysis when conducting such studies (Barnard et al., 2016). The importance of using objectively measurable markers is also related to the fact that due to the diversity of applicable methods in zoopsychological studies and differences in the studied populations, reproducibility of such results is no more than 50% (Rodriguez et al., 2021).

A valid marker is rapid assessment of the distance between owner and dog. Identification, already at the visual analysis stage, of differences in distance between owner and dog - primarily associated with distance shortening with increasing anxiety level and its lengthening with excitability - creates the possibility of using this metric for rapid analysis of relationships in the dyad. The chosen method of selecting frames in which precisely the dog, not the owner, determines the analyzed distance also allows using this metric to analyze the possibility of using the owner as a safe haven. This concept finds confirmation in the literature (Gacsi et al., 2013; Karl et al., 2020).

Based on CBARQ test analysis for the pilot sample, the most valid were high scores on the "Aggression," "Anxiety," and "Excitability" scales, which in combination with the "Contact" metric allowed objective identification of three dog groups. Considering the CBARQ test indicator analysis, we can assume that in the "Anxious dogs" group, the main factors of problem behavior may be aggression, anxiety, and excitability, while in the "Excitable dogs" group, excitability and to a lesser extent anxiety.

In our study, the small weight of the accelerometer and use of the dog's own collar reduces such a disadvantage of accelerometry as invasiveness due to the need to wear the device. Testing and database collection confirmed the possibility of its use, including in small breed dogs. Visual observation showed adaptation time to the device from one to three minutes depending on dog size. The totality of data obtained through video recording provided comprehensive characterization of behavioral patterns, including both quantitative indicators of motor activity and parameters of social interaction with humans. Based on motor activity analysis results, we selected markers for dog differentiation, key among which were distance between human and dog, mean movement speed, switching frequency, distance between concentration points, and percentage of fast movements. We used these metrics subsequently for classifying dogs by behavior type and analyzing differences between experimental groups.

The obtained data indicate that accelerometry allows differentiation of behavioral reaction types in animals with different behavioral profiles. Switching frequency between activities can serve as an additional objective marker of anxiety and excitability under near-natural conditions. Particularly important is that using a neural network model (autoencoder) allows processing large arrays of native data without the need for manual labeling. Visual analysis of accelerometry signals also allowed identification of specific activity patterns: standing on hind legs, jumping, and interaction with the owner. These episodes are consistent with video recording observations and confirm the accuracy of spatiotemporal positioning.

Based on digitization of three video analysis metrics, we showed that dogs for which increased excitability is assumed as a predictor of behavioral problems are characterized by the highest movement speed and maximum coverage of the testing ground area. Anxious dogs are characterized by high switching frequency between activity types, high movement speed, and small coverage of testing ground area. Intergroup comparisons showed the possibility of using the "Owner" and "Being Alone" trials for differentiating anxious and excitable dogs, since anxious dogs had higher switching frequency values. In a healthy dyad, owner presence could increase exploratory activity, which also finds confirmation in studies (Volter et al., 2022; 2023).

Hence, we can assert that based on analysis of switching frequency and decreased values in the "Being Alone" trial compared to interaction with humans, we can separate excitable dogs from calm ones, and values in the "Owner" trial can separate anxious dogs from calm and excitable ones.

Based on this, we can assume that contact with humans itself is a revealing situation for identifying problem behavior in dogs, the marker of which in this case can be considered the expression of exploratory behavior. The highest indicators of both metrics compared to those for human absence also indicate the revealing role of contact with humans. At the same time, for calm dogs as the most stable group, absolute differences between metric values were minimal.

The combination of high activity, switching frequency, and short distance from humans corresponds to decreased exploratory behavior in the anxious dogs group. This is confirmed by decreased movement speed during contact with an unfamiliar person, where exploratory behavior probably decreased even more. In contrast, for excitable dogs, human presence, due to similar values of studied indicators with the "Calm dogs" group, is a stabilizing factor. This is evidenced by excessive excitability manifesting in the "Excitable dogs" group only in the "Being Alone" trial. It should be noted that the two groups

of dogs with potentially problem behavior reacted differently to the absence of human contact. Despite decreased absolute values in this trial, anxious dogs still demonstrated maximum switching frequency, while excitable dogs demonstrated movement speed.

Moreover, these metrics can be interpreted from the perspective of the behavioral synchronization concept based on interspecific motor resonance and involvement of the mirror neuron system (Duranton et al., 2016; Lamontagne & Gaunet, 2024). In this regard, optimal is the use of trials related to contact with humans as revealing when determining the type of behavioral disturbances in dogs. Decreased motor activity and high switching frequency in the "Anxious dogs" group can be explained from the perspective of the deprivation syndrome concept. According to this concept, increased anxiety is accompanied by decreased exploratory behavior and motor activity in general, as well as activation of voluntary attention and increased vigilance (Zamansky et al., 2018). Based on our data, this concept also finds confirmation in increased switching frequency (as a reflection of voluntary attention), short distance between owner and dog, and a small proportion of fast movements around the testing ground (decreased exploratory behavior).

Thus, the combination of various methods allowed us to obtain a picture considering history (CBARQ), visual observation (distance by frames), data on motor activity dynamics using a wearable accelerometer, and data on behavior patterns using a stationary video camera. In total, already within the pilot study, we obtained test ethograms that allow objective classification of dog behavior type.

Common indicators for anxious and excitable dogs were high switching frequency and mean movement speed, and high scores on the "Excitability" scales. For anxious dogs, we determined high scores on the "Anxiety" and "Aggression" scales, short distance between dog and owner as well as activity concentration points, and high switching frequency in the "Owner" trial. For excitable dogs, we determined high movement speed and switching frequency, high percentage of fast movements, and large distance between activity concentration points and between dog and human.

Since it is behavior that is a reflection of the level of well-being and adaptability of dogs, behavioral parameters can and should underlie the methodology for assessing the level of anxious and aggressive behavior (Barnard et al., 2016).

Measurable indicators such as movement speed and switching frequency can be used as markers for analyzing probable disturbances in the adaptation process and predicting behavioral disturbances. This approach eliminates such an obvious disadvantage of measurable methods using biochemical indicators as invasiveness and the need to use expensive reagents (Miller et al., 2022) while allowing reproducible results.

## Conclusion

This article presents a pilot study aimed at comparing data obtained from owners using the validated CBARQ questionnaire with objective parameters of motor activity in pet dogs. We used accelerometry and automated video recording analysis with convolutional neural networks as objective recording tools. The use of inexpensive video surveillance equipment and wearable sensors makes the proposed approach technologically accessible and promising for wide practical application and research in human and veterinary medicine. At the same time, it is necessary to consider that this study is a pilot and is based on a relatively small sample size.

Combining video tracking, accelerometry, and owner surveys can become the basis for a comprehensive system for assessing the psychoemotional state of animals. At the same time, questionnaire data can be used as an additional verification tool, compensating for possible AI errors associated with insufficient model training. This is especially relevant in the context of ongoing dataset formation in this field.

The advantage of such an approach is the simplicity of data labeling, their comprehensibility for interpretation, and the possibility of using short video fragments, which is consistent with approaches adopted in the literature for applying artificial intelligence, including for analyzing animal behavior (Martvel et al., 2025).

An ethogram as a set of behavioral activities of animals in certain situations can and should be used to analyze the level of animal welfare. The classical ethological method of observing animals in natural and controlled conditions allows, with certain competencies, identification of behavior patterns and their correlation with changes in dog adaptability level. At the same time, the method has quite high error rates due to possible observer bias, diversity of behavioral patterns, and influence of factors such as sex, age, and breed characteristics. Also, the visual observation method and ethogram construction, due to obvious limitations, is possible only over relatively short time periods.

Moreover, since the dog is a universal experimental animal maximally close to humans (compared to other small animals), competent behavior analysis based on motor activity can become an important aspect of conducting laboratory and clinical studies.

Application of artificial intelligence systems allows significant improvement of metric reliability and validity of applicable methods in general (Stubsjoem et al., 2022) by reducing bias and enabling calculation of indicator values. At the same time, despite obvious advantages, artificial intelligence methods can also be biased, since compilation of training datasets and subsequent interpretation of obtained data requires expert human participation (Menaker et al., 2022). Therefore, it is necessary to consider that

neural networks are primarily a tool for analyzing large volumes of empirical data, and expert opinion remains decisive.

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# Homework Motivation Questionnaire

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## Abstract

**Introduction.** The issue of homework is one of the most acute and relevant for modern schoolchildren, as well as for their parents and teachers. While educators do not doubt the benefits of homework to improve learning skills and foster independence, students often respond with reluctance to complete it. In Russian psychology, there is a lack of diagnostic tools for assessing different types of homework motivation. The aim of this study was to develop a new diagnostic instrument for assessing homework motivation among students in grades 3-11 of secondary schools. **Methods.** The proposed Homework Motivation Questionnaire (HMQ) assesses three characteristic types of motivation – autonomous motivation, introjected motivation, and external motivation; the theoretical foundation of the questionnaire is Self-Determination Theory. To test the validity of the questionnaire on a large sample of students from elementary, middle, and high school (N=1854), measures of satisfaction of basic psychological needs at school, academic performance, perseverance, as well as satisfaction with school, teachers, family, and self were used. **Results.** Analysis of the factor structure and psychometric properties of the questionnaire showed that it is characterized by acceptable indices of internal consistency and a factor structure consistent with theoretical expectations. The validity of the scales is confirmed by correlations with indicators of basic needs satisfaction at school and life satisfaction. The importance of autonomous motivation for perseverance and academic achievement is demonstrated, as well as the dynamics of the three types of homework motivation from elementary to middle and high school among students in mainstream schools.**Discussion.** A new compact homework motivation scale has been developed,

which can be useful both for further research on the role of psychological predictors of homework perseverance and in the practical work of school psychologists to identify adolescents at risk of low academic performance.

**Keywords**
homework motivation, self-determination theory, questionnaire, validity, reliability, perseverance, academic performance, schoolchildren

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## Introduction

The aim of the present study is the development of a homework motivation questionnaire. Survey results from parents, teachers, and students themselves show that the volume of homework constitutes one of the most acute problems for modern schoolchildren, associated with student overload (Arshinskaya, 2014), stress and negative health consequences (Katz et al., 2012; Zhao et al., 2024), a decline in their learning motivation, and growing negative attitudes towards school (Uskova, 2017). Data from international OECD studies on representative samples of fifteen-year-old students indicate that the time spent by Russian adolescents on homework is among the highest among these countries (1st place - China, 2nd place - Russia, 9.7 hours per week, 3rd place - Singapore) (OECD, 2012). Psychological and pedagogical aspects of homework are actively researched and discussed abroad in recent years (Tagunova, 2020; Cooper, 2015), and to a much lesser extent in Russia, which may be related, among other things, to the lack of appropriate Russian-language diagnostic instrument.

To date, the problem of issues of motivation, its types, origins, and consequences has been theoretically, empirically, and methodologically developed within Self-Determination Theory (E. Deci and R. Ryan). The theory is well-applicable to the educational context (Ryan & Deci, 2020). There exist reliable and valid measures for assessing different types of academic motivation in students at different educational levels: elementary

school students (Gordeeva et al., 2020), middle and high school students (Gordeeva et al., 2017). Data obtained with these measures indicate that intrinsic and identified motivation (together forming autonomous motivation) are related to perseverance and academic performance, while controlled external motivation is related to and is a predictor of cheating, reduced well-being, anxiety, and other negative emotions (Gordeeva & Sychev, 2024b; Howard et al., 2021), whereas introjected motivation occupies an intermediate position. These findings are confirmed not only by correlational but also by experimental and qualitative studies of motivation (Katz et al., 2011).

Previous research convinces that information about a student's dominant types of homework motivation will be an important addition to information about their general academic motivation profile. Although homework is part of the overall learning process, its uniqueness lies in the fact that it is done at home, presumably by student alone. Accordingly, the reasons motivating children and adolescents to work in the classroom and at home may differ due to the different contextual environment.

In the international literature, despite dozens of studies dedicated to different types of classroom academic motivation and their consequences (Howard et al., 2021), homework motivation has only recently begun to be studied. Firstly, Katz and her colleagues, based on Self-Determination Theory, developed a homework motivation questionnaire distinguishing two types of motivation – autonomous (the desire to do homework due to interest and understanding its importance for the future) and controlled motivation (motivation driven by external control and pressure from parents and teachers, fear of punishment, as well as personal feelings of shame and a desire to get good grades) (Katz et al., 2011). The questionnaire consists of 19 items; its reliability is shown (Cronbach's alpha equals 0.93 and 0.88 for the two scales, respectively); the scales are not correlated. This questionnaire has been adapted and widely used in China (Liu et al., 2017). Secondly, a short questionnaire of autonomous homework motivation was also used in a study by Nunez et al. (2019).

Research conducted in recent years has shown a link between autonomous homework motivation and less student procrastination in completing homework and higher self-efficacy (Katz et al., 2014), as well as cognitive engagement in its quality completion (Nunez et al., 2019). These results demonstrate that the type of homework motivation is important for success in academic activities.

## Methods

Subjects were 1854 students in grades 3-11 from a Moscow school, including 915 girls, 903 boys, and 36 children who did not indicate their gender. The sample comprised 492 (26%) elementary school students, 1074 (58%) middle school students, and 288 (16%) high school students. The average age was 12.51 years, SD = 3.44. The survey was anonymous, participants took part in study voluntarily in their classrooms using paper forms.

We created items for the Homework Motivation Questionnaire (HMQ) relying on the text of similar international instruments (Katz et al., 2011), as well as Russian-language questionnaires for assessing academic motivation in general (Gordeeva et al., 2017). However, considering the data from studies by I. Katz and colleagues (Katz et al., 2010, 2011), where subtypes within controlled motivation were not distinguished, we decided to represent this scale in more detail, distinguishing introjected and external motivation. We assumed that their effects would correspond to the idea of a motivational continuum (Sheldon et al., 2017). Items were developed for autonomous, introjected, and external motivation. Considering the complex composition of autonomous motivation demonstrated in previous research (Gordeeva et al., 2017; Vallerand et al., 1992), items measuring motives to know, self-development motives, and motives related to understanding the importance of learning (identified motives) were included in its structure. The resulting questionnaire along with instructions and response scales is provided in the Appendix.

To analyze the validity of the HMQ, we used a set of instruments measuring basic psychological needs satisfaction at school, academic perseverance.

The Basic Psychological Needs Satisfaction at School Questionnaire (Gordeeva & Sychev, 2024a) was used to assess satisfaction of needs for autonomy, competence, relatedness with teachers and peers, as well as frustration of the autonomy need.

To assess academic perseverance, we used the Academic Perseverance Scale (Gordeeva & Sychev, 2024b).

To assess life satisfaction, we used four scales from the Multidimensional Students' Life Satisfaction Scale: Family, School, Teachers, and Self (Sychev et al., 2018; Huebner, 1994). This scale was administered only to middle and high school students.

We used students' self-reported grades for the past academic quarter in all subjects except physical education to calculate the grade point average (GPA) as an indicator of academic performance.

### *Data Analysis Methods*

Data analysis was conducted using descriptive statistics, confirmatory factor analysis (CFA), correlation analysis, Mann-Whitney U test, and Kruskal-Wallis test. Computations were performed in the R statistical environment, CFA was conducted using the Mplus 8 program (Wang & Wang, 2020). The following indices were considered acceptable (good) for model fit (Mueller & Hancock, 2018): CFI > 0.90 (0.95), RMSEA < 0.08 (0.06), SRMR < 0.08 (0.06). The proportion of participants with missing values in each sample did not exceed 5%. Pairwise deletion was used in correlation analysis. CFA was conducted using the Full Information Maximum Likelihood (FIML) method (Enders & Bandalos, 2001), which provides the most efficient model estimation based on all available observations.

Due to the large sample size and the number of statistical tests performed, we interpreted only the results statistically significant at $p < 0.001$.

## Results

In the process of analyzing the factorial structure of the questionnaire we considered four alternative models: 1) a one-factor model; 2) a two-factor model including factors of autonomous and controlled motivation; 3) a three-factor model including factors of autonomous, introjected, and external motivation; 4) a similar three-factor model with added covariances between pairs of items belonging to separate subscales of the autonomous motivation scale. According to CFA results (Table 1), the three-factor model had acceptable fit, and the three-factor model with additional covariances had good fit. The latter model is presented in Figure 1.

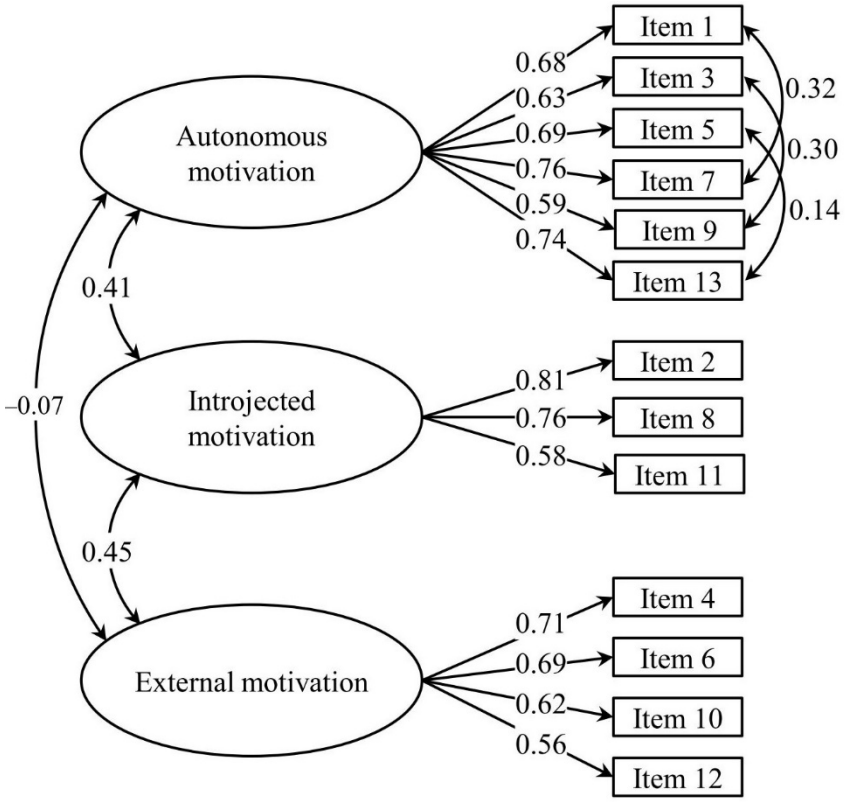
**Table 1**
*Results of Confirmatory Factor Analysis of Alternative HMQ Models*

| Model | $\chi^2$ | *df* | *p* | CFI | TLI | SRMR | RMSEA [90% CI] |
|---|---|---|---|---|---|---|---|
| 1. 1F | 3066.91 | 65 | < 0.001 | 0.54 | 0.448 | 0.149 | 0.158 [0.153, 0.163] |
| 2. 2F | 1606.79 | 64 | < 0.001 | 0.763 | 0.712 | 0.099 | 0.114 [0.109, 0.119] |
| 3. 3F | 597.22 | 62 | < 0.001 | 0.918 | 0.897 | 0.049 | 0.068 [0.063, 0.073] |
| 4. 3FC | 334.45 | 59 | < 0.001 | 0.958 | 0.944 | 0.043 | 0.050 [0.045, 0.055] |

*Notes. Models: 1F — one-factor, 2F — two-factor, 3F — three-factor, 3FC — three-factor model with pairwise item covariances. CFI — comparative fit index, TLI — Tucker-Lewis index.*

**Figure 1**

*Structural Model of the HMQ (all coefficients shown are statistically significant at $p < 0.05$; residuals omitted for clarity).*




Thus, the expected scales and subscales of the questionnaire was confirmed by the CFA results. The internal consistency of scales and subscales was acceptable across all age groups (see Table 2).

**Table 2**

*Internal Consistency Coefficients (Cronbach's Alpha) of HMQ Scales in Different Samples*

| Scales and subscales of HMQ | The whole sample (N = 1848) | Elementary school (N = 489) | Middle school (N = 1071) | High school (N = 288) |
|---|---|---|---|---|
| *Main Scales of HMQ* | | | | |
| Autonomous motivation | 0.85 | 0.84 | 0.84 | 0.85 |
| Introjected motivation | 0.75 | 0.75 | 0.73 | 0.79 |
| External motivation | 0.74 | 0.74 | 0.74 | 0.70 |

| Scales and subscales of HMQ | The whole sample (N = 1848) | Elementary school (N = 489) | Middle school (N = 1071) | High school (N = 288) |
|---|---|---|---|---|
| *Subscales of autonomous motivation* | | | | |
| Motivation to know | 0.80 | 0.82 | 0.79 | 0.71 |
| Self-development motivation | 0.78 | 0.76 | 0.78 | 0.78 |
| Identified motivation | 0.76 | 0.73 | 0.74 | 0.77 |

Descriptive statistics for the HMQ scales and their correlations with other indicators are presented in Table 3. Correlations of HMQ scales with GPA proved the productive nature of autonomous and introjected motivation, while no association between GPA and external motivation was discovered. Differences in the effects of various motivation types are more pronounced with respect to perseverance: its correlation with autonomous motivation is strong, with introjected motivation — weak, and with external motivation — weak and negative. We also obtained the expected correlations of motivation scales with satisfaction/frustration of basic needs and with life satisfaction indicators.

**Table 3**
*Descriptive Statistics and Correlations of HMQ Scales with Other Variables*

| Scales | *N* | Scales of HMQ | | |
|---|---|---|---|---|
| | | Autonomous motivation | Introjected motivation | External motivation |
| GPA | 1779 | 0.23* | 0.14* | –0.04 |
| Perseverance | 1842 | 0.69* | 0.20* | –0.14* |
| Autonomy need satisfaction | 1848 | 0.38* | 0.04 | –0.20* |
| Autonomy need frustration | 1848 | –0.38* | –0.01 | 0.25* |
| Competence need satisfaction | 1848 | 0.51* | 0.14* | –0.10* |
| Relatedness need satisfaction (teachers) | 1848 | 0.49* | 0.19* | –0.06 |
| Relatedness need satisfaction (peers) | 1848 | 0.33* | 0.05 | –0.18* |
| MSLSS Family | 1337 | 0.37* | 0.04 | –0.30* |

| Scales | *N* | Scales of HMQ | | |
|---|---|---|---|---|
| | | Autonomous motivation | Introjected motivation | External motivation |
| MSLSS School | 1337 | 0.66* | 0.17* | −0.21* |
| MSLSS Teachers | 1337 | 0.56* | 0.19* | −0.15* |
| MSLSS Self | 1337 | 0.33* | 0.01 | −0.26* |
| Mean | 1854 | 3.55 | 3.08 | 2.66 |
| Standard deviation | 1854 | 0.96 | 1.20 | 1.13 |
| Skewness | 1854 | −0.48 | −0.07 | 0.33 |
| Kurtosis | 1854 | −0.38 | −0.99 | −0.86 |

***Notes.*** *Statistical significance: * — $p \le 0.001$. Correlations with subscales of autonomous motivation are not given due to their redundancy and similarity to correlations for the autonomous motivation scale.*

Analysis of differences between boys and girls (Table 4) revealed that boys had higher external motivation, while no differences were found for other motivation types.

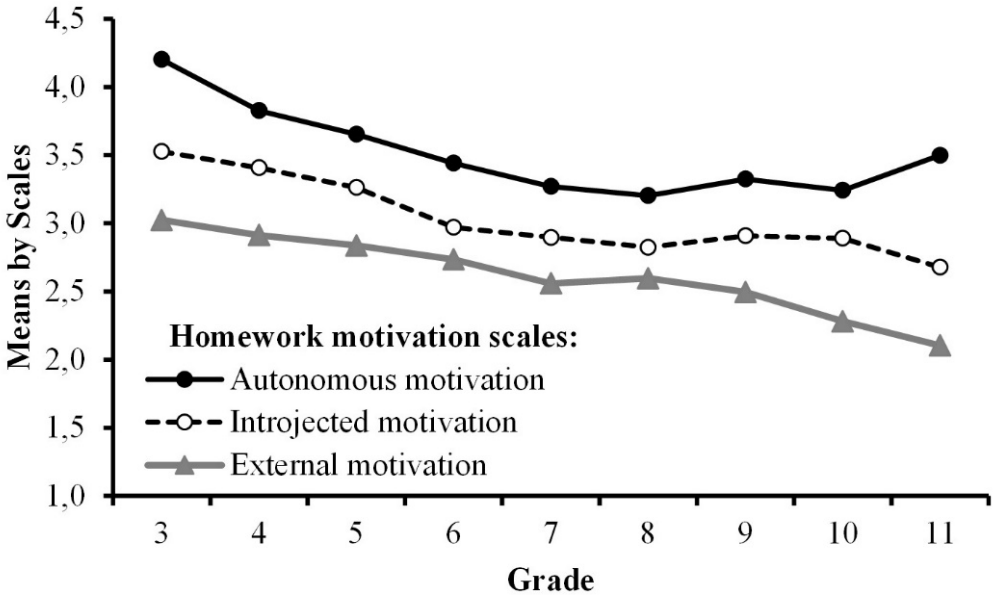
**Table 4**
*Differences in HMQ Scale and Subscale Scores Between Boys and Girls*

| Scales and subscales of HMQ | Means | | Standard deviations | | *Cohen's d* | *Mann–Whitney U test* | *z(U)* | *p* |
|---|---|---|---|---|---|---|---|---|
| | Girls | Boys | Girls | Boys | | | | |
| Autonomous motivation | 3.54 | 3.57 | 0.93 | 0.98 | 0.04 | 401284.5 | 1.06 | n.s. |
| Introjected motivation | 3.13 | 3.04 | 1.19 | 1.20 | 0.08 | 431427.5 | 1.73 | n.s. |
| External motivation | 2.50 | 2.83 | 1.10 | 1.14 | 0.30 | 342111.5 | 6.29 | <0.001 |
| Motivation to know | 2.91 | 3.01 | 1.17 | 1.23 | 0.09 | 391422 | 1.88 | n.s. |
| Self-development motivation | 3.81 | 3.85 | 0.99 | 1.02 | 0.03 | 399390 | 1.12 | n.s. |
| Identified motivation | 3.86 | 3.78 | 1.02 | 1.09 | 0.08 | 426382.5 | 1.19 | n.s. |

***Notes.*** *n.s. — not significant.*

Comparison of motivation scales across age groups by grade (Figure 2) showed that all three types of motivation decline with age, although autonomous motivation became more stable in high school and even showed a slight upward trend in grade 11.

**Figure 2**
*Homework Motivation Indicators Across Different Age Groups (by Grade).*




Statistically significant differences between grades in the level of autonomous motivation were found using the Kruskal-Wallis test: $H(8)=202.61$; $p < 0.001$. Similarly, significant age differences were revealed by introjected ($H(8)=91.82$; $p < 0.001$) and external motivation ($H(8)=95.74$; $p < 0.001$).

## Discussion

Given the significance of the homework problem in modern children, a Homework Motivation Questionnaire applicable to schoolchildren starting from elementary school age has been developed. The questionnaire aims to diagnose three types of motivation – autonomous, introjected, and external. The presented data testify to its reliability and validity; thus, it can be used with students of different age groups.

The results of the study confirmed the suitability of the proposed scale for assessing homework motivation in schoolchildren, starting from the third grade, i.e. 8-9 years old. They indicate acceptable internal consistency of the scale and the expected factor structure. Evidence of the scale's validity, also illustrating the importance of considering different types of homework motivation, are the discovered moderate yet highly

significant correlations with the average grade point. The most convincing evidence of validity are the obtained correlations of the scales with academic perseverance, which determines its effectiveness. The validity of the proposed scale is also confirmed by its links with indicators of basic psychological needs satisfaction at school and frustration of the need for autonomy. Expected links with life satisfaction indicators also testify to the validity of the scales.

All three types of motivation decrease with higher grade levels; although autonomous motivation shows a tendency to increase in grade 11, which may be related to the selection factor which in common for Russian schoolchildren when transitioning to high school. The data on the decline of autonomous homework motivation in middle grades align well with data obtained by Katz and her colleagues, who found a decrease in autonomous homework motivation from grade 4 to grade 8 among Israeli schoolchildren, which was also associated with a less positive perception of teachers as being less supportive of basic psychological needs (Katz et al., 2010). This is also consistent with data on the age-related decline in intrinsic motivation, interest, and perceived utility of homework in Spanish schools (Regueiro et al., 2015) and Chinese schools (Hong et al., 2009). The discovered pattern itself is of substantial interest and requires further research. The decline in autonomous motivation may be a cause of declining academic performance, which is also related to the general decrease in academic motivation. We assume that this result is largely related to the teaching methods and programs used, teachers' interaction styles with students, and the feedback they provide.

It is shown that external motivation is more pronounced in boys, which indicates that they feel more pressure from parents and may correspond to their lower academic achievements in most school subjects, except for mathematics (Tikhomirova & Malykh, 2023; Chertkova & Pyankova, 2014). The possible subject-specific nature of these gender differences is evidenced by the fact that in a study of Chinese students, boys were characterized by more pronounced autonomous motivation for doing mathematics homework (Feng et al., 2019).

The proposed measure provides broad opportunities for further research on students' academic motivation, causes of their underachievement, and unproductive academic behaviors, including cheating. The developed questionnaire will allow Russian researchers in the fields of motivation psychology and educational psychology to investigate the different types of schoolchildren's homework motivation as a predictor of their academic success, as well as to study various environmental and educational factors influencing it, including the role of teachers and parents.

A limitation of the study is the absence of concurrent validity indicators, which is due to the lack of alternative Russian-language tools for assessing homework motivation. The relationship between homework motivation and general academic motivation may be of interest and represents a direction for future research.

## Conclusions

As a result of the conducted research, based on modern developments in the psychology of motivation, namely self-determination theory, a compact instrument for assessing homework motivation among students in grades 3-11 of secondary schools has been proposed. The developed instrument assesses three most characteristic types of motivation — autonomous, introjected, and controlled, each of which has its own associations with perseverance, academic achievement, and indicators of satisfaction with learning activities.

The questionnaire has a theoretical foundation, i.e. Self-Determination Theory, builds upon previous developments in this direction, and is characterized by acceptable levels of internal consistency and a factor structure consistent with theoretical concepts. Evidence supporting the validity of the questionnaire has been obtained, convincingly demonstrating the importance of autonomous homework motivation for perseverance and academic achievement in samples of both middle/high school and elementary school students.

The questionnaire may be useful to researchers studying motivation and academic achievement. The questionnaire can be also useful for school psychologists to identify students at high risk of low academic achievement, as well as to assess the effectiveness of new pedagogical approaches to homework.

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# Appendix

## *Homework Motivation Questionnaire (HMQ)*

Please read the statements carefully and mark the answer that suits you best. Use the following scale for your responses: 1 = False (NO), 2 = Rather false, 3 = Neither true nor false, 4 = Rather true, 5 = True (YES)

**I do my homework because...**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. I enjoy doing lessons. | | | | | |
| 2. I would be ashamed if I didn't do them. | | | | | |
| 3. I feel I am developing by solving challenging tasks. | | | | | |
| 4. Otherwise, I will have problems with my parents. | | | | | |
| 5. It will help me succeed in school. | | | | | |
| 6. I don't want to be scolded by my parents. | | | | | |

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 7. I love learning. | | | | | |
| 8. I am ashamed to get bad grades. | | | | | |
| 9. I like knowing and being able to do more and more. | | | | | |
| 10. I am not allowed to do anything else until they are done. | | | | | |
| 11. I feel guilty for not doing it. | | | | | |
| 12. I have no choice; I must do it. | | | | | |
| 13. It will help me in the future to become who I want to be. | | | | | |

**Scoring Key:**

Autonomous motivation: items 1, 3, 5, 7, 9, 13.

Introjected motivation: items 2, 8, 11.

External motivation: items 4, 6, 10, 12.

For a more detailed analysis, subscales of the autonomous motivation scale can be used: motivation to know — items 1, 7; self-development motivation — 3, 9; identified motivation — 5, 13.

## Author Contributions

**Tamara O. Gordeeva** – research idea, conceptualization, questionnaire development, data collection, Introduction, Discussion, Conclusion.

**Oleg A. Sychev** – questionnaire development, data analysis, Methods, Results, Discussion.

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## Conflict of Interest Statement

The authors declare no conflict of interest.