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EMPIRICAL ARTICLE

Mental Imagery Representation by Model of Spots in Psychology

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Abstract: This paper considers in general the concept of a new mathematical model of spots with the apparatus and its possible application for the representation of mental imagery. The inherent spatial properties of imagery make it possible to represent them as spots, which are models of vague spatial objects. The proposed approach allows modeling mental operations also, in particular, nonmonotonic reasoning, when conclusions are drawn on the basis of existing knowledge, and obtaining new knowledge can change the conclusions. The paper proposes a new paradigm for creating intelligent systems capable not only for representing information in imagery form, but also modeling imaginative thinking.
Keywords: Mental Imagery, Imaginative Sphere, Nonmonotonic Reasoning, Artificial Intelligence

1. Introduction

To solve the problem of flexibility and reliability of artificial intelligence (AI), it is necessary to use methods for presenting information and the results of mental activity, primarily reasoning, in a manner characteristic of a person. Undoubtedly, this corresponds to the task of creating intelligent systems capable not only to represent information in imagery form, but also modeling imaginative thinking.

However, the problem is that the study and mathematical modeling of imagery have not been sufficiently developed so far. A.A. Gostev wrote that “Despite the growing attention to the imagery problems of various areas of psychology and related sciences, we have to state a lag in the study of the imaginative sphere of a person compared to other mental processes. Modern scientific knowledge of the nature and functioning of secondary imagery is characterized by terminological ambiguity, incompleteness, "blurring"” (Gostev, 2022, p. 9).

1.1. Primary and secondary mental imagery

It should be noted that in Russian psychology the term “secondary imagery” is traditionally used, which is equivalent to the term “mental imagery” accepted in world science (Nanay, 2021). L.M. Vekker wrote that at the first sublevel of higher nervous activity, the signal function is carried out by imagery – primary and secondary (sensations, perceptions and representations), and at the second sublevel – by speech-thinking processes (Vekker, 1998). In this paper we will use

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the term imagery mAInly for secondary (or mental) imagery. In modern psychology, secondary imagery is defined for objects and phenomena in the absence of a prototype stimulus directly affecting them in the material world (Gostev, 2022). Note that the imagery is an abstract concept that allows describing the structure of semantic information stored in the brain. According to A.A. Gostev, the secondary imagery is the natural language of the mind associated with the pre-conceptual level of reflection (Gostev, 2022). It is known that the experimental study of the imagery is a difficult problem, as they appear before researchers, according to L.M. Vekker, elusive "volatile" structures, difficult to fix (Vekker, 1979). V.A. Barabanschikov argued that sensations, perceptions, representations act as imagery that reflect the world around a person and himself (Barabanschikov, 2000, p. 44). A special kind of imagery, described by N.A. Bernstein, are motor imagery of movements that are created and precede the actual performance of movements and actions (Chuprikova, 2022).

The concept of an imagery was also addressed by many specialists working in the field of AI. For example, D.A. Pospelov assumed that the basis of the human mechanism of cognition is an integrated system in which the imagery and symbolic-logical components are merged into one (Pospelov, 1989). B.A. Kobrinsky pointed out that the direction of actions of a highly qualified doctor is determined, in many respects, by the presence of an imagery representation of the disease. He emphasized that intuition, which is quite closely related to imaginative thinking, plays a significant role in the formation of primary hypotheses in poorly structured and humanitarian areas of knowledge (Kobrinsky, 1998). However, it can be noted here that intuition and imaginative thinking also play an important role in the exact sciences, such as mathematics (Hadamard, 1954). O.P. Kuznetsov wrote that for brain informatics, imagery are the main type of data and knowledge representation, a person thinks and stores his/her knowledge in the form of vague and blurry imagery, where thoughts and notions more often manifest themselves in the form of imagery than abstract concepts (Kuznetsov, 1995).

The Stanford Encyclopedia of Philosophy has devoted two articles to the concept of mental imagery. D. Pitt (Pitt, 2021) argues that the mental imagery is one of the models that is used for mental representations in the field of Computational Theory of Mind. Mental representations are construed as mental objects with semantic properties. B. Nanay (Nanay, 2021) states that mental imagery is far more pervasive in our mental life than just visualizing. They play a crucial role not just in perception, but also in memory, emotions, language, desires and action-execution.

Gostev claims that I. Hoffman talked about the possibility of representing an object with different levels of detail, containing visual-imaginative characteristics of objects or semantic representation. The ability to move from one form of representation to another is considered an important source of human creativity (Gostev, 2022).

According to Vekker, thinking is “obviously based on the information processing of primary and secondary imagery” (Vekker, 1998, p. 118). However, he emphasized that the structural unit or “molecule” of thought is judgment. There is also a distinction between analytical thinking (having conscious stages) and intuitive (minimally conscious, characterized by speed and lack of stages). The basis of imaginative thinking, which transforms a specific secondary image, is traditionally considered to be analysis-synthesis of the sensory level, elements of abstraction, generalization, comparison, evaluation.

1.2. Limitations of classical logic

Many researchers note the limitations of classical logic for modeling reasoning. For example, D.A. Pospelov wrote that “strict reliable reasoning that meets the most complete limitations of formal logical systems does not model all types of reasoning that a person operates in his activity. Many types of scientific knowledge are based on reasoning that is not rigorous, of a plausible nature, or on conclusions that use incomplete initial information" (Pospelov, 1989, p. 93). A.A. Gostev noted that logic is necessary, but not sufficient for understanding thinking. In the thought process there is always a certain "residue" that cannot be explained by logic (Gostev, 2022). A. Poincare wrote that formal logic always leads only to tautology, and syllogism cannot teach us anything essentially new (Poincare, 1905).

A number of non-classical, cognitive logics have been proposed that could be close to the logic of human reasoning. Tarasov noted that D.A. Pospelov conducted research in the field of knowledge representation and organization, modeling "common sense" reasoning (Tarasov, 2020). Yu.M. Arsky and V.K. Finn consider cognitive plausible reasoning (Arsky et al., 2008; Finn 1988, 2009). P. Wang wrote that first-order predicate logic faces many problems when used to explain or reproduce human cognition and intelligence, and he suggested using the Non-Axiomatic Reasoning System (NARS) model instead (Wang, 2004).

1.3. Spatial properties of imagery

One of especially important properties of the imagery and imaginative sphere of a person are their spatial properties. This fact made it possible to propose a special mathematical model, where the imagery is presented in the form of vague spatial objects – spots, and to use some geometric analogies (Simonov, 2020). The referred article noted that the spatial properties of the imagery are reflected in natural language, for example, when they talk about the edges and different sides of a concept or phenomenon, about points of view, about the proximity or connection of concepts, about their breadth or narrowness, about considering an issue in a certain plane, about the contours of a problem, about areas of knowledge, etc. A good geometric analogy of the relation between more general and specific concepts is the relation between a figure and its parts. The concept of context can be associated with the spatial arrangement of the imagery in the environment, which is a structure of other mental imageries.

J. Beck writes that Kosslin and Shepard's experiments showed that although mental imagery are not literally spatial, they nevertheless function as if they were located in space (Beck, 2018). Many authors have introduced the concept of imagery space as a system or structure of human imagery. For example, A.A. Gostev called this as the imaginative sphere of a person, which is understood as a multidimensional, multilevel dynamic subsystem of the mind, the "imageries-elements" of which perform specific functions in mental reflection-regulation in accordance with actual life circumstances (Gostev, 2022). He also writes about the existence of separate classes of secondary imageries, about the multidimensionality of mental phenomena and the need to consider them in different coordinate systems.

R. Shepard represented a form of mental imagery as a set of points in a multidimensional space with non-Euclidean geometry (Shepard, 1978). Petrenko wrote that the development of complex and multidimensional models of the semantic space is required (Petrenko, 1988). B.A. Kobrinsky argued that holistic imagery is multidimensional or multi-meaning signs (Kobrinsky, 2009). Gostev points that B.F. Lomov spoke about the multidimensionality of mental phenomena and the need to consider them in different coordinate systems (Gostev, 2022). V.B. Tarasov (Tarasov, 1998) also defined the space of mental imagery and talked about multidimensional subjective spaces. He wrote that D.A. Pospelov believed that the fusion of algebraic and geometric approaches will make it possible to create complete intelligent systems with much greater capabilities than modern AI systems (Tarasov, 2020).

The proposed mathematical model of

spots makes it possible to represent imagery as vague spatial objects in multidimensional spaces (Simonov, 2020, 2021, 2023). These works show the possibility of modeling reasoning based on nonmonotonic logic inherent in human thinking (Simonov, 2023). For the nonmonotonic logic, conclusions are made on the basis of existing knowledge, and the acquisition of new knowledge can change the conclusions. This issue will be discussed in more detail in Section 4.

2. Modeling imagery using spots

2.1. Basic concepts of the spot model

J. Hadamard shared his self-observations about what happens in the mind when he began to build or understand mathematical reasoning: "Now, personally, if I had to think of any syllogism, I should not think of it in terms of words – words would hardly allow me to see whether the syllogism would be right or wrong but with a representation analogous to Euler's, only not using circles, but spots of an undefined form, no precise shape being necessary for me to think of spots lying inside or outside of each other" (Hadamard, 1954, p. 76).

First let us consider a qualitative description of the spot model, on the basis of which it is possible to represent mental imagery as spatial objects. A more rigorous mathematical description of the proposed apparatus will be considered in the next section. Although spots are mathematical objects for describing vague or blurry figures, we will also consider crisp geometric figures as a special, limiting case of spots. For spots, their internal parts and their environments are determined, and all information about their "shape", internal structure and the structure of the environment is given using qualitative data on their elementary spatial relations (*ER*) with other spots, that is, *the relations of separation, intersection, inclusion of one spot in others*, etc. Therefore, in the general case, we do not have complete information about the spot, but we can refine our knowledge of it by obtaining additional data. The possibility of gradually "filling in with information" the spot is consistent with the process of imagery formation, which as L.M. Vekker wrote "begins with discrimination and then proceeds through recognition to the full and adequate perception of the given object" (Vekker, 1998, p. 11).

Let us call a basis of spots some of their structure onto which the considered spot can be represented using its *ER* with spots of this basis. Such a representation can be regarded as an imaging, mapping, projection, or section on the basis. Note that although the projections of certain spot-on different basises are different, they are characteristics of the same spot. Likewise, certain mental imagery can be represented with different modality or different levels of detail or generalization. It should be emphasized that, although the *ER* data are qualitative, it is possible to obtain a fairly clear "image" of a spot if to process its *ER* with a large number of basis spots. In the limit of an infinite amount of such data, it is possible to precisely reconstruct the image of a crisp figure. (Simonov, 2023).

The environment of the spot is a surrounding space near its location. When considering the semantic content of the text, the environment of the spot that models its semantic imagery corresponds to the context. The environment is also a spot, and its properties, such as continuity, dimension, curvature, are not predetermined. However, using data on the *ER* of the spot's environment with basis spots, one can approximately estimate these properties. Note that with the help of *ER* data, it is possible to form homogeneous or inhomogeneous spot spaces with arbitrary properties. One can, for example, consider separated (non-intersecting) spaces of spots, which allow one to model different classes of secondary imagery or different levels of their representation, for example, "sensory (concrete) and conceptual (abstract)" (Gostev, 2022, p. 28). From what has been said, it follows that spots allow one to build a much more flexible spatial model for representing imagery and the imaginative sphere than the conventional crisp geometry.

2.2. Semantics of imagery

To model mental imagery, it is necessary to determine the spots corresponding to them and provide the *ER* between these spots, corresponding to the relations between the imagery. The spot model allows us to represent the "distribution" of imagery in the imaginative sphere in the form of certain structures, which make up their environmental structures and internal structures. We will call such a representation a spatial representation of imagery and define the imagery space.

Since the semantic of an imagery can be determined with the help of its relations with other imageries, its semantic is determined by a certain location in the imagery space. Therefore, the imaging of corresponding spot on the basis represents the semantics of the imagery or a judgment about it. The internal structure of the spot represents the degree of fragmentation of the imagery. Obviously, the spots model provides multidimensional spatial representation of mental imagery. Furthermore, suggested approach can be applied to the representation of semantic imagery and semantic space in the field of AI.

2.3. Structure and detail of imagery

Mental imagery is an abstract concept that allows to describe the structure of information stored in the brain. It is well known that imagery of the same object can be represented in different degrees of generalization (abstractness). Therefore, psychology considers such concepts as a hierarchy of different levels of generalization (Vekker, 1998) and a multilevel mental imagery (Lomov, 1984). The structure of imaginative sphere can be represented in form of different levels associated with the detail or generalization (abstractness) of imagery. For example, A.A. Gostev stated that the cognitive system includes sensory-perceptual, representational, and speech-thinking levels (Gostev, 2022). Using the spot apparatus, it is possible to model imagery with any degree of detail or generalization, from visual imagery to abstract conceptual ones. An important feature of suggested model is that it allows one to represent the same imagery with different levels of fragmentation or abstraction, mapping it on different basises.

Each level of generalization can be considered as a subspace of the imaginative sphere and it is possible to introduce specific basis of mental imagery in each of them. Obviously, the *ER* between the detailed and the corresponding generalized imageries is the relation of inclusion. Therefore, the level (or space) of generalized imagery must include levels (or subspaces) of detailed imagery. This has a geometric analogy of the inclusion of two-dimensional (2D) subspaces (planes and surfaces) in three-dimensional (3D) space. Obviously, a large number of detailed imageries can be associated with a single generalized imagery-concept that is similar to the taxonomy of species in biology. When modeling imagery with spots, all detailed imagery, corresponding to given generalized imagery, must have the same property. Namely, their mappings on the basis of generalized imageries are indiscernible (i.e., coincide) with each other and with the mapping of the given generalized imagery.

2.4. Formation of new imagery

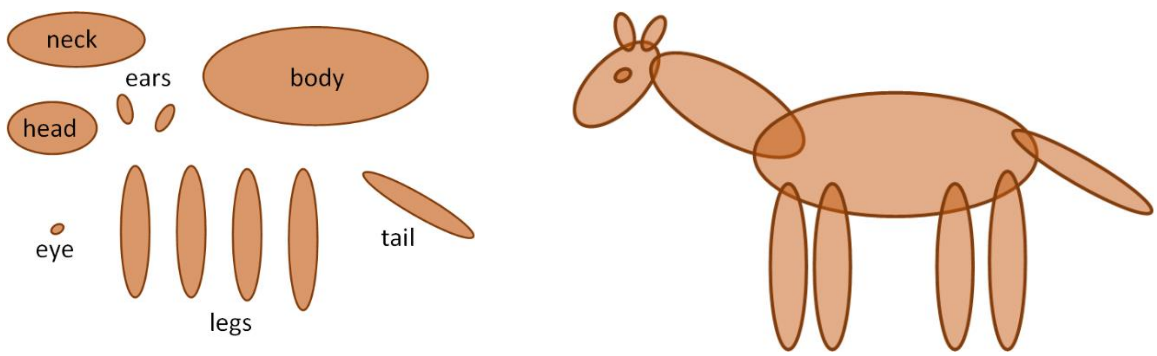
A.A. Gostev (Gostev 2008) wrote that in psychology, imagination is traditionally understood as a mental process of creating new images based on the transformation of images-elements of experience. The creation of new images was very clearly described by Marvin Minsky: "What can we do when things are hard to describe? We start by sketching out the roughest shapes to serve as scaffolds for the rest; it doesn't matter very much if some of those forms turn out partially wrong. Next, draw details to give these skeletons more lifelike flesh. Last, in the final filling-in, discard whichever first ideas no longer fit" (Minsky, 1988, p. 17).

A spatial analogy of the formation of a new imagery is the drawing or painting images that can be done on the basis of small material objects only. For example, these basis objects can be mosaic tiles, brush strokes in a painting, drawing strokes with pencil, charcoal, chalk or paint on paper, or stone in cave, and silver crystals as in a photograph. In the modern digital world, these are pixels in a photo, movies or monitors. Therefore, we can also assume that a new imagery is formed as a representation (or imaging) on a structure of existing imagery or on their intersections.

An example of such a basis is the model of geons as a set of elementary figures for the formation of Biederman's primary visual imagery (Biederman, 1987). I. Biderman suggested and confirmed it experimentally that the primary visual images are formed as reflections on the basis of 36 elementary figures - geons, which, like the letters of the alphabet, form a certain system. According to Biderman, visual object recognition is carried out as a process in which the input visual image is segmented into simple geometric components such as blocks, cylinders, wedges, and cones, and then approximated by one of the possible sets of geons.

Considering the formation of new imagery as their reflection on the basis of existing imagery allows, in principle, by continuing this process, to create basis of new imagery and form new imagery on them. This property is reflected in the fact of the development of human culture and science. Therefore, although the imaginative sphere of a person is the result of a reflection of his experience, but this is not a "mirror reflection", since there are elements of subjectivity and the results of creative processing of imagery in it. Such an understanding shows the inconsistency of the critical objections to the idea of the mind as a reflection of reality, about which N.I. Chuprikova wrote, for example, the alleged impossibility of explaining the existence of the concepts of ideal objects and the ability of human creativity (Chuprikova, 2022).

Such a general scheme of an imagery creation can be illustrated applying a representation of a generalized imagery of a horse by spots with a minimum level of detail. This can be visualized with the Euler-Venn diagram shown in Figure 1, which looks like a child's drawing. In Figure 1a, parts of the horse's body are presented as a set of separated spots and they do not give an understanding of the horse imagery. However, the same spots, combined into a structure with corresponding intersections, form the recognizable image of a horse (Figure 1b). Here we see that the structure that unites parts of imagery plays an important role. This example, in particular, illustrates the principle of Gestalt Psychology (Solso, 2004), according to which the semantics of the whole is not reduced to the sum of the semantics of its parts.



(a) (b)

Figure 1. Euler-Ven diagrams showing the relationship between imagery of body parts and the whole imagery of a horse: (**a**) Spots represents imagery of body parts as a set of separate elements; (**b**) The imagery of a horse as a structure of spots – parts of its body, connected by *ER* between them.

Though it should be noted that the image in Figure 1 is quite abstract and can refer not only to a horse, but also to other animals, such as a cat, dog, sheep, but does not correspond to fish, crayfish, snakes or spiders. For unambiguous recognition of a horse, it is necessary to detail the structure of its image. However, too much details are not necessary for that, since the imagination can restore the missing elements. For example, images of a horse detailed enough for recognition are shown in Figure 2.

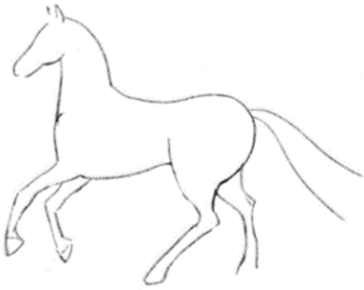


Figure 2. Pencil drawing and cave painting of a horse with sufficiently detailed imaging for recognition.

3. Mathematical apparatus of the spots

3.1. Definition of the spots

The mathematical apparatus of spots is described in detail in my previous article (Simonov, 2023), so now I will restrict myself to a brief description.

Spots are a mathematical object with elementary *spatial properties*, for which their *inner area*, *outer area* (environment) and *logical connections* between them are defined for any spots. The logical connection *ab* of two spots *a, b* is determined by two axioms:

$$\forall a, aa = 1 \text{ (logical)} \qquad (1)$$

$$\forall a \forall b, ab = ba \qquad (2)$$

The environments $\tilde{a}$, $\tilde{b}$ of the spots a, b are also considered as spots; therefore, a logical connection is defined for them that satisfies axioms (1) and (2). We postulate that spots are not connected to their environment, i.e.

$$a\tilde{a} = 0, \qquad b\tilde{b} = 0 \qquad (3)$$

In general, the "shape" of spots and the properties of their environment, such as dimension, space curvature, etc., are not determined in advance, but can be estimated from qualitative information about their elementary relations (*ER*) with other spots. As it was mentioned before, *ER* are defined between spot, including *separation, intersection, inclusion, indiscernibility*, etc. Also, we consider crisp geometric figures as a particular, limiting case of spots.

It should be noted that the introduced concept of a basis of spots is considered as a structure of "known" spots with certain ERs between them, on which representation (mapping, projections or sections) of other spots can be made, using ERs with the basis spots (Simonov, 2020, 2023). Consequently, the basis plays the role of a coordinate system for spots. It should differ the abstract concepts of atomic spots, basis spots, and separated spots. The atomic spots are separated from each other and from other spots. Note that concept of atomic spots is similar to points, pixels, or voxels. The basis spots are also analogous to (numerical) basis functions, and separated spots are analogous to orthogonal basis functions. One example of an orthogonal basis is an atomic basis, and another example – is a basis of parts of intersection of basis spots, which are also separated. The last example can also be considered as an approximation of the atomic basis.

By analogy with geometric bodies, we defined the operations of union ∨ and intersection ∧ for spots that allow one to form new spots (Simonov, 2023). Note that in relation to imagery modeling, the union operation ∨ can be used to form a structural or generalized imagery, and the intersection operation ∧ can be used to increase the fragmentation and detail of the imagery. For example, the diagram in Figure 3 illustrates the division of spots a and b into the intersection parts A, B, C. These parts and their environment D can be expressed in terms of the intersection operation as follows:

$$A = a \wedge \tilde{b},\ B = \tilde{a} \wedge b,\ C = a \wedge b, \text{ and } D = \tilde{a} \wedge \tilde{b} \quad (4)$$

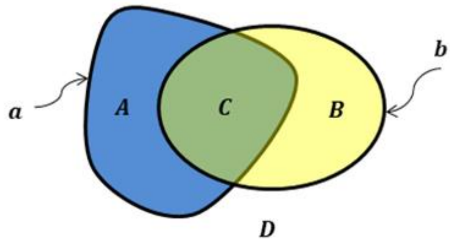


Figure 3. Euler-Venn diagram for the elementary relations between spots.

3.2. Definition of L4 numbers, vectors and matrices

Instead of real numbers, the spot model uses L4 numbers, which formalize the qualitative ERs between spots. Since the apparatus of L4 numbers is described in detail in my previous works (Simonov, 2020, 2021, 2023), we will briefly outline the main content and reveal the meanings of the concepts introduced there.

For spots a, b and their environment $\tilde{a}$, $\tilde{b}$ we defined L4 number $\langle a|b\rangle$ as the following 2×2 logical table:

$$\langle a|b\rangle = \begin{bmatrix} ab & a\tilde{b} \\ \tilde{a}b & \tilde{a}\tilde{b} \end{bmatrix} = \begin{bmatrix} C & A \\ B & D \end{bmatrix} \quad (5)$$

where ab, $a\tilde{b}$... denote the logical connections, and A, B, C, and D denote a *binary measure* of the intersection parts of the spots a, b, and their environments (see Figure 3). Such L4 numbers, in general, make it possible to distinguish 16 different *ERs* between spots. Examples of *ER* and their correspondence with L4 numbers is illustrated in Figure 4 and listed in Table 1.

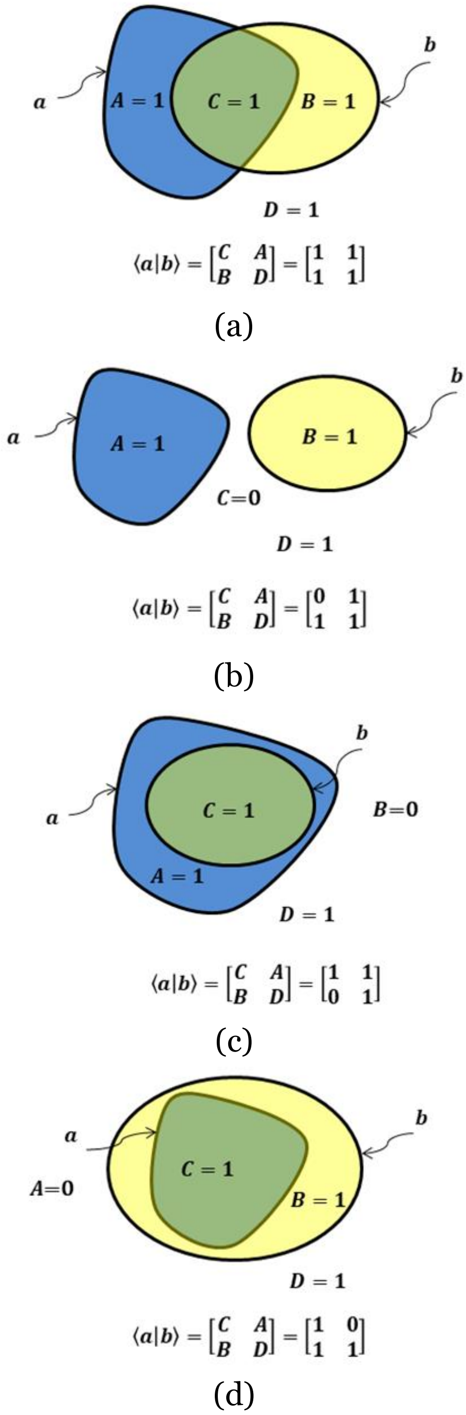


Figure 4. Euler-Venn diagram illustrates the meaning of definition of L4 numbers for *ER* between two spots: (**a**) Intersection of a and b; (**b**) Separation of a and b; (**c**) Inclusion b in a; (**d**) inclusion a in b.

We call these spatial relations "elementary" because they carry the lowest level of qualitative information about spots. However, a large amount of such qualitative data makes it possible to extract higher level information, including numerical.

Table 1. An example of the elementary relations of spots.

Elementary Relations	$\langle a\|b\rangle$
Intersection (a Ts b), $a >< b$	$\begin{bmatrix}1 & 1\\1 & 1\end{bmatrix}$
Separation (a Sp b), $a <> b$	$\begin{bmatrix}0 & 1\\1 & 1\end{bmatrix}$
Inclusion (b In a), $b < a$	$\begin{bmatrix}1 & 1\\0 & 1\end{bmatrix}$
Inclusion (a In b), $a < b$	$\begin{bmatrix}1 & 0\\1 & 1\end{bmatrix}$
Indiscernibility (a Dc b), $a \cong b$	$\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$

The representation of a spot on any basis can be coded using an L4 vector, which is similar to a numerical vector, but its coordinates are L4 numbers of *ER* with spots of the basis (Simonov, 2020, 2021, 2023). For example, the L4 vector $\boldsymbol{a}_X$ of the spot a, represented on a basis $X = \{x_i\}$, determines relation $\langle a|X\rangle$ and is defined as

$$\boldsymbol{a}_X \equiv [\langle a|x_1\rangle;\ \langle a|x_2\rangle;\ \dots;\ \langle a|x_n\rangle] \qquad (6)$$

where n is the number of spots in the basis X.

The L4 matrix $\langle Y|X\rangle$ determines relation between the spots of two basises, $X = \{x_i\}$ and $Y = \{y_j\}$, and also formalizes the mapping from the X to the Y basises (Simonov, 2020, 2023):

$$\langle Y|X\rangle \equiv [\langle y_j|x_i\rangle] = [(\boldsymbol{y}_1)_X;\ (\boldsymbol{y}_2)_X;\ \dots;\ (\boldsymbol{y}_n)_X] \quad (7)$$

Here $(\boldsymbol{y}_j)_X$ are L4 row vectors of spots y_j, represented on the basis X. The L4 matrix can be used to transform the mapping of the L4 vector from one basis to another, which can formally be written as the following multiplication of a matrix by a vector

$$\boldsymbol{a}_Y = \langle Y|X\rangle\, \boldsymbol{a}_X \qquad (8)$$

Unfortunately, in general, there is no simple rule for calculating such a product, and we will consider this issue in detail below. However, there is a simple special case of the L4 indiscernibility matrix **I** (Simonov, 2023), the diagonal elements of which correspond to the *ER* of indiscernibility, and all other elements correspond to the *ER* of separation (Table 1):

$$\boldsymbol{a} = \mathbf{I}\, \boldsymbol{a}$$

where $\boldsymbol{a}$ is an arbitrary L4 vector defined on the same basis as matrix **I**.

As mentioned above, the mapping of spots on the basis by L4 vector models some judgment or statement about the imagery, and hence the multiplication of the L4 matrix by this vector describes such an information processing as reasoning.

3.3. Multiplication rules for L4 matrices and L4 vectors

First let us consider the simplest case of an atomic basis $A = \{u_i\}$, where the basis spots are orthogonal and do not intersect with other spots. Then we determined the *ER* $\langle a|b\rangle_A$ between spots a and b with respect to the basis A according to the rule (Simonov, 2020, 2021, 2023)

$$\langle a|b\rangle_A = \begin{bmatrix} \sum_{i=1}^{n} au_i \cdot bu_i & \sum_{i=1}^{n} au_i \cdot \tilde{b}u_i \\ \sum_{i=1}^{n} \tilde{a}u_i \cdot bu_i & \sum_{i=1}^{n} \tilde{a}u_i \cdot \tilde{b}u_i \end{bmatrix} \qquad (9)$$

where summation corresponds to the logical disjunction and the symbol "·" denotes a logical conjunction. Then for an arbitrary basis $B = \{b_i\}$ and an atomic basis $A = \{u_i\}$, the transformation of the spot a representation from the basis A to the basis B is determined by the following multiplication rule:

$$\boldsymbol{a}_B = \langle B|A\rangle\, \boldsymbol{a}_A = [\langle a|b_i\rangle_A] \qquad (10)$$

where $\langle a|b_i\rangle_A$ is the L4 number defined in (9).

More complicated case corresponds to arbitrary basises $X = \{x_i\}$ and $Y = \{y_i\}$, in which the basis spots x_i and y_i can intersect. Paper (Simonov, 2023) contains approximate rules for calculation product $\langle Y|X\rangle\, \boldsymbol{a}_X$ (8). To do this, we first construct the following orthogonal basises: $U = \{u_i\}$ for intersections u_i of spots $\{x_i\}$, $V = \{v_i\}$ – for intersections v_i of spots $\{y_j\}$, and $W = \{w_i\}$ – for intersections w_i of spots in basises U and V. Then the algorithm for the matrix product can be written in the following form (see 11).

Note that equation (11) should be considered as a series of transformations from one basis to another, namely: $\boldsymbol{a}_U = \langle U|X\rangle\, \boldsymbol{a}_X$, $\boldsymbol{a}_W = \langle W|U\rangle\, \boldsymbol{a}_U$, $\boldsymbol{a}_V = \langle V|W\rangle\, \boldsymbol{a}_W$, $\boldsymbol{a}_Y = \langle Y|V\rangle\, \boldsymbol{a}_V$. One can calculate the product $\boldsymbol{a}_U = \langle U|X\rangle\, \boldsymbol{a}_X$, using the formulas (15) and (16) from (Simonov, 2023):

$$\boldsymbol{a}_Y = \langle Y|X\rangle\, \boldsymbol{a}_X = \langle Y|V\rangle \cdot \langle V|W\rangle \cdot \langle W|U\rangle \cdot \langle U|X\rangle\, \boldsymbol{a}_X (11)$$

$$\text{if } u_k = x_1 \wedge \tilde{x}_2 \wedge x_3 \ldots \wedge \tilde{x}_n \rightarrow$$

$$\langle a|u_k\rangle = \begin{bmatrix} ax_1 \cdot a\tilde{x}_2 \cdot \ldots \cdot a\tilde{x}_n & a\tilde{x}_1 + ax_2 + \cdots + ax_n \\ \tilde{a}x_1 \cdot \tilde{a}\tilde{x}_2 \cdot \ldots \cdot \tilde{a}\tilde{x}_n & \tilde{a}\tilde{x}_1 + \tilde{a}x_2 + \cdots + \tilde{a}x_n \end{bmatrix} \qquad (12)$$

$$\text{if } \{\forall x_j : ax_j = 0,\ u_k x_j = 0\}\ then\ u_k < a$$
$$\text{if } \{\ \forall x_j : \tilde{a}x_j = 0,\ u_k x_j = 0\}\ then\ a <> u_k \qquad (13)$$

where the symbols <> and < denote the separation and inclusion relations, respectively (see Table 1). For the calculation vectors $\langle V|W\rangle\, \boldsymbol{a}_W$ and $\langle Y|V\rangle\, \boldsymbol{a}_V$ formulas (9), (10) can be used, and for the vector $\langle W|U\rangle\, \boldsymbol{a}_U$ – rule: if $w_k < u_i \rightarrow \langle a|w_k\rangle = \langle a|u_i\rangle$. In order to test the algorithms of the spot model presented above, the works (Simonov, 2021, 2023) demonstrated results of simulation the problem of reconstructing images of flat figures using qualitative data on their *ER* with sets of basis figures, which were circles or squares scanning with a small step in the plane of the figures. The reconstruction results showed good accuracy and noise reduction property for the developed algorithms.

4. Modeling Reasoning and Learning

4.1. Modeling Nonmonotonic Reasoning

As it was mentioned before, L.M. Vekker stated that thinking is based on information processing of primary and secondary imagery, and the structural unit of thought is the judgment (Vekker, 1998). In the spot model, the L4 vector codes some judgment or statement about the imagery, and the multiplication of the L4 matrix by this vector models the information processing, i.e., reasoning. As a result of multiplication, a new L4 vector is obtained, which can be interpreted as the resulting conclusion. Therefore, when applied to imagery, L4 matrix models the corresponding knowledge about relations between two basises that is used in the process of reasoning. So, the L4 product of the matrix **A** and the L4 vector $\boldsymbol{a}$ models the reasoning in the form of

$$\boldsymbol{b} = \mathbf{A} \cdot \boldsymbol{a}$$

where $\boldsymbol{a}$ is the proposition and $\boldsymbol{b}$ is the conclusion. Hence, the conclusion $\boldsymbol{b}$ is obtained on the basis of information (knowledge) contained in L4 matrix **A**:

$$\boldsymbol{a} \ \rightarrow_{\mathbf{A}}\ \boldsymbol{b}$$

An important property of this type of reasoning is their proximity to the peculiarities of human thinking, namely:

– conclusions are made on the basis of existing knowledge,

– reasoning has the property of non-monotonic logic, when the acquisition of new knowledge can change the conclusions.

4.2. Modeling learning in AI

Within the framework of the spots model the learning process in AI can be identified with the task of finding an unknown L4 knowledge matrix **A** if we have a number of training examples $\{\boldsymbol{x}_i, \boldsymbol{y}_i\}$ that correspond to the equality:

$$\boldsymbol{y}_i = \mathbf{A} \cdot \boldsymbol{x}_i$$

Consider, for definiteness, the problem of learning image recognition (classification), where $\boldsymbol{x}_i$ is an L4 vector for image represented on pixels, and $\boldsymbol{y}_i$ is the corresponding L4 vector, represented on the basis of considered classes of the images.

Let us regard $\boldsymbol{x}_i, \boldsymbol{y}_i$ as L4 vectors for spots x_i and y_i that form the basises $X = \{x_i\}$ and $Y = \{y_i\}$ of the training data. Then we can compose L4 matrix $\langle Y|X\rangle$ for representation the matrix $\mathbf{A}$ in (14) in the following form:

$$\mathbf{A} = \langle B_Y|Y\rangle \cdot \langle Y|X\rangle \cdot \langle X|B_X\rangle \qquad (15)$$

Here B_X and B_Y are atomic basises, which represent L4 vectors $\boldsymbol{x}_i$ and $\boldsymbol{y}_i$, correspondingly. Obviously, for testing set the data matrix $\langle Y|X\rangle$ is equal to the indiscernibility matrix **I**. Note that equation (15) is a schematic interpretation of the learning process in AI (Goodfellow, 2016).

5. Studies of imagery in neurophysiology – arbitrary regulation of mental imagery of the imagination

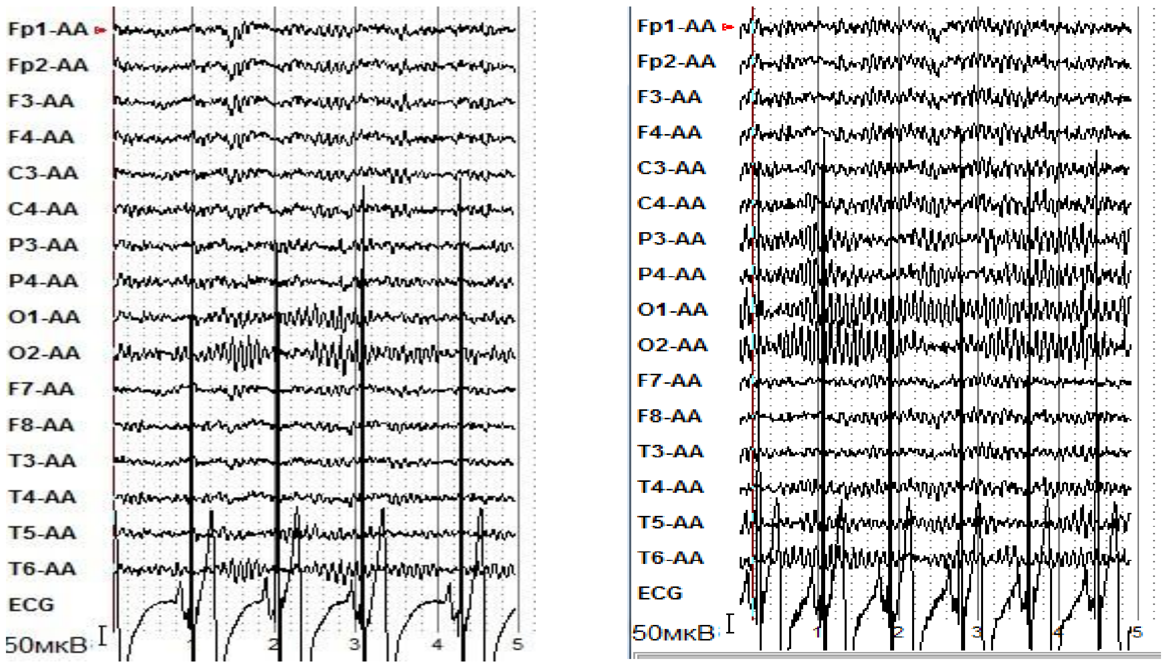
To illustrate the theoretical constructions described above, let us consider some experimental results of neurophysiological studies of emotional imagery and the extensive structure of relations between imagery in the imaginative sphere of a person.

Humans possess the ability to arbitrarily regulate images of both neutral content and their emotionally colored mental representation. It should be emphasized that a person is able to mentally reproduce not only the valency of emotions, but their intensity as well. In Russian psychophysiology, the use of mental representation of emotionally colored images to study the psychophysiology of emotions was first proposed by Academician P.V. Simonov (at that time a senior research fellow) (Simonov, 1981). This approach compensates for the difficulty of obtaining various human emotions in the laboratory. M.N. Rusalova, developing the P.V. Simonov' ideas, performed a number of electroencephalographic studies of emotional states (Rusalova, 2004, 2021) based on the mental representation technique. Since people differ in their ability to produce emotionally colored images, volunteers with the most pronounced mental representation abilities were invited to participate in the experiment.

5.1. Material and methods

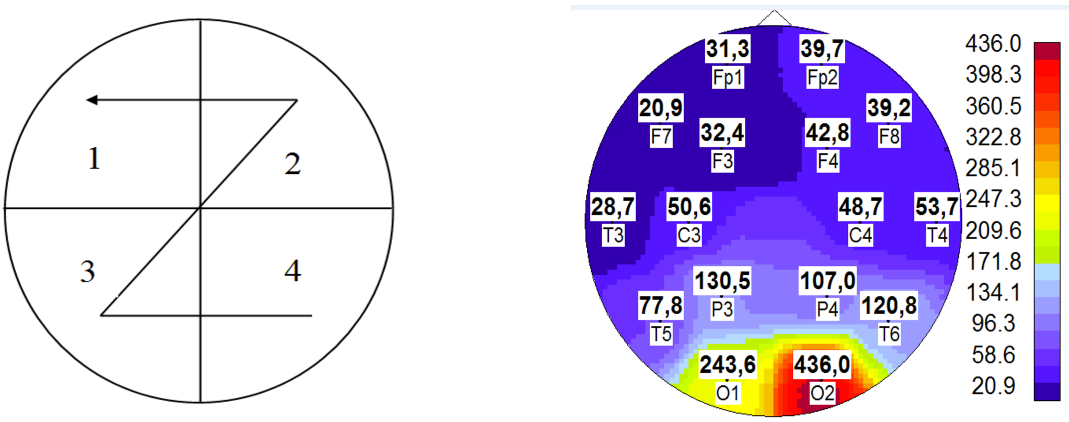
The test subjects were in a soundproof dark room, sitting in an armchair, with their eyes closed. Brain biopotentials (*EEG*) were recorded from the head surface at 16 positions of *EEG* electrodes according to the international 10-20 system: Fp1, Fp2, F3, F4, F7, F8, C3, C4, R3, P4, T3, T4, T5, T6, O1, O2, which were further processed by the computer. A combined ear electrode was used as a reference. The *EEG* analysis epoch was 4 s, the sampling rate was 500 Hz, bandwidth 0.3–80 Hz. The recording of biopotentials was carried out on a setup consisting of PC and the 21-channel Computer Electroencephalograph Neuro-KM (Ltd. Scientific and medical Co. “Statokin”). *EEG* registration and processing were carried out using the “Software package for analysis and topographic mapping of electrical activity of the brain with the neurometric data bank “Brainsys”. As an indicator of brain activity in this study, we chose the alpha rhythm as the most frequently used in research. After registering a calm state, the subject was asked to mentally imagine himself in a state of sadness (lasting 40 seconds).

Figure 5 shows fragments of *EEG*, where (a) corresponds to calm wakefulness and (b) – to mental reproduction of an emotional imagery. The scale on the left correspond to a conventional designation of *EEG* electrode placements of brain regions for



(a) (b)

Figure 5. Fragments of brain biopotential (or *EEG*) records: (**a**) Calm wakefulness; (**b**) Mental reproduction of an emotional imagery.



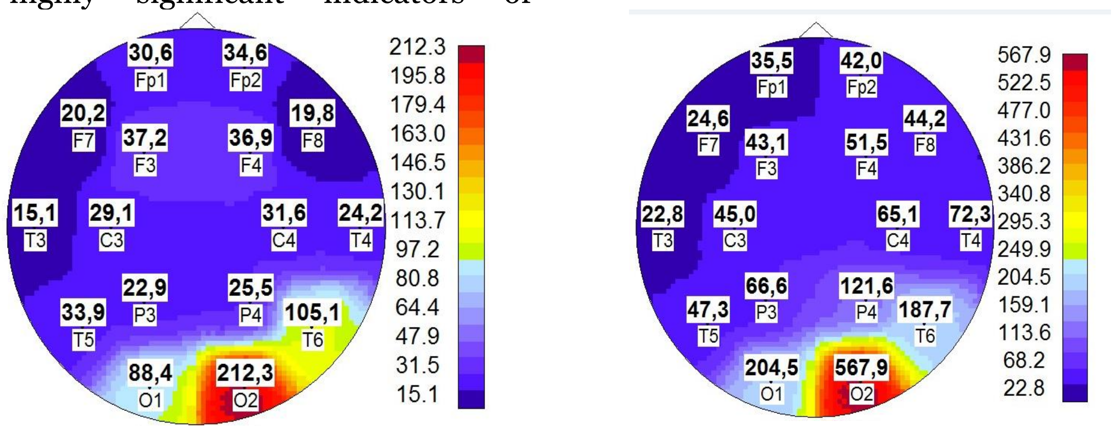
(a) (b)

Figure 6. Diagram of the dependence of the localization of the focus of local activation on the level of general activation.

international 10-20 system, from which biopotentials (EEG) are recorded.

Figure 6 demonstrates a diagram of the connection between the general brain activation and an example of the levels of local activation in each of the 4 quadrants of the cortex, according to which the highest level of general activation can be observed in sector 1 when the focus of local activation is located in it (the left anterior region of the hemispheres), and the smallest - in sector 4 (right occipital region). It is known that with an increase in the total activation of the cerebral cortex, the amplitude of the alpha rhythm decreases and, conversely, an increase in the amplitude corresponds to a decrease in the activation of the general and local. As can be seen, the scheme presented in Figure 6a is reproduced in Figure 6b, which shows that the smallest amplitude of the alpha rhythm is recorded in the anterior sections of the left hemisphere, and the largest – in the occipital sections of the right hemisphere that corresponds to the scheme in Figure 6a. Indeed, if we compare the powers of alpha oscillations in Figure 6b, we get the following series for the items: $F7 < F8 < O1 < O2$, which reproduces the "Z" pattern in Figure 6a.

As can be seen from Figure 7a, there are no highly significant indicators of asymmetry in the state of calm wakefulness. Against the background of the mental representation of the emotional imagery (Figure 7b), there is a significant increase in *EEG* power (maximum ~568 $\mu V^2/Hz$), and there is also a high level of interhemispheric asymmetry in favor of the right hemisphere. These facts indicate a more active participation of the right hemisphere in the process of mental representation of an emotional imagery.



(a) (b)

Figure 7. Comparison of the powers of biopotentials in the alpha rhythm for different states: (**a**) Calm wakefulness; (**b**) Mental representation of an emotional image. Symbols $Fp1, \ldots, O2$ designate the international 10-20 system regions of the brain, from which the *EEG* are recorded. The numbers correspond to the power in units of $\mu V^2/Hz$.

Figure 8 demonstrates example of intra- and extra-hemispheric coherent connections between regions of brain for the international 10-20 system, which reflect the synchronism of changes in bioelectrical activity of brain structures. On the brain maps, the coherent connections are shown as straight lines of links, which have different coherence levels, from 0 to 1. Here we use a threshold 0.4 of coherence factor. Apparently, this wide network of connections with different coherence levels reflects an extensive structure of relations and associative connections between imagery in the imaginative sphere of a person.

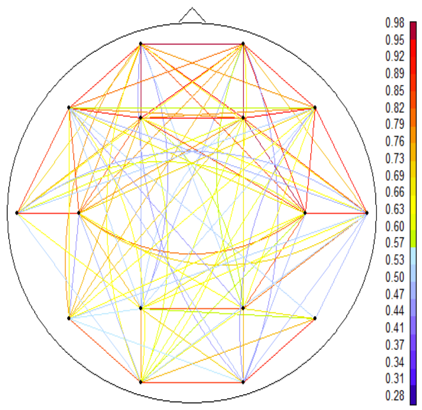


Figure 8. Demonstration of intra- and extra-hemispheric coherent connections of the brain. The threshold of coherence factor is 0.4.

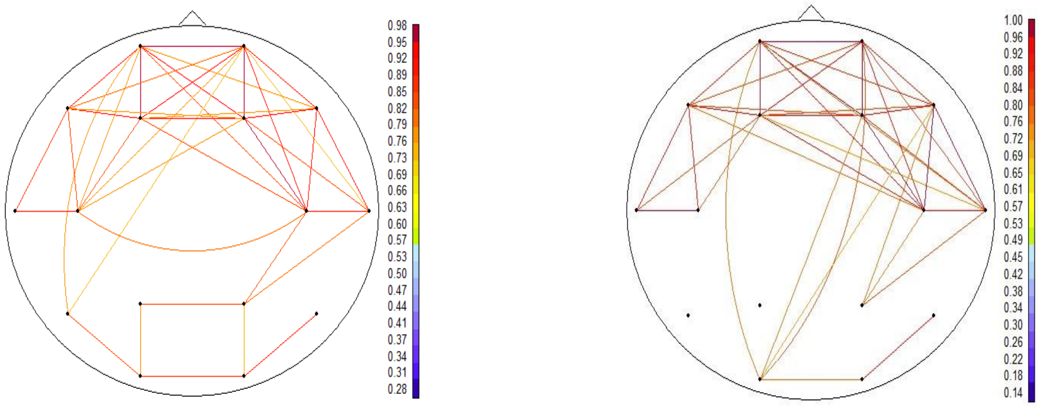


Figure 9. Coherent connections between brain regions, corresponding to Figure 7: (**a**) Calm wakefulness; (**b**) Mental representation of an emotional imagery. The threshold of coherence factor is 0.75.

Figure 9 shows coherent connections in a state of calm wakefulness (Figure 9a) and with a mental representation of an emotional imagery of sadness (Figure 9b). Compared to Figure 8 we increased the threshold of coherence factor up to 0.75.

As can be seen from Figure 9a, in a calm state, coherent connections of various parts of the brain are observed that, apparently, is due to involuntary, spontaneously arising associations and images. At the same time, with an arbitrary mental reproduction of an emotional imagery of sadness, a focus of coherent connections is formed in the anterior part of the right hemisphere (Figure 9b). The results are consistent with the idea of the localization of negative experiences in the right hemisphere, as well as with the position of A.R. Luria on the leading role of the anterior parts of the brain in the organization of behavior (Luria, 2004).

In recent years, interest has increased in the arbitrary regulation of various mental processes with the help of their mental representation. Mental representations are increasingly used for practical purposes, in particular, when creating computer systems for biocontrol, for example, for people with paralyzed limbs who need special devices to implement movements. The reproduction of emotional events from memory is also widely used in psychiatric clinics in order to study the physiological mechanisms of emotions for patients in comparison with healthy ones, as well as in medical hypnosis. The problems of study the arbitrary regulation of emotions with the help of mental representation, the study of the cortical mechanisms of this phenomenon, as well as the ability to imagine in people of different temperaments, are actual and has important theoretical and practical significance.

6. Discussion

6.1. Representation of imagery at different levels of detail or generalization

It should be emphasized that the mathematical apparatus presented above makes it possible to represent the same spots in the form of mappings on different basises. This makes it possible to model imagery with different levels of detail or generalization, as discussed above. Thus, the proposed apparatus of spots allows one to describe imaginative sphere as a hierarchy of different levels of generalization (Vekker, 1998) and a multilevel mental imagery (Lomov, 1984).

Indeed, formula (9) describes the *ER* between two spots a and b, which are represented on the atomic basis $A = \{u_i\}$, which determines the detail of these spots. Let us now consider a certain basis $X = \{x_k\}$ of spots, which, like the spots a and b, are represented on the same atomic basis A. It is obvious that the mapping of spots on the basis X will correspond to the representation of images at a higher level of generalization (abstraction) compared to with a mapping on the basis A. One can determine a mapping, for example, of a spot a on the basis X by replacing the spot b in formula (9) with any spot x_k of this basis and then finding the value $\langle a|x_k\rangle_A$. Thus, we get an apparatus for recalculating representations with more detail to a higher level of generalization.

It is easy to understand that formula (12) and conditions (13) allow modeling the process of fragmentation of imagery, that is, the transition to a level of greater detail of them. Indeed, (12) and (13) describe transform of a spot representation from the basis $X = \{x_k\}$ to the basis $U = \{u_i\}$ of the intersections of spots $\{x_k\}$ that provides to get more detailed imagery relatively to those on the basis X.

6.2. Geometric and topological analogies for mental imagery

We believe that the spatial representation of imagery potentially has an advantage over other approaches due to the fact that it more adequately reflects their inherent spatial properties, as mentioned above. Using the spatial analogy and the apparatus of spots, one can get a more understandable and meaningful representation of the structure of the imaginative sphere and gives a new approach to the study of mental imagery. For example, a spatial analogy of the different representations of some phenomenon or event on the imaginative spheres of different individuals are projections of a 3D body on planes located at different angles. Obviously, despite these projections are generally different, it does not follow from this fact that some of them are “correct” and others are “false”. Moreover, based on the different projections and sections, the shape of the 3D body can be reconstructed. Computed tomography is an example of such a 3D reconstruction of a body image from its X-ray projections at different angles. This analogy clear illustrates the well-known fact that the discussion and correct comparison of different points of view helps to create a more objective view of an event or problem. This is also the basis for the phenomenon of "collective intelligence", which, in particular, is manifested in the development of science and culture.

Let us consider the question of the existence of a special type of secondary (mental) imagery representing "spiritual semantics " in the "spiritual layers" of its imaginative sphere (Gostev 2022). They can be called mental “spiritual imagery”. There Gostev also states that “the main feature of secondary imagery is that the sensual-concrete and conceptual-abstract interpenetrate in them” (Gostev 2008, p. 104). However, we can formulate the peculiarity of spiritual imagery, separating them from conceptual imagery. Indeed, while the semantics of the latter is mainly determined by the conceptual component, for spiritual imagery the sensual component always plays an important role, and ignoring it significantly distorts or leads to the loss of the semantics of the spiritual imagery.

We can offer the following geometric interpretation of this property of the spiritual imagery. Let us consider a 3D body as an analogue of an imagery, where X, Y coordinates correspond to the conceptual component, and Z coordinate – to the sensual component. If the body has a simple form, then one can recognize its shape (that is, the semantics of the imagery) considering only its projection onto X, Y plane. However, if the body has a complex structure, then its projection onto X, Y plane does not convey the features of this structure. This example clearly explains the nature of possible semantics loss if to assume that the spiritual imagery has such a structure, in which conceptual and sensual components are intertwined in a complex way.

It should be noted an important aspect of the proposed mathematical apparatus of spots, namely, that it allows not only to model imagery and the imaginative sphere of a person, but also be applied beyond it. Namely, generalizing the concept of mental imagery, we can introduce semantic imagery and information imagery spaces to describe universal knowledge as an element of culture. This circumstance also makes it possible to apply the model under consideration for application in AI and for creating intelligent systems of a new type, which can not only represent information in an imagery form, but also model imaginative thinking.

To realize the potential advantage of the spatial representation of imagery, further development of the spot apparatus is necessary. In this regard, we will define some new concepts for the analysis of the spatial structures of spots, which are based on geometric and topological analogies. On the other hand, the introduction of such concepts should harmonize the spot model with the conventional crisp geometry in the limit.

Note that geometric and topological analogies can be introduced specifically for the structure of spots, and the spatial properties of these structures are determined locally, that is, for certain spots. For example, continuity or discreteness for the structure of spots correspond to situations where spots are intersected or separated, respectively. The boundary of a spot is defined as the “minimal” structure of spots intersecting with this spot.

The spatial structure of spots is similar to a topological structure or a geometric body. By analogy with topology, we assume that the dimension of a spot without an internal structure is equal to zero, and the dimension of a spot inside the structure is equal to a number that exceeds the dimension of its boundary by one.

Using the definition of dimension given above, let us consider the spot structures in Figure 10. For the structure in Figure 10a, obviously, the local dimension for all internal spots is 1, that is, it is a line. Figure 10b demonstrates that the structure dimension is 2 for the central spot. Similarly, the structure in Figure 10c can be called a surface, since the dimension for all internal spots is also 2. One can introduce a measure for the structure of spots, defining it be equal to the number of spots included in this structure. Then the length of the line (Figure 10a) is equal to the number of spots in it. The straight line that connects two spots can only be defined using the "external geometry" of the surrounding structure of spots. Namely, the straight line is the shortest line between two spots. As we mentioned above, the basis of spots is similar to a coordinate system and L4 numbers – to coordinates. A continuous mapping in topology can be associated with a one-to-one mapping of the basis spots, which preserves their mutual relations. Isometry is similar to continuous spot mapping, which also preserves the distances between spots.

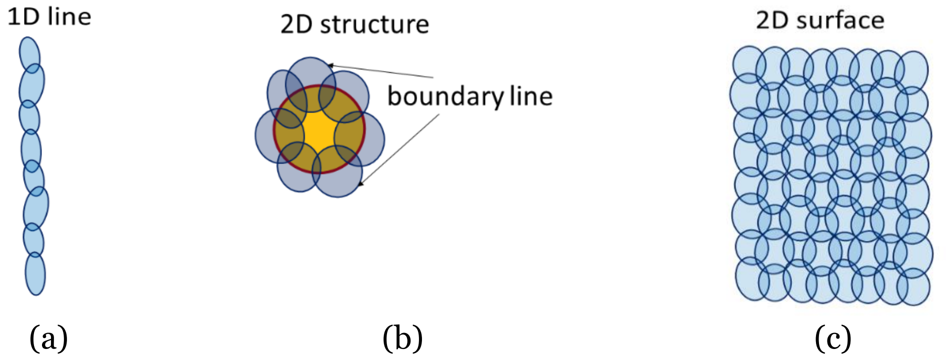


Figure 10. Some types of spot structures: (**a**) 1D structure – line; (**b**) Definition of the local 2D structure; (**c**) 2D structure – surface.

6.3. Analogy between spots and Minsky's frames

The spot model has a certain analogy with the Minsky frame concept (Minsky, 1975). However, spots form a spatial model of imagery, and frames represents imagery as network structure of hierarchically ordered elements: subframes, frames, and superframes. We can note the following common properties of the spot and the frame.

1. The spot and frame are not fully defined initially. For example, frames include different levels: the higher levels are defined, and the lower levels have many special terminal vertices or "cells", which must be filled with specific examples or data. The spots are specified by their mappings on the basises of the spots that determines the structures of their inner parts and environments. Hence, using different basis, we can refine information about the spot.

2. Combination of semantically similar frames into a frame system is similar to combination (inclusion) spots into united spot, representing a structural or more abstract imagery.

3. The common terminals of different frames are similar to the common parts of the intersecting spots.

4. Subframes are analogous to spots that are parts of the main spot, and superframes are analogous to the structure of spots.

It follows from item 1 that, similarly to the cells of the frame, internal part and the environment of a spot allows "filling" with additional information. However, unlike frames, a spot, in principle, allows an unlimited amount of information to be embedded. Figuratively speaking, upon closer examination, the spot may turn out to be a galaxy.

7. Conclusions

The spot model allows one to represent the structures of mental imagery, taking into account their spatial properties, including the multidimensionality and multilevel nature of the human imaginative sphere. The spatial representation of mental imagery allows to highlight and understand the peculiarity of spiritual imagery.

Generalizing the concept of mental imagery, the spot apparatus allows to model human knowledge as an element of culture in the form of semantic imagery and information imagery space. The spot apparatus also makes it possible to formulate a new paradigm for creating strong AI, namely the development of a new type of intelligent systems capable of not only representing information in an imagery form, but also modeling imaginative thinking.

It is necessary to further develop the spot model in the direction of developing a vague geometric theory, which will allow creating a more complete and detailed description of the imaginative sphere and imaginative thinking.

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Highlights:

- A new mathematical model of spots is described for the spatial representation of mental imagery and modeling imaginative thinking.
- The spots can represent multidimensional and multilevel nature of the human imaginative sphere.
- Mathematical apparatus of L4 logical numbers, L4 vectors and L4 matrices allow to process information in imagery form.
- A new paradigm for the development of strong AI is proposed, based on the representation of information in imagery form and the modeling of nonmonotonic reasoning.

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A Genetically Informed Test of the Cognitive-Colorism Hypothesis

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Abstract: In the Americas, less European-looking people have on average worse academic outcomes than more European-looking people. According to the colorism model, these associations between race-related phenotype and academic-related outcomes are due to contemporary phenotypic-based discrimination and not due to family-background or intergenerational factors. Previous studies have attempted to use sibling designs to disentangle the latter two causes from the effects of discrimination. We argue that admixture-regression analysis is an additional helpful tool for disentangling the various causes. Using a large, genetically-informed dataset, we created a genetically-based predictor of European appearance. We tested the hypothesis that European appearance will be associated with academic outcomes independent of genetic ancestry. We also tested the hypothesis that *g* mediated the relations between ancestry/European appearance and grades. We did not find evidence of this in the case of *g* (and most cognitive tests), but we did find tentative evidence in the case of parent-reported grades. When genetic ancestry was included in the models, European appearance was not significantly related to *g*. We also found that while *g* was a substantial and statistically significant mediator of the association between European ancestry and grades, this was not the case in the context of European appearance and grades. These results are in line with the position that cognitive inequalities in the US are intergenerationally transmitted, and are not the result of contemporaneous color-based discrimination. The admixture-regression method employed here could be applied to different outcomes to test for evidence of phenotypic-based discrimination or, at least, family-background independent effects.

Keywords: IQ, Colorism, Admixture Study, Genetic Ancestry, Appearance, *G*, School Grades, Discrimination

1. Introduction

In the Americas, research shows that less European-looking and/or darker-looking people are on average less successful than more European-looking and/or lighter-looking people. For example, stereotypically race-related phenotypes, such as skin, hair, and eye color, are generally associated with better socioeconomic outcomes (Hochschild, & Weaver, 2007; Hunter, 2013). Many sociologists attribute this association to phenotypic-based discrimination, also known as "colorism" (e.g., Dixon & Telles, 2017). According to theorists of colorism, phenotypic-based discrimination is common in the Americas, favoring

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individuals with stereotypical European phenotypes. This discrimination is hypothesized to result in better health, higher occupational and educational attainment, and other more positive outcomes for individuals with a paler or 'whiter' appearance; even among those categorized as belonging to the same race/ethnicity, the paler ones will do better than the darker ones (Hochschild & Weaver, 2007; Marira & Mitra, 2013).

Proponents of this colorism model frequently maintain that 'race' is a social construct according to which people are arbitrarily categorized based on geographic origins and physical appearance and that modern racial categories have originated primarily based on the work of eighteenth- and nineteenth-century European naturalists and anthropologists (Dixon & Telles, 2017). 'Color,' in contrast, is not a social construct but refers to gradations of physical appearance associated with different levels of skin tone (Dixon & Telles, 2017). Theorists of the colorism model place primacy on "the causal role of skin tone in engendering the colorism phenomenon" (Marira & Mitra, 2013, *p*. 103). Many theorists of colorism argue that other visually conspicuous, stereotypically race-associated traits such as hair color, eye color, hair texture, and facial features may also elicit phenotypic discrimination (Crutchfield et al., 2022; Ryabov, 2013).

In addition to differences in income, health outcomes, and occupational status, colorism has been invoked to explain academic and cognitive differences, including differences in attained years of education, grade point average, and academic/cognitive test scores (Hailu, 2018; Hill, 2002; Kim & Calzada, 2019; Liu et al., 2022; Thompson & McDonald, 2016). In their review, Crutchfield et al. (2022, *p*. 10) conclude that "lighter skin tones and more Eurocentric features were linked to better academic outcomes, including higher GPAs, additional years of schooling, [and] improved academic performance".

Concerning specific mechanisms by which individual variability in color could be linked to variation in academic and cognitive outcomes, Thompson and McDonald (2016, *p*. 6) argue for discrimination, including "direct mechanisms – educational encouragement, evaluation, and provision of learning opportunities – as well as indirect mechanisms – the use of disciplinary actions". Crutchfield et al. (2022, *p*. 10) similarly emphasize teacher-student relations as causes, further noting that "darker-skinned students face the greatest barriers to optimal educational outcomes due to differential treatment". Similarly, Hannon (2014) suggests that adults and educators may have a light-skin-equals-intelligence bias which, in turn, influences both their expectations and their treatment of children of different complexion.

According to theorists of colorism, appearance-based outcome differences directly result from appearance-based discrimination. Ancestry or racial identification matters in so far as "racial classifications are determined more closely by how one phenotypically appears to belong to one race rather than strictly by one's ancestors" (Hernández, 2015, *p*. 684), and the same author argues that this is especially true in parts of Latin America. As Hall (2020, *p*. 79) notes, "in consideration of racism as pertains to colorism, ultimately such biological attributes as ancestry and bloodline may be all but completely irrelevant in the course of discrimination via various acts of colorism". Making a related point, Harris (2008, *p*. 61) states that "[t]raditional racism places a higher value on ancestry than colorism… while colorism assigns people to places along a spectrum from dark to light, indigenous or African to European". Thus, from the perspective of the proponents of colorism, ancestry per se is irrelevant.

If color phenotypes are found to merely proxy the effects of genetic ancestry, the results would be more consistent with what Abascal and Garcia (2022) describe as the inherited (dis)advantage model or what Hu et al. (2019) name the distributional model, and which we consider essentially the same model. According to this model, for various reasons, populations differ in traits, and these trait differences are transmitted vertically or intergenerationally. Because both racial appearance/color and family heritage, including ancestry, correlate in ancestrally heterogeneous populations, there is potential confounding between ancestry-related family influences and discrimination conditioned on color phenotypes.

Due to a concern for confounding, some research has attempted to control for intergenerational factors by employing sibling designs and measuring academic or educational outcomes (Bucca, 2018; Francis-Tan, 2016; Francis & Tannuri-Pianto, 2012; Hu et al.,2019; Kizer, 2017; Marteleto & Dondero, 2016; Mill & Stein, 2016; Rangel, 2015; Ryaboy, 2016; Telles, 2004). The reasoning is that in recently-admixed populations, siblings may differ noticeably in race-associated phenotypes such as skin color (see: e.g., Leite et al., 2011), but siblings will exhibit little differences in genetic ancestry and no difference in family environment. As a result, with a sibling design, it should be possible to disentangle appearance-based effects from family-heritage-based ones. The academic outcome differences examined in these studies include the following variables: educational attainment (Buca, 2018; Francis-Tan, 2016; Kizer, 2017; Marteleto & Dondero, 2016; Mill & Stein, 2016; Rangel, 2015; Ryaboy, 2016), grade-point average (Francis & Tannuri-Pianto, 2012), age-appropriate grade (Telles, 2004), aptitude test scores (Francis & Tannuri-Pianto, 2012; Hu et al.,2019), and literacy (Mill & Stein, 2016).

Most researchers either found modest associations between color phenotype and academic outcomes among siblings and interpreted their results as mainly supporting an intergenerational model (Francis-Tan, 2016; Mill & Stein, 2016; Rangel, 2015) or reported slight within-sibship differences but interpreted these as support for some color-based discrimination (Telles, 2004). However, a minority of researchers reported substantial and statistically significant within-sibship effects (Marteleto & Dondero, 2016; Ryabov, 2016). Although no formal meta-analysis has been conducted, carefully studying all the outcomes shows a relatively small overall within-sibships effect. The results from the eight sibling studies involving academic outcomes are reviewed in Table 15 of the supplementary file. As seen in 16 out of 20 effects, darker siblings have on average worse academic outcomes, and the mean effect between siblings is about 10% of the effect, unconditioned on family background, among families or in the population. These analyses, though, have been limited by the modest number of variables available in the case of the census-based studies (e.g., Francis-Tan, 2016; Mill & Stein, 2016; Rangel, 2015; Telles, 2004) or non-optimal statistical power in the case of the longitudinal studies (e.g., Buca, 2018; Hu et al., 2019; Kizer, 2017).

An alternative approach to testing colorism vs. inheritance hypotheses involves using admixture-regression designs (e.g., Connor & Fuerst, 2023; Fuerst, 2021; Fuerst et al., 2021). In these designs, recently-admixed populations are treated as natural experiments, and this admixture is used to disentangle various cultural, environmental, and genetic factors. In the present context, the design is employed to try to disentangle inherited (dis)advantages associated with racial appearance from non-inherited (dis)advantages due to, for example, contemporaneous discrimination. For this purpose, global genetic ancestry and either a phenotype or genetic markers of a phenotype are included in a regression analysis along with other variables. The objective is to determine whether racial appearance affects outcomes independent of global genetic ancestry.

A theoretical path model is presented in Figure 1. The colorism model posits that discrimination based on phenotype results in disparities in cognitive abilities and other academic outcomes through the direct effects of discrimination on learning. According to this model, in populations with a mix of ancestries, academic performance is likely indirectly linked to genetic ancestry due to the correlation between racial phenotypes and genetics. Conversely, the inherited disadvantage model argues that genetic and cultural factors, which are tied to global ancestry, drive academic outcome disparities. Because genetic ancestry is correlated with racial phenotypes, academic related traits will tend to be indirectly correlated with racial phenotype in admixed populations. In the admixture-regression design, global genetic ancestry is controlled for to account for inherited disadvantages.

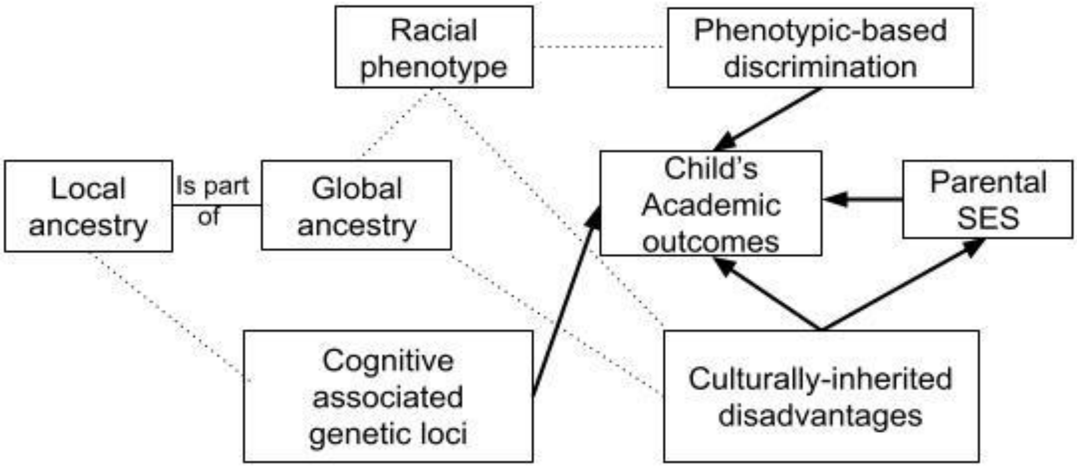

Figure 1. Theoretical Model of the Association between Putative Causes (Discrimination vs. Inherited Disadvantage), Ancestry, Racial-Phenotype, Academic Outcomes, and Parental-Socioeconomic Status.

The colorism model clearly predicts that racial appearance affects outcomes independent of genetic ancestry. If the model is correct, individuals with lighter skin, hair, and eye color should have better outcomes controlling for overall genetic ancestry. An opposite finding would be consistent with an intergenerational model, according to which traits conducive to better outcomes are being transmitted down lines of descent as indexed by genetic ancestry. This inheritance of traits could be mediated by genes, epigenetic factors, or culturally-inherited factors. Applying the admixture-regression design to data from the US and Brazil suggests that educational attainment and cognitive ability are primarily related to genetic ancestry, and are mostly unrelated to racial appearance (Fuerst et al., 2021; Kirkegaard et al., 2017; Lasker et al., 2019).

The admixture-regression design comes with a couple of assumptions that can be easily tested. The first assumption is that there is little cross-assortative mating for race-associated phenotype and the relevant traits (e.g., cognitive ability). In the presence of such assortment, race-associated phenotype can become genetically correlated with the outcomes independent of ancestry (Jensen, 1998). If so, race-associated phenotype and outcomes may be associated with one another, independent of ancestry, for genetic and not discriminatory reasons. The second assumption is that there is no substantial reverse causation from outcomes to race-associated phenotype; for example, low-prestige occupations often are associated with increased outdoor work, sun exposure, and, consequently, darker color. These two assumptions are common to colorism research, but, in this design, they only become a concern if an association between race-associated phenotype and outcomes is found independent of genetic ancestry.

The third assumption is that genetic ancestry and racial appearance are not collinear in samples. Dissociation between race-associated traits, especially non-highly polygenic ones, and genetic ancestry is expected in admixed populations due to genetic crossover and segregation (Kim et al., 2021). The extent of dissociation is an empirical question. The final assumption is that inherited (dis)advantages correspond with differences in ancestry. This is expected based on a simple model of vertical transmission of inherited traits given an initial inequality between groups and assuming that the estimated ancestry corresponds with the percentage of ancestors of relevant parental groups. In admixed American groups this assumption holds, because genetic ancestry percentages can be understood in terms of the number of ancestors from different ancestry groups (e.g., Mooney et al., 2022).

Most studies on the effects of racial appearance use single phenotypic measures of appearance. However, interviewer-rated color scales, in particular, have often been found to have modest reliability (Campbell et al., 2020; Hannon & DeFina, 2016; Hannon & DeFina, 2020). Moreover, skin color ratings have been found to be influenced by interviewer-related characteristics (Campbell et al., 2020; Cernat et al., 2019) and, additionally, the interviewer's perceptions about the participants' socioeconomic status (Roth et al., 2022). So, there are some concerns about the reliability and validity of skin color ratings. An alternative approach is to use genetic predictors of phenotype; they have an advantage in that they do not suffer from the problems of reverse causality and interviewer-related biases. Therefore, in this study, we created several new genetically-based predictors of European appearance. Moreover, we combine these predictors of skin, hair, and eye color through factor analysis to increase reliability. Afterward, we conducted admixture-regression analyses to test if European appearance was associated with general intelligence (*g*) and school grades independently of global genetic ancestry, as predicted by theorists of colorism. Cognitive ability was of particular interest because it has been found to partially mediate the relation between color and other outcomes (Campos-Vazquez & Medina-Cortina, 2019; Fuerst et al., 2019; Kreisman & Rangel, 2015). Therefore, cognitive ability differences may partially explain the relationship between color and socioeconomic or academic outcome differences. For this reason, Huddleston and Montgomery (2010, *p*. 69) note that "more research is needed in intragroup differences among Blacks and intelligence... Results from this research have huge implications for the skin tone hierarchy in the African American community". In line with this recommendation, we examine the extent to which cognitive ability plays a mediating role for genetic ancestry and grades.

As we already noted, studies which have used sibling designs overall show a modest association between European appearance and academic outcomes. Based on these results, we hypothesized that European appearance will show an association with both *g* and grades in regression models which also include genetic ancestry. Moreover, meta-analyses indicate that general mental ability and school grades are highly correlated (e.g., Roth et al., 2015), so we hypothesized that the relation between both European appearance and genetic ancestry and between school grades will be strongly mediated by *g*.

2. Data and methods

2.1. Sample

The Adolescent Brain Cognitive Development Study (ABCD) is a collaborative longitudinal project involving 21 collection sites across the US. It was created to research the psychological and neurobiological bases of human development. At baseline, around 11,000 9-10-year-old children were sampled, mostly from public and private elementary schools. A probabilistic sampling strategy was used to create a broadly representative sample of the population for this age group. We used the 3.0 data release.

For the main analyses, we focused on the 3814 (with grades) to 4459 (with *g* scores) individuals who were parentally identified as Black, Hispanic, Native American, or Other; we also included individuals who were marked as belonging to multiple race/ethnic categories. The choice to focus on these ethnic groups was influenced by Marira and Mitra (2013), who note that "the most rigorous research concerning the nexus of colorism and labor market outcomes has been conducted on African American and Latino populations in the United States" (*p*. 104). Although there is little ancestry-related color variability among non-Hispanic White Americans, we also ran the analyses including this group; we relegated most of these results to the supplementary file. We excluded anyone who was parentally identified as East Asian, South Asian, or Pacific Islander primarily because there were potential problems with reliable and interpretable East and South Asian ancestry estimates. Among South Asians, admixture estimates capture both recent and archaic Indo-European admixture, rendering the interpretation of these estimates unclear. Moreover, since we were unable to create a separate Pacific Islander ancestry component due to a lack of reference samples, East Asian and Pacific Islander ancestry was confounded. In contrast, the interpretation of European, African, and Amerindian admixture among Black, Hispanic, and Native American populations is unambiguous since this admixture occurred within the last 500 years, following the Age of Discovery and the settling of the New World.

2.2. Variables

A number of theoretically relevant variables were used. They are described in the sections below.

2.2.1 Admixture estimates

The ABCD Research Consortium conducted the imputing and genotyping using Illumina XX. Quality control was performed using PLINK 1.9; a total of 516,598 genetic variants survived the quality control. When computing admixture estimates, we used only directly genotyped, bi-allelic, autosomal SNP variants (494,433 before, 493,196 after lifting). We filtered variants in the reference population dataset to reduce bias from sample non-representativeness. Variants were pruned for linkage disequilibrium at the 0.1 R^2 level using PLINK 1.9 (--indep-pairwise 10000 100 0.1), leaving 99,642 variants after pruning. Next, target samples from ABCD were merged with reference population data from 1000 Genomes and HapMap. We excluded the following 1000 Genomes and HGDP reference populations: Adygei, Balochi, Bedouin, Bougainville, Brahui, Burusho, Druze, Hazara, Makrani, Mozabite, Palestinian, Papuan, San, Sindhi, Uygur, and Yakut. These populations were excluded because either they were overly admixed or because the individuals in the ABCD sample lacked significant portions of these ancestries (as in the case of Melanesians and San). The ABCD target sample was then split into 50 random subsets (of approximately 222 persons each) and merged sequentially with the reference data. Repeat subsetting was done to avoid skewing the admixture algorithm to European ancestry, as this ancestry was dominant in the ABCD sample. Next, we performed cluster analysis and estimated ancestry based on a k = 5 solution (European, Amerindian, African, East Asian, and South Asian ancestries), as this provided the most comprehensive yet also parsimonious model of the US population and captured all predominant ancestral backgrounds in the US population. Our European, African, and Amerindian estimates perfectly correlated with the estimates provided in the ABCD dataset (genetic_af_european, genetic_af_african, and genetic_af_european). As ABCD does not clearly document the construction of these estimates, we used our own ancestry estimates instead.

2.2.2. General cognitive ability, 11 cognitive tests, and NIHTBX fluid and crystal composite scores

The baseline ABCD data contained the following cognitive tests: Picture Vocabulary, Flanker, List Sorting, Card Sorting, Pattern Comparison, Picture Sequence Memory, Oral Reading Recognition, Wechsler Intelligence Scale for Children's Matrix Reasoning, the Little Man Test (efficiency score), the Rey Auditory Verbal Learning Test (RAVLT) immediate recall, and RAVLT delayed recall. The first seven of these are from the NIH Toolbox® cognitive battery. For details about these measures, see Thompson et al. (2019). In addition, ABCD provides a precomputed measure of crystallized cognitive ability (based on the Picture Vocabulary Test and the Oral Reading Recognition Test) and a measure of fluid cognitive ability (based on Flanker, List Sorting, Card Sorting, Pattern Comparison, and Picture Sequence Memory) measures. Details of these measures are provided by Akshoomoff et al. (2014). The crystallized ability subtests are said to be more dependent on learning experience and "represent accumulated store of verbal knowledge and skills, and thus are more heavily influenced by education and cultural exposure, particularly during childhood" (Akshoomoff, 2014, *p*. 120).

We computed *g* scores via the multi-group confirmatory factor-analytic method detailed in Fuerst et al. (2021). In this earlier publication, we outputted the *g* scores from the best-fitting and, additionally most-parsimonious model. In this case, *g* alone was found to explain the mean parentally-identified race and ethnicity (henceforth 'race and ethnicity') differences. Scores were standardized (M = 0.00; SD = 1.00) on the total sample of 10,370 children.

2.2.3. Grades

Parents were asked: "What kind of grades does your child get on average?" (1 = As /2 = Bs /3 = Cs / 4 = Ds / 5 = Fs). We recoded this variable using a 4-point scale as is commonly used in the US (with 4.0 representing an A, 3.0 representing a B, etc.), and then standardized the scores (M = 0.00; SD = 1.00). These data were available for N = 9128 for the Black-Hispanic-Other-White sample and N = 3814 for the Black-Hispanic-Other sample.

2.2.4. Child US-born and immigrant family

Parents reported if the child was born in the United States. This variable is recoded as "1" if the child was born in the United States and "0" for all other responses. Additionally, parents reported if any family members (including the child's maternal or paternal grandparents) were born outside of the United States. This variable, immigrant family, was also recoded as "1" if any family member was born outside the United States and "0" for all other responses.

2.2.5. Sex

Parents identified the sex of the children as female or male. Sex was recoded as "1" for females, and "0" for males.

2.2.6. Age

Age was calculated starting with age in months at the time of the interview ("interview age") divided by 12.

2.2.7. General socioeconomic status (SES)

Using Principal Components Analysis (PCA), we computed a general factor of SES based on seven substantially correlated indicators, which explained 42% of the variance. The loadings on the first factor were: financial adversity (.31), area deprivation index (.49), neighborhood safety protocol (.31), parental education (.54), parental income (.66), parental marital status (.43), and parental employment status (.23). We used the *PCA mixdata* R package (Chavent et al., 2014) to analyze these data, since this algorithm handles mixed categorical and continuous data. Fuerst et al. (2021) provide more details on this variable.

2.2.8. Predicted European appearance

As interviewer-rated phenotype is often unreliable and influenced by interviewer characteristics and as we only had phenotypic data for a small subset of the sample, we created genetic predictors of phenotype for analysis of the main sample. Specifically, we used tanning ability and hair pigment polyfun scores from Weissbrod et al. (2022; note that the SNP weights for these phenotypes were first published at the beginning of 2020) and skin color, hair color, and eye color probabilities calculated using the HIrisPlex-S web application (https://hirisplex.erasmusmc.nl/). To create a genetic index of European appearance, we employed PGSs developed by Weissbrod et al. (2020; 2022) for tanning propensity and hair pigment. These were created by applying genome-wide functionally-informed fine-mapping to individuals of British descent in the UK Biobank. These scores likely better estimate causal effects, thus reducing the likely adverse effects on between-population portability stemming from the impacts of linkage phase disequilibrium differences between populations (Weissbrod et al., 2020; Weissbrod et al., 2022).

The HIrisPlex-S web application, developed for use by the US Department of Justice in forensic investigations, and validated on thousands of people from around the world (Chaitanya et al., 2018; Walsh et al., 2017; Walsh et al., 2014), imputes probabilities for skin, hair, and eye color based on 41 SNPs that are functionally related to what could broadly be termed color traits (of these 36 were for skincolor, 22 for hair color, and six for eyecolor, with overlap). HIrisPlex-S gives probabilities that a given individual occupies a level associated with the Fitzpatrick Scale skin type (i.e., Type I, scores 0–6, "palest, freckles"; Type II, scores 7–13; Type III-IV (combined), scores 14–27; Type V, scores 28–34; Type VI, scores 35–36, this being associated with "deeply pigmented dark brown to darkest brown"). We weighted the medium score of each Type (e.g., Type I = 3) by the probability of each type to create a singular color measure. For hair color, HIrisPlex-S gives probabilities of light as opposed to dark hair color. For eye color, HIrisPlex-S gives probabilities of blue, intermediate, and dark eye color. We summed the blue and intermediate colors to create the light eye color probability.

The five phenotypic predictor scores, all based on functionally-informed SNPs, overlapped due to pleiotropy, meaning that different traits are co-influenced by a common set of genes. Because of these pleiotropic relationships, we were able to use factor analysis, yielding summary scores. Specifically, we factor-analyzed the tanning ability, hair pigment, skin color, hair color, and eye color scores, using the built-in R command *factanal*. This command function fits a common factor model using maximum likelihood estimation. A single-factor model explained 81% of the variance, and the loadings were: tanning ability .96, hair pigment .98, skin color .89, hair color .88, and eye color .79. We centered and standardized these scores in the full sample of 10,370 children. The correlation matrices are shown in Table 1.

2.2.9. European Phenotype

The ABCD twin data contained race-related phenotypic ratings for N = 239 individuals (after removing one MZ twin from each MZ twin pair). There were two ordinal-scale ratings for each phenotype. The phenotypes were as follows:

(1) Hair color ("zyg_ss_t1_hair_dark";

Table 1. Correlation matrices for European genetic ancestry, predicted European appearance, and genetically predicted hair, skin, and hair color scores.

a. Black-Hispanic-Other sample (N =4459)

Variable	*M*	*SD*	1	2	3	4	5	6
1. European ancestry	0.44	0.28						
2. European appearance	-0.89	0.79	.84**					
			[.83, .85]					
3. UKBB tanning ability	-0.85	0.87	.85**	.95**				
			[.84, .86]	[.95, .96]				
4.UKBB hair pigment	-0.88	0.80	.82**	.99**	.92**			
			[.81, .83]	[.99, .99]	[.92, .92]			
5. HirisPlex skin color	-0.82	0.81	.67**	.82**	.78**	.77**		
			[.66, .69]	[.81, .83]	[.76, .79]	[.76, .79]		
6. HirisPlex hair color	0.21	0.29	.64**	.84**	.75**	.80**	.71**	
			[.62, .66]	[.83, .84]	[.73, .76]	[.79, .81]	[.69, .72]	
7. HirisPlex eye color	0.13	0.26	.52**	.71**	.59**	.68**	.63**	.73**
			[.50, .54]	[.69, .72]	[.57, .61]	[.67, .70]	[.61, .65]	[.71, .74]

b. Black-Hispanic-Other-White sample (N =10,370)

Variable	*M*	*SD*	1	2	3	4	5	6
1. European ancestry	0.75	0.33						
2. European Appearance	0.00	1.00	.89**					
			[.89, .89]					
3. UKBB tanning ability	0.00	1.00	.89**	.97**				
			[.89, .89]	[.96, .97]				
4. UKBB hair pigment	0.00	1.00	.88**	.99**	.94**			
			[.88, .89]	[.99, .99]	[.94, .95]			
5. HirisPlex skin color	0.00	1.00	.80**	.90**	.87**	.87**		
			[.79, .80]	[.89, .90]	[.87, .88]	[.86, .87]		
6. HirisPlex hair color	0.53	0.39	.77**	.89**	.82**	.87**	.77**	
			[.76, .78]	[.89, .89]	[.82, .83]	[.86, .87]	[.77, .78]	
7. HirisPlex eye color	0.44	0.41	.66**	.80**	.70**	.78**	.74**	.79**
			[.65, .67]	[.79, .80]	[.69, .71]	[.77, .79]	[.73, .75]	[.79, .80]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation. * indicates $p < .05$. ** indicates $p < .01$.

"zyg_ss_t2_hair_dark") which was rated as "0" = light, "1" = medium, "2" = dark, and which we reverse-coded.
(2) Hair pigment ("zyg_ss_t1_hair_col"; "zyg_ss_t2_hair_col") which was rated as "0" = light blond, "1" = blond, "2" = red, "3" = brown, "4" = black, and which we reverse-coded.

(3) Eye color ("zyg_ss_t1_eye_col"; "zyg_ss_t2_eye_col"); this scale was originally rated as "0" = blue, "1" = gray, "2" = green, "3" = hazel, "4" = brown, and we recoded this scale as follows: light (blue, grey, and green) = "1" and dark (hazel & brown) = "0".

(4) Hair form, based on the sum of scores from hair texture ("zyg_ss_t1_hair_txtr"; "zyg_ss_t2_hair_txtr"), which was rated as "0" = coarse, "1" = medium, "2" = fine, and hair type ("zyg_ss_t1_hair_type"; "zyg_ss_t2_hair_type") which was rated as "0" = curly, and "1" = wavy, "2" = straight.

Higher values were associated with a more typical European hair form.

Since we had data from two raters, we were able to compute reliability estimates. Internal consistency coefficients (ICC) estimates and their 95% confidence-intervals were calculated using the *Psych* statistical package (Revelle & Revelle, 2015). These values were based on a mean rating (k = 2), absolute-agreement, one-way random model (i.e., ICC1k; Koo & Li, 2016). The one-way model used phenotypic data sourced from two data collection sites (02 and 19). The one-way model is recommended in cases such as these (Koo & Li, 2016). Hair color, hair pigment, eye color, and hair form had average reliabilities [and confidence intervals] of .67 [.59, .73], .68 [.82, .88], 84 [.80, .87], and .89 [.86, .91], respectively. These values indicate moderate to good reliability (Koo & Li, 2016), so we used the average of ratings in subsequent analyses. Moreover, the four phenotype scores were strongly correlated with European ancestry (r_s = .44 to .57); the correlation matrices are shown in Table 2.

To create rated-European phenotype scores, we factor-analyzed the scores using the R command *factanal*. A single-factor model explained 35% of the variance, and the loadings were as follows: hair color .46, hair pigment .74, eye color .71, and hair form .36. We centered and standardized these scores on the subsample of 239 individuals with phenotypic data.

Table 2. Correlation matrices for European genetic ancestry, genetically predicting European appearance, phenotypic European appearance, and specific phenotypes in the twin sample with phenotypic ratings (*N* = 239).

Variable	*M*	*SD*	1	2	3	4	5	6
1. European ancestry	0.85	0.21						
2. Predicted European appearance	0.00	1.00	.79**					
3. Phenotypic European appearance	0.00	1.00	.71**	.76**				
4. Phenotype: light hair	0.00	1,00	.44**	.48**	.54**			
5. Phenotype: hair pigment	0.00	1.00	.56**	.61**	.87**	.34**		
6. Phenotype: light eyes	0.00	1.00	.57**	.64**	.83**	.32**	.53**	
7. Phenotype: fine hair form	0.00	1.00	.53**	.43**	.43**	.21**	.26**	.25**

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. * indicates $p < .05$. ** indicates $p < .01$. *N* = 239.

The correlation between our genetically predicted European appearance and rated European phenotype was r = .76, which can be regarded as high-magnitude (Gignac & Szodorai, 2016). Notably this correlation was higher than that with global ancestry at r = .71, as would be expected if our variable predicted physical appearance above and beyond genetic ancestry. The ICCs for genetically predicted European appearance and rated European phenotype (N = 239) were .80 and .89 for single and average raters, respectively. For the Black-Hispanic-Other subsample (N = 88), these ICCs were .75 and .86, respectively. These magnitudes are usually interpreted to mean good reliability (Koo & Li, 2016).

2.2.10. Race and ethnicity fraction and Hispanic

Based on the 18 questions asking about the child's race, we created four dummy race and ethnicity variables: Black, White, Native American, and Not Otherwise Classified (NOC).

The NOC category included those identified as "Other Race," "Refused to answer," or "Don't Know". Asians and Pacific Islanders were previously excluded and so were not included in the NOC category. We transformed these variables into interval race and ethnicity variables. These were calculated as the value selected for each of the four groups (0 or 1) over the total number of responses (0 to 4). Thus, individuals were assigned four race and ethnicity fractions ranging from 0 to 1. We used the White interval variable as the benchmark group. As a result, this variable is dropped from the regression models. As with ancestry, we leave these variables unstandardized so that the unstandardized beta coefficients for race and ethnicity fraction can be interpreted as a change in 100 percent race and ethnicity identity for every standardized unit of the dependent variable. We further create a variable for Hispanic ethnicity, coded as "1" for "Hispanic" and "0" for non-Hispanic. The correlation matrices for the predicted European appearance, genetic ancestry, and race and ethnicity variables, based on the Black-Hispanic-Other-White sample, are shown in Table 3.

Table 3. Correlation matrices for predicted European appearance, genetic ancestry, and race and ethnicity in the Black-Hispanic-Other-White sample (N = 10,370).

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. Predicted European appearance	0.00	1.00								
2. European ancestry	0.75	0.33	.89**							
3. African ancestry	0.18	0.31	-.78**	-.89**						
4. Amerindian ancestry	0.06	0.14	-.32**	-.31**	-.13**					
5. frac White	0.73	0.43	.77**	.86**	-.83**	-.13**				
6. frac Black	0.20	0.38	-.72**	-.83**	.95**	-.17**	-.82**			
7. frac Native American	0.02	0.11	-.03**	-.03**	-0.01	.08**	-.18**	-.05**		
8. frac NOC	0.06	0.23	-.21**	-.19**	-.03**	.49**	-.41**	-.13**	-.04**	
9. Hispanic	0.19	0.40	-.27**	-.22**	-.12**	.76**	-.07**	-.17**	.04**	.38**

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. * indicates $p < .05$. ** indicates $p < .01$.

2.2.11. eduPGS

To create educational polygenic scores (PGS), we scored the genomes using PLINK v1.90b6.8. We used the multi-trait analysis of genome-wide association study (MTAG) eduPGS SNPs (N = 8,898 variants in this sample) to compute eduPGS, and we based ourselves on the results from the genome-wide association study (GWAS) of Lee et al. (2018). These scores were based on educational attainment (N = 1,131,881), cognitive ability (N = 257,841), hardest math class taken (N = 430,445), and mathematical ability (N = 564,698) (Lee et al., 2018). Previous research has shown these scores to have good predictive validity in European populations, and reasonable trans-ethnic predictive validity in Hispanic, and African-American populations (Fuerst et al., 2021; Lasker et al., 2019).

2.3. Analysis

2.3.1 Validation of European Phenotypic Predictor

To validate our genetic predictor of European appearance, we ran two analyses. First, we ran regression models in which we predicted parentally-identified-child-racial category (White = "1"; non-White = "0") based on our European phenotypic predictor, with European genetic ancestry controlled. While racial classifications in the US are primarily based on perceived continental *lme4* package (Bates, Mächler, Bolker, & Walker, 2015).

As noted in Section 2.2.9 our European phenotype predictor had excellent reliability. So, second, using the subsample for which we had phenotypic ratings, we examine the degree to which our genetically predicted European appearance variable predicted rated European phenotype independently of genetic ancestry and, in supplemental analyses, race and ethnicity. We expect our appearance predictor to have validity as a predictor of rater reported appearance above and beyond global genetic ancestry. Since, we only had two sample sites and since we dropped one of two MZ twins we ran ordinary least square (OLS) for simplicity. However, we also report results based on linear mixed-effects, controlling for site, in Tab 2 of the supplementary file.

2.3.2 Main regression analyses

We next ran a series of regression analyses, using mixed-effects models, in which *g* or parentally-reported grades was the dependent variable and European ancestry (Harris, 2008; Hall, 2020), skin color has been found to influence the classifications independently of ancestry (Schachter, Flores & Maghbouleh, 2021). Thus, we expected European appearance to predict the identified race of the child, independently of genetic ancestry.

In line with the recommendation of Heeringa and Berglund (2021), we used a linear mixed-effects model rather than ordinary least squares. Linear mixed-effects involve partially decomposing the residual term into linear random effects components linked to the data-collection-site identifiers and same-family identifiers within the sample. This allows for the possibility of error term correlations within data collection sites or within families with multiple tested individuals (see: Heeringa & Berglund, 2021). This specification replicates that which was used by the ABCD Data Exploration and Analysis Portal (DEAP), and so the use of this multilevel model also aids in replication. To run these analyses, we employed the *lmer* command from the appearance was the main independent variable. We ran five models, which sequentially added (parentally-identified) racial and ethnic category, SES, and ancestry, and both ancestry and SES to the initial regression model. The expectation was that if the colorism model was correct, predicted European appearance would retain validity when we added race and ethnicity, SES, and ancestry. In running these models, we followed a methodology similar to that of Telles and Paschel (2014) and Telles, Flores, and Urrea-Giraldo (2015), except that we also added genetic ancestry to the models. So, we followed established models of analyzing these kinds of data.

For the analyses with *g* (and also cognitive subtests), we used the mixed-effects model discussed above. However, parent-reported school grades showed a strong censoring effect (A = 49%; B = 36%; C to F = 15%), with many individuals receiving the highest grade of an A and the distribution not being normal. Therefore, we also ran analyses for grades using tobit regression, which adjusts for censored data, since censoring can induce effects resembling model misspecification. For these analyses, we used the *tobit* function in the **AER** package (Kleiber et al., 2020). No package for multilevel tobit regression is available for R, so for these tobit regression analyses we dropped the site and family random effects and included dummy variables for recruitment site instead. This is a suboptimal method, so we ran all analyses using both the standard mixed-effects model based on linear regression and the tobit regression models and compared the results. We also assessed the degree of collinearity for the European appearance variable, using the variance inflation factor (VIF) statistic. We used the **car** statistical package (Fox and Weisberg, 2011) to calculate the values of VIF.

2.3.3 Causal mediation analyses

Following the suggestion of Huddleston and Montgomery (2010), we ran causal mediation analysis using the **mediation** R package (Tingley et al., 2013). This package estimates both the mediation effect and the proportion of the effect that is directly causally mediated. We ran analyses with *g* as a mediator of the relation between grades and either European ancestry or European appearance. We ran these analyses both in the Black-Hispanic-Other-White sample and the Black-Hispanic-Other sample. European ancestry, European appearance, sex, age, child US-born, immigrant family, race and ethnicity, and interview site are included as covariates in all of the mediation analyses. Since this package cannot handle two levels of random effects, we dropped the family level from the analyses when using the mixed-effects model. We alternatively ran the models using linear regression for *g* and tobit regression for grades, in which case site effects were included as dummy variables.

2.3.4 Robustness analyses

Finally, as a robustness check, we reran the main regression analyses using the UKBB tanning and the HIrisPlex skin color variables instead of European appearance. This was done because theorists of colorism put the causal role of skin-color-based discrimination central (Marira & Mitra, 2013), and it may be that our European appearance variable is obscuring the relation between skin color and academic outcomes by also taking into account hair and eye color. We also reran the main analyses on the Hispanic and Black subsamples independently to determine if effects were present in subgroups. This was done because researchers using sibling designs have reported significant appearance-related effects among Hispanics (Ryaboy, 2016) without these effects being present in the full sample (Kizer, 2017). It may be that there are appearance-related effects among Hispanics or Blacks but not in the combined sample.

Additionally, we ran the analyses on all eleven cognitive subtests used to create *g* scores, and the NIH toolbox crystallized and fluid ability scales since it is possible that discriminatory effects will be localized on certain measures of cognitive ability. Differences might be expected to be more pronounced on crystallized measures since crystallized intelligence is “more heavily influenced by education and cultural exposure” (Akshoomoff, 2014, *p*. 120) and since theorists of colorism argue that colorism will manifest as a barrier to learning opportunities.

We further tested for possible cross-trait assortative mating by examining if eduPGS scores predict European appearance, tanning, and color independent of European ancestry. If there was cross-trait assortative mating, we would expect a substantial effect of eduPGS on these traits independent of European genetic ancestry. Norris (2019) reports polygenic evidence of assortative mating for education among Latin-American populations, while Zou et al. (2015) report evidence of assortative mating on European appearance. So, it is plausible that there was simultaneous assortative mating on both European appearance and education. While generally not mentioned by theorists of colorism, cross-trait assortative mating has long been hypothesized to explain advantages associated with European appearance in admixed American populations (e.g., Jensen, 1998; Reuter, 1917; Valenzuela, 2011).

2.4. Data and code

The R-code and additional model outputs are included in the supplementary file, available at Open Science Frame: https://osf.io/jqkns/. ABCD data are available to qualified researchers at: https://nda.nih.gov/abcd.

3. Results

3.1. Validation

Table 4 shows the regression results for predicting White racial and ethnic categorization. Model 1 shows the results for the Black-Hispanic-Other sample, while Model 2 shows the results for the Black-Hispanic-Other-White sample. Model 1a and Model 2a include only European ancestry as the predictor, while Model 1b and Model 2b include all non-European ancestries as predictors. We note that our genetically-predicted European appearance variable predicts participant race and ethnicity independently of genetic ancestry. The effect is small, as expected, because race and ethnicity in the US are mostly understood in terms of ancestry.

Table 4. Regression models with genetically-predicted European appearance as the key independent variable and white racial and ethnic categorization as the dependent variable using the Black-Hispanic-Other sample (Model 1) and the Black-Hispanic-Other-White sample (Model 2).

	Model 1a: Race/ethnicity, Appearance, & European Ancestry		**Model 1b: Race/ethnicity, Appearance, & non-European Ancestries**		**Model 2a: Race/ethnicity, Appearance, & European Ancestry**		**Model 2b: Race/ethnicity, Appearance, & non-European Ancestries**	
Predictors	*b*	*P*	*b*	*P*	*b*	*P*	*b*	*P*
(Intercept)	-0.10 (0.04)	**0.005**	0.76 (0.03)	**<0.001**	-0.14 (0.02)	**<0.001**	0.94 (0.02)	**<0.001**
Predicted European appearance	0.03 (0.01)	**0.004**	0.02 (0.01)	**0.017**	0.02 (0.00)	**<0.001**	0.02 (0.00)	**<0.001**
European ancestry	0.88 (0.03)	**<0.001**			1.07 (0.01)	**<0.001**		
Child US Born	0.04 (0.02)	0.071	0.04 (0.02)	0.124	0.05 (0.01)	**0.001**	0.04 (0.01)	**0.003**
Immigrant Family	0.14 (0.01)	**<0.001**	0.06 (0.01)	**<0.001**	0.07 (0.01)	**<0.001**	0.02 (0.01)	**<0.001**
African ancestry			-0.92 (0.03)	**<0.001**			-1.13 (0.01)	**<0.001**
Amerindian ancestry			-0.35 (0.04)	**<0.001**			-0.67 (0.02)	**<0.001**
East Asian ancestry			-0.96 (0.13)	**<0.001**			-0.81 (0.08)	**<0.001**
South Asian ancestry			-1.14 (0.21)	**<0.001**			-1.00 (0.13)	**<0.001**

Random Effects				
σ^2	0.02	0.01	0.01	0.01
τ_{00}	0.08 site_id_l:rel_family_id 0.00 site_id_l	0.07 site_id_l:rel_family_id 0.01 site_id_l	0.04 site_id_l:rel_family_id 0.00 site_id_l	0.03 site_id_l:rel_family_id 0.00 site_id_l
ICC	0.85	0.84	0.8	0.79
N	22 site_id_l 3863 rel_family_id	22 site_id_l 3863 rel_family_id	22 site_id_l 8672 rel_family_id	22 site_id_l 8672 rel_family_id
Observations	4459	4459	10370	10370
Marginal R^2 / Conditional R^2	0.464 / 0.918	0.527 / 0.925	0.739 / 0.948	0.754 / 0.948

Note: Beta coefficients (*b*) and *p*-values (*p*) from the mixed-effects models, with recruitment site and family common factors treated as random effects are shown. The values in parentheses are standard errors. The marginal and conditional R^2s of the mixed-effects model are shown at the bottom. ICC = Intraclass Correlation Coefficient.

Next, Table 5 shows the regression results for predicting interviewer rated phenotype based on genetically predicted European appearance in the small twin sample that had phenotypic ratings. Model 1 shows the results without genetic ancestry, while models 2a and 2b add European ancestry and non-European ancestries, respectively. We note that our genetically predicted European appearance variable predicts interviewer-rated European phenotype over and above genetic ancestry. The results, for the equivalent Model 2a, are substantially the same when we subset to the 88 Blacks, Hispanics, and Others in the twin sample (Predicted European appearance b = .59; *S.E.* = .11) or when we additionally include parental reported race in the models.

Table 5. Regression models with genetically predicted European appearance as the key independent variable and interviewer-rated phenotype as the dependent variable.

	Model 1: Phenotype ~ Predicted Phenotype		**Model 2a: Phenotype ~ Predicted Phenotype w/European ancestry**		**Models 2b: Phenotype ~ Predicted Phenotype w/non-European Ancestries**	
Predictors	*b*	*P*	*b*	*P*	*b*	*P*
(Intercept)	0.04 (0.06)	0.469	-1.09 (0.27)	**<0.001**	0.28 (0.09)	**0.001**
European appearance	0.76 (0.04)	**<0.001**	0.54 (0.07)	**<0.001**	0.53 (0.07)	**<0.001**
Sex	-0.09 (0.08)	0.286	-0.08 (0.08)	0.309	-0.07 (0.08)	0.360
European ancestry			1.32 (0.31)	**<0.001**		
African ancestry					-1.14 (0.33)	**0.001**
Amerindian ancestry					-1.61 (0.45)	**<0.001**

East Asian ancestry					-2.18 (3.10)	0.483
South Asian ancestry					-11.22 (13.97)	0.423
Observations	239		239		239	
R^2 / R^2 adjusted	0.584 / 0.581		0.614 / 0.610		0.619 / 0.610	

Notes: Beta coefficients (*b*) and *p*-values (*p*) from the OLS regression models. The values in parentheses are standard errors. The marginal and conditional R^2 of the mixed effects model are shown at the bottom.

3.2 Main results

Table 6 shows the main results with *g* as the dependent variable for the Black-Hispanic-Other sample. Its Model 1 reveals that the relation between predicted European appearance and *g* is statistically significant. When we add race and ethnicity in Model 2, this relation is reduced but still statistically significant. When we add SES, in Model 3, the effect is further reduced but still statistically significant. However, when we add genetic ancestry in Model 4a (without SES) and 4b (with SES) the relation becomes statistically non-significant. The results for the Black-Hispanic-Other-White sample, provided in the supplementary material, also reveal no statistically significant effect when adding European ancestry in Model 4a (without SES) and 4b (with SES).

Table 7 shows the main results, again for the Black-Hispanic-Other sample, using grades as the dependent variable. In this table, tobit regression is used. Model 1 reveals that the relation between predicted European appearance and grades is statistically significant. When we add race and ethnicity in Model 2, this relation is reduced but is still statistically significant. When we add SES, in Model 3, the effect is further reduced but is still statistically significant. Adding genetic ancestry in Models 4a and 4b (with SES) does not change this.

However, in the final Model (4b), the relation is only marginally statistically significant (p = 0.042). In contrast, the results for the Black-Hispanic-Other-White sample, provided in the supplementary material, show no statistically-significant effect of European appearance in Model 4a (without SES) and 4b (with SES). Moreover, the effects of European appearance in the Black-Hispanic-Other-White sample are trivial. Thus, the effect of European appearance on parent-reported grades only shows up in the Black-Hispanic-Other sample.

Table 6. Regression results for the effect of predicted European appearance on *g* in the Black-Hispanic-Other sample.

	M1: *g* ~ European appearance		**M2: *g* ~ European appearance + race and ethnicity**		**M3: *g* ~ European appearance + race and ethnicity + SES**		**M4a: *g* ~ European appearance + race and ethnicity + European ancestry**		**M4b: *g* ~ European appearance + race and ethnicity + European ancestry + SES**	
Predictors	*b*	*P*	*b*	*P*	*b*	*P*	*b*	*P*	*b*	*P*
Intercept	0.31 (0.25)	0.22	0.42 (0.26)	0.11	0.38 (0.25)	0.14	-0.62 (0.28)	**0.03**	-0.28 (0.27)	0.30
age	-0.05 (0.02)	**0.03**	-0.05 (0.02)	**0.03**	-0.05 (0.02)	**0.03**	-0.04 (0.02)	0.06	-0.05 (0.02)	**0.04**

sex	0.02 (0.03)	0.45	0.03 (0.03)	0.37	0.04 (0.03)	0.22	0.02 (0.03)	0.44	0.03 (0.03)	0.26
Predicted European appearance	0.34 (0.02)	**<0.01**	0.25 (0.03)	**<0.01**	0.15 (0.03)	**<0.01**	0.03 (0.04)	0.41	0.01 (0.03)	0.72
Child US Born	0.05 (0.08)	0.55	0.05 (0.08)	0.54	0.13 (0.08)	0.09	0.07 (0.08)	0.37	0.14 (0.08)	0.07
Immigrant Family	0.25 (0.04)	**<0.01**	0.20 (0.04)	**<0.01**	0.12 (0.04)	**0.04**	0.22 (0.04)	**<0.01**	0.14 (0.04)	**0.01**
Frac Black			-0.31 (0.07)	**<0.01**	-0.23 (0.07)	**0.02**	0.08 (0.08)	0.36	0.02 (0.08)	0.83
Frac Native American			-0.10 (0.12)	0.40	-0.05 (0.11)	0.66	-0.07 (0.12)	0.58	-0.03 (0.11)	0.78
Frac NOC			-0.19 (0.06)	**0.01**	-0.07 (0.05)	0.18	-0.07 (0.06)	0.23	-0.00 (0.05)	0.93
Hispanic			-0.05 (0.06)	0.38	-0.01 (0.05)	0.86	-0.04 (0.06)	0.45	-0.01 (0.05)	0.86
SES					0.35 (0.02)	**<0.01**			0.32 (0.02)	**<0.01**
European ancestry							1.24 (0.13)	**<0.01**	0.79 (0.12)	**<0.01**
Random Effects										
σ^2	0.52		0.52		0.51		0.51		0.51	
τ_{00}	0.52 site_id_l:rel_family_id		0.52 site_id_l:rel_family_id		0.43 site_id_l:rel_family_id		0.50 site_id_l:rel_family_id		0.43 site_id_l:rel_family_id	
	0.02 site_id_l		0.02 site_id_l		0.04 site_id_l		0.02 site_id_l		0.04 site_id_l	
ICC	0.51		0.51		0.48		0.51		0.48	
N	22 site_id_l		22 site_id_l		22 site_id_l		22 site_id_l		22 site_id_l	
	3863 rel_family_id		3863 rel_family_id		3863 rel_family_id		3863 rel_family_id		3863 rel_family_id	
Observations	4459		4459		4459		4459		4459	
Marginal R^2 / Conditional R^2	0.085 / 0.549		0.095 / 0.556		0.180 / 0.571		0.116 / 0.565		0.187 / 0.574	

Notes: Beta coefficients (b) and p-values (p) from the mixed-effects models, with recruitment site and family common factors treated as random effects are shown. The values in parentheses are standard errors. The marginal and conditional R^2 of the mixed effects model are shown at the bottom. ICC = Intraclass Correlation Coefficient.

Table 7. Tobit regression results for the effect of predicted European appearance on grades in the Black-Hispanic-Other sample.

	M1: Grades ~ European appearance		**M2: Grades ~ European appearance + SIRE**		**M3: Grades ~ European appearance + SIRE + SES**		**M4a: Grades ~ European appearance + SIRE + European ancestry**		**M4b: Grades ~ European appearance + SIRE + European ancestry + SES**	
Predictors	*b*	*P*	*b*	*p*	*b*	*P*	*b*	*P*	*b*	*P*

Age	-0.03 (0.03)	0.27	-0.03 (0.03)	0.30	-0.04 (0.03)	0.24	-0.03 (0.03)	0.34	-0.03 (0.03)	0.25
Sex	0.29 (0.04)	**<0.01**	0.29 (0.04)	**<0.01**	0.29 (0.04)	**<0.01**	0.29 (0.04)	**<0.01**	0.29 (0.04)	**<0.01**
European appearance	0.21 (0.02)	**<0.01**	0.20 (0.03)	**<0.01**	0.12 (0.03)	**<0.01**	0.10 (0.04)	**0.01**	0.09 (0.04)	**0.04**
Child US Born	-0.07 (0.10)	0.50	-0.08 (0.10)	0.43	-0.03 (0.10)	0.77	-0.07 (0.10)	0.47	-0.03 (0.10)	0.78
Immigrant Family	0.07 (0.04)	0.12	0.08 (0.05)	0.12	0.03 (0.05)	0.55	0.09 (0.05)	0.08	0.03 (0.05)	0.49
Frac Black SIRE			0.00 (0.09)	0.99	0.05 (0.09)	0.54	0.16 (0.10)	0.11	0.11 (0.10)	0.25
Frac Native American SIRE			0.12 (0.14)	0.36	0.15 (0.13)	0.27	0.13 (0.14)	0.33	0.15 (0.13)	0.26
Frac NOC SIRE			-0.13 (0.07)	0.06	-0.06 (0.07)	0.40	-0.08 (0.07)	0.23	-0.04 (0.07)	0.55
Hispanic			0.03 (0.07)	0.62	0.07 (0.07)	0.27	0.04 (0.07)	0.55	0.07 (0.07)	0.26
SES					0.22 (0.02)	**<0.01**			0.22 (0.02)	**<0.01**
European ancestry							0.50 (0.15)	**0.01**	0.19 (0.15)	0.20
Observations	3814		3814		3814		3814		3814	
R^2 Nagelkerke	0.056		0.058		0.089		0.061		0.089	

Notes: Beta coefficients (b) and p-values (p) from the tobit models, with recruitment site (not shown) added as dummy variables. The values in parentheses are standard errors.

Table 8, Model 1 shows the alternative multi-level regression results. For these, when we add genetic ancestry in Models 4a and 4b (with SES), the relation becomes statistically non-significant, although the model approaches statistical significance in the case of 4a (without SES) (p = 0.06). The results for the Black-Hispanic-Other-White sample, provided in the supplementary material, show no statistically significant effect of European appearance in Model 4a (without SES) and 4b (with SES). The discrepancy between the tobit and multilevel regression results could be due to not including random effects in the latter or due to censoring-related bias in the former. Regardless, the betas for both 4b models are fairly similar (b = .09 vs. b = .06) and suggest some unaccounted-for European appearance-related effect on parent-reported student grades.

Table 8. Mixed-effects regression results for the effect of predicted European appearance on grades in the Black-Hispanic-Other Sample.

	M1: Grades ~ European appearance	M2: Grades ~ European appearance + race and ethnicity	M3: Grades ~ European appearance + race and ethnicity + SES	M4a: Grades ~ European appearance + race and ethnicity + European ancestry	M4b: Grades ~ European appearance + race and ethnicity + European ancestry + SES

Predictors	*b*	*P*	*b*	*P*	*b*	*P*	*b*	*P*	*b*	*P*
(Intercept)	0.45 (0.29)	0.11	0.42 (0.29)	0.15	0.46 (0.29)	0.11	-0.03 (0.31)	0.93	0.26 (0.31)	0.40
Age	-0.06 (0.03)	**0.03**	-0.06 (0.03)	**0.04**	-0.06 (0.03)	**0.02**	-0.05 (0.03)	**0.04**	-0.06 (0.03)	**0.02**
Sex	0.34 (0.03)	**<0.01**	0.34 (0.03)	**<0.01**	0.34 (0.03)	**<0.01**	0.34 (0.03)	**<0.01**	0.34 (0.03)	**<0.01**
Predicted European appearance	0.19 (0.02)	**<0.01**	0.17 (0.03)	**<0.01**	0.10 (0.03)	**0.01**	0.08 (0.04)	0.06	0.06 (0.04)	0.13
Child US Born	-0.15 (0.09)	0.10	-0.17 (0.09)	0.07	-0.11 (0.09)	0.24	-0.15 (0.09)	0.09	-0.10 (0.09)	0.26
Immigrant Family	0.04 (0.04)	0.36	0.04 (0.05)	0.38	-0.02 (0.05)	0.62	0.05 (0.05)	0.27	-0.02 (0.05)	0.73
Frac Black			-0.00 (0.08)	0.97	0.05 (0.08)	0.54	0.16 (0.09)	0.08	0.12 (0.09)	0.19
Frac Native American			0.03 (0.13)	0.81	0.07 (0.12)	0.60	0.04 (0.13)	0.74	0.07 (0.12)	0.58
Frac NOC			-0.20 (0.06)	**0.01**	-0.13 (0.06)	**0.03**	-0.14 (0.06)	**0.02**	-0.11 (0.06)	0.07
Hispanic			0.05 (0.06)	0.40	0.07 (0.06)	0.26	0.06 (0.06)	0.34	0.07 (0.06)	0.24
SES					0.22 (0.02)	**<0.01**			0.21 (0.02)	**<0.01**
European_ ancestry							0.53 (0.14)	**<0.01**	0.23 (0.14)	0.10
Random Effects										
σ^2	0.76		0.75		0.75		0.75		0.75	
τ_{00}	0.32 site_id_l:rel_family_id		0.32 site_id_l:rel_family_id		0.29 site_id_l:rel_family_id		0.32 site_id_l:rel_family_id		0.29 site_id_l:rel_family_id	
	0.01 site_id_l		0.01 site_id_l		0.00 site_id_l		0.01 site_id_l		0.00 site_id_l	
ICC	0.30		0.30		0.28		0.30		0.28	
N	22 site_id_l		22 site_id_l		22 site_id_l		22 site_id_l		22 site_id_l	
	3296 rel_family_id		3296 rel_family_id		3296 rel_family_id		3296 rel_family_id		3296 rel_family_id	
Observations	3814		3814		3814		3814		3814	
Marginal R^2 / Conditional R^2	0.048 / 0.338		0.051 / 0.339		0.086 / 0.339		0.056 / 0.343		0.087 / 0.340	

Notes: Beta coefficients (*b*) and *p*-values (*p*) from the mixed-effects models, with recruitment site and family common factors treated as random effects, are shown. The values in parentheses are standard errors. The marginal and conditional R^2s of the mixed-effects model are shown at the bottom. ICC = Intraclass Correlation Coefficient.

We additionally computed the values of variance inflation factors (VIFs), which measure the amount of multicollinearity in a regression analysis. In cases of high multicollinearity, it can be difficult to distinguish between the effects of individual independent variables owing to high correlations among these. The full results for these tests for excessive multicollinearity are provided in Tab 5 of the supplementary file. For the Black-Hispanic-Other sample, the values of VIFs for predicted European appearance in Models 4a to 4b of Tables 6-8 ranged from 2.9 to 3.6. For the Black-Hispanic-Other-White sample, VIFs for predicted European appearance ranged from 4.0 to 4.6. Usually, a VIF value > 5 or, less strictly, > 10 is said to be problematic (James et al., 2013), but the values found here for European appearance are lower than these commonly-used thresholds, indicating that multicollinearity is not likely to be confounding our results. We also ran the models dropping the frac_SIRE variables, which, in the presence of European appearance, were leading to collinearity with European ancestry. As expected, doing so decreased the values of VIFs for European ancestry but did not substantially change the results.

3.3. Mediation analysis

The results from the causal mediation analyses are summarized in Table 9. The full results are provided in Tab 6 of the supplementary file. In both the Black-Hispanic-Other and the Black-Hispanic-Other-White samples, *g* was a substantial and statistically significant mediator of the relation between genetic ancestry and grades. In contrast, *g* was not a statistically significant mediator of the relation between European appearance and grades. In the Black-Hispanic-Other sample, European appearance had a significant total effect on grades (p = .03) with the same magnitude of effect as in Model M4a of table 7. Nonetheless, *g* was not a statistically significant mediator of the relation between predicted European appearance and grades.

Table 9. Summary of the causal mediation results for the full sample and race and ethnicity subsamples.

Method: LMER					
Predictor	Mediator	Criterion	Mediation Effect	Proportion of total effect mediated	*N*
Black-Hispanic-Other					
Predicted European appearance	*g*	grades	0.02 [-0.01, 0.05]	0.26	4459
European Ancestry	*g*	grades	**0.53** [0.41, 0.66]	1.03	3814
Black-Hispanic-Other-White					
Predicted European appearance	*g*	grades	0.01 [-0.01, 0.03]	0.25	10370
European Ancestry	*g*	grades	**0.61** [0.53, 0.71]	0.75	9128
Method: LM-Tobit					
Predictor	Mediator	Criterion	Mediation Effect	Proportion of total effect mediated	*N*
Black-Hispanic-Other					
Predicted European appearance	*g*	grades	0.02 [-0.01, 0.06]	0.24	4459

European Ancestry	*g*	grades	**0.54** [0.43, 0.67]	1.12	3814
Black-Hispanic-Other-White					
Predicted European appearance	*g*	grades	0.01 [-0.01, 0.02]	0.25	10370
European Ancestry	*g*	grades	**0.52** [0.44, 0.60]	0.83	9128

Notes: Statistically significant results ($p < 0.05$) are presented in bold.

3.4 Robustness analyses

As a robustness check, we reran the main regression analyses using the UKBB tanning and the HIrisPlex skin color variables instead of European appearance. These results are reported in Tab 8 and Tab 9 of the supplementary file. Neither the effects of UKBB tanning nor the effects of HIrisPlex skin color were close to significant for *g* or grades. So, using a composite indicator of hair, eye, and skin tanning/color instead of skin tanning/color alone did not decrease the effects. Rather, effects, particularly for grades, were stronger when using the European appearance predictor.

Next, we reran the main analyses on both the Hispanic (*n* = 2021 to 1741) and non-Hispanic Black (*n* = 1690 to 1432) subsamples. These results are shown in Tab 10 of the supplementary file. Again, European appearance, tanning, and color were not significantly related to either *g* or grades in the Hispanic and Black subsamples.

Additionally, we ran the analyses on all eleven cognitive subtests used to create *g* scores in addition to the NIHTBX fluid and crystallized composite scores. These results, for the Black-Hispanic-Other sample, are shown in Tab 13 of the supplementary file. We found statistically significant results only for the Picture Vocabulary test (*b* = 0.097; *S.E.* = .033), but not the other crystallized test, namely Oral Reading Recognition (*b* = 0.000; *S.E.* = .034). We also found marginally significant results for the crystallized composite scores (*b* = 0.068; *S.E.* = .033), which were due to the highly significant results for Picture Vocabulary, since the crystallized composite was derived from the Picture Vocabulary and Oral Reading Recognition tests. These results for crystallized composite scores and for Picture Vocabulary scores could represent a real effect, since it seems more likely that appearance-based discrimination would be present on a measure of knowledge and crystallized cognitive ability than fluid ability. Alternatively, this could represent a coincidence due to multiple testing (i.e., looking at the effects on eleven independent measures).

Finally, we tested for possible cross-trait assortative mating by examining if eduPGS scores predicted European appearance independent of European ancestry. These results are shown in Tab 11 of the supplementary file. We did not find significant associations between eduPGS and European appearance independent of European ancestry, which is inconsistent with the cross-trait assortative mating hypothesis.

4. Conclusion

4.1. Discussion

The colorism model states that there is ongoing discrimination based on physical appearance in the Americas, which contributes to the link between European phenotype and better social outcomes. This model predicts that European appearance, regardless of ancestry, will have a positive impact on academic outcomes. We tested the colorism model using the admixture-regression methodology. Specifically, we hypothesized, first, that European appearance would be related to *g* when taking into account genetic ancestry, and second, that European appearance would have a relationship with grades independent of genetic ancestry. However, we found no substantial evidence to support the first hypothesis and only limited evidence to support the second. As a result, our findings do not strongly support the colorism hypothesis.

Additionally, due to meta-analyses showing a significant connection between *g* and grades, we formulated two more hypotheses: third, that *g* would play a role in the relationship between European ancestry and grades, and fourth, that *g* would play a role in the relationship between European appearance and grades. Our findings provided strong evidence for the third hypothesis, but not for the fourth hypothesis. This suggests that the relationship between European ancestry and grades is dependent on *g*, while the relationship between European appearance and grades is not dependent on *g*.

We conducted several robustness tests. When we used tanning or color, instead of European appearance, as the main predictor, we did not find any significant statistical connections between these two variables and either *g* or grades. Moreover, we did not find statistically significant associations when subsetting to the two largest admixed groups, Hispanics and Blacks. The lack of an association between either tanning or color and academic outcomes further weakens a colorism model, since this model places primacy on "the causal role of skin tone in engendering the colorism phenomenon" (Marira & Mitra, 2013, *p*. 103). So, we conclude that the outcomes are robust, and that the results of the robustness tests did not support a colorism model.

Across 15 outcome measures (*g*, grades, eleven subtests, the fluid ability composite, and the crystallized ability composite), three traits (European appearance, UKBB tanning, and HIrisPlex skin color), and four groupings (Black-Hispanic-Other-White, Black-Hispanic-Other, Black, and Hispanic) we found three statistically significant results, two of which were redundant (i.e., the effect on Crystalized intelligence resulted from the effect on Picture Vocabulary). Given that 15 different overlapping academic outcomes were examined across three traits, these results could simply be chance results due to multiple testing. Moreover, the interpretation of the results for grades is complicated since the grades were parent-reported, not actual school-reported grades, and since the parent-reported grades were very course (e.g., mostly As, mostly Bs, mostly Cs, etc.).

On the other hand, the three statistically significant results may make theoretical sense. Theorists of colorism have argued that colorism will manifest as a barrier to learning opportunities (Thompson & McDonald, 2016) and optimal education (Crutchfield et al., 2022), acting against less European-appearing students. On this basis, it is reasonable to hypothesize that the effects would be larger on crystalized abilities and outcomes dependent on teachers' judgment. Therefore, future research should attempt to evaluate whether there are robust European-appearance effects on measures of crystalized ability and grades.

Regarding the general lack of association with respect to cognitive ability, one could perhaps argue that global genetic ancestry is a better predictor of overall racial appearance. Accordingly, discrimination might be based on an overall assessment of morphological differences, not just conspicuous race-associated differences in skin, eye, and hair color. However, this is somewhat different from what "colorists" have narrowly hypothesized, hence the term "colorism". If race-associated discrimination is said to be based on ancestry-indexing phenotypes, then perhaps a good alternative term might be "ancestrysim". It is not clear, though, why discrimination would be finely tuned to overall phenotypic markers of genetic ancestry instead of features that are stereotypic of racial groups.

A more likely explanation for these findings is that color is associated with cognitive ability predominantly because the color phenotype proxies global ancestry. Global ancestry could be related to how differences in these characteristics are inherited or passed on from parents to children along genealogical lines. Several researchers have argued that genetic ancestry might index social disparities intergenerationally transmitted for cultural, genetic, or epigenetic reasons (Corach & Caputo, 2022; da Silva et al., 2020; Fuerst & Kirkegaard, 2016). This possibility has largely been not discussed by sociologists who have focused instead on discriminatory or diffuse cultural models concerning disparities by caste, nation, ethnicity, or race. Our results suggest that researchers should also focus on genetic ancestry and identifying the specific genetic, epigenetic, and cultural factors which mediate the intergenerational transmission of academic outcomes.

4.2. Limitations

One could argue that our genetic predictor of European appearance is not perfectly reliable. However, frequently used skin tone scales, such as the Massey and Martin (2003) scale, have been found to have low reliabilities (Hannon & DeFina, 2016; 2020), so we would argue, based on our own results, that our genetically-predicted European appearance scores appear to be more reliable than the sorts of color measures which are typically used. A genetic-based predictor of color captures phenotype over an individual's lifetime without the variability due to the low reliability of interviewer rating skin tone scales which have been found to be influenced by interviewer-rated characteristics such as race/ethnicity (Campbell et al., 2020; Cernat et al., 2019) or the interviewer's perceptions about the participants socioeconomic status (Roth et al., 2022). So, we conclude that a genetic predictor of European appearance is preferable to interviewer-rated skin tone.

It is possible that there are substantial ancestry-independent associations between color and academic outcomes in other populations or for other academic traits. The novel admixture-regression method described here can be used to investigate if this is the case.

4.3 Implications

We focused on Hispanic, Black, Other, and White Americans. This is because, according to Marira and Mitra (2013, p. 104), "the most rigorous research concerning the nexus of colorism and labor market outcomes has been conducted on African American and Latino populations in the United States". Given that the best support for colorism is said to come from the study of Black and Hispanic Americans, we would have expected the association between European appearance/color and academic outcomes to be robust in this sample. However, we did not find this to be the case, which weakens the colorism hypothesis.

4.4. Conclusions

We found little support for the colorism hypothesis. Our results suggest that the relationship between racial appearance and academic outcomes cannot be considered as prima facie evidence of discrimination, as genetic ancestry, and the inherited disadvantage associated with it, is a plausible confounding variable. In future studies on colorism, it is recommended to consider genetic ancestry as a factor in the analyses. Because discrimination is such an important topic, it is essential that more studies are carried out before we are able to draw strong conclusions.

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Highlights: Admixture-regression analysis is a powerful tool that can be used to test the colorism hypothesis.

- We test the colorism hypothesis that academic outcome differences in the USA are due to phenotypic-based discrimination.
- The results generally do not support the colorism hypothesis and are more congruent with the hypothesis of inherited disadvantage according to which disadvantages are being intergenerationally transmitted.

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The Method of Vector Modelling of Personality Development Environment

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Abstract: The paper highlights the general statements of various methodological concepts of the environment of personal development. The summary of different methodological approaches to the analysis of educational environments is presented and their disadvantages are discussed. Original method of vector modeling of the environment of personality development based on Janusz Korczak's typology of "educating environments" is offered. The scales "Freedom – Dependence" and "Activity – Passivity" are distinguished. It is shown that "dogmatic" environment contributes to the formation of dependent and passive personality; "ideological" (creative) to the formation of free and active personality; "serene" to the formation of free, however, passive; "career" environment contributes to the formation of active, but dependent personality. Examples of several empirical and analytical studies based on the method of vector environment modeling are given. This method demonstrated the complementarity of different pedagogical and socio-psychological typologies.
Keywords: Environmental Expertise, Environmental Analysis Techniques, Personality Development, Vector Modeling Method, Typology of Environments.

1. Introduction

1.1. Methodology of the environmental studies

The educational philosophy traditionally considers the environment as one of the most important factors of personal development. All the heritage of the classical pedagogical scholars from J.M. Comenius, J. Locke, J.-J. Rousseau, and J.G. Pestalozzi to M. Montessori, J. Korchak, and A.S. Makarenko. Montessori, J. Korczak, and A.S. Makarenko is essentially dedicated to the description of the authors' personal development environments.

A.A. Leontiev states that that the educational environment concept is one of the key psychological and educational concepts that is now being actively developed. Thus, it is possible to identify at least five significantly different methodological approaches to the study of the school environment.

1. *The collectivist approach* includes numerous studies based on identifying and describing a wide range of "pedagogical conditions and factors. It is characterized by insufficient scientific rigor and completeness of the proposed structural and content models of various functional environments (from "information-educational" to "health-forming") and empirical eclecticism. The methodological roots of this approach can be found in the works on environmental studies and pedology in the 1920s.

2. *The socio-psychological approach*

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is the most widespread approach in the world, the research tasks are successfully solved within the frame-work of social and pedagogical psychology.

3. *The spatial-subjective approach* was formed based on the methodology of scientific direction as behavioral geography (J. Gold). The studies are focused on the analysis of behavior as conditioned by the spatial features of the environment. M. Montessori's researchers can be referred to this direction, which emphasizes the pedagogical organization of the subject learning environment.

4. *Y.S. Manuylova's environmental approach* to education is original that considers systematically the environment. This approach is a perspective methodology that can be used due to its pedagogical design (Manuilov, 1997). Nevertheless, the flipside of the originality of the conceptual apparatus is proven to be the difficulty of its "compatibility" with the traditional terminology of other researchers.

5. *The eco-personal approach* to the analysis of the environment is based on psychological and pedagogical methodology (E. Brunswick, K. Levin, A. Maslow, R. Sommer, H. Ozmond, C. Pavlik, W. Bronfenbrenner, J. Gibson, etc.). The approach is systemic in nature and has a wide and successfully applied instrumental and methodological support, which makes it extremely popular with scientists and practitioners.

The comparative analysis of various methodological approaches to the study of the environment of personal development allows us to high-light several common complementary, non-contradictory standpoints (Yasvin, 2013):

1. The developing personality is seen as an agent in the relationship with the environment.
2. The environment is considered as a spatially and/or event-limited environment of the personality.
3. The environment is conceptualized as a set of conditions, circumstances, events, factors, and influences on the developing personality, as well as personality-developing opportunities to which special pedagogical value is attributed.
4. The environment becomes the environment for personal development through activities and/or communication aimed at this environment.
5. The environment has the resource potential of personal development which can be implemented only by means of the activity of the person him/herself.
6. The environment is of a dynamic nature.
7. The environment structure includes spatial-subject, informational, organizational, technological, and social components. The social component of the environment is assigned the most significant role in the formation and development of the personality.
8. In a certain type of environment, which has specific characteristics, a certain type of personality is formed.
9. The educational environment can be described through the system of parameters characterizing various aspects of its organization and functioning.

Thus, the environment of personal development is seen as institutionally limited set of changing opportunities about its development, which emerge under the influence of organizational and technological and spatial-subject conditions, as well as multidirectional factors in the context of event interaction and activity of the individual as a member of the community.

1.2. Tools of personal development environment study

Insufficient support of the special criterial apparatus and diagnostic tools remains the problem of the personal development environment study, due to which environmental researchers are forced to adapt to their scientific tasks the methodological repertoire that was previously developed for solving other research problems, primarily socio psychological. The most popular of the methodological complex to study the educational environment used, in particular, by B. Fraser: *Questionnaire on*

Teacher Interaction (QTI); *Science Laboratory Environment Inventory* (SLEI); *Constructivist Learning Environment* (SLEI); *What Is Happening In This Clas*s (WIHIC)? The QTI focuses on the nature of interpersonal relationships between teachers and students. The SLEI assesses the high school learning environment in terms of cohesiveness, openness, integration, clarity, and the quality of the material to be studied. The CLES questionnaire analyzes student engagement in conversations and discussions. The WIHIC questionnaire includes scales of student cohesion, teacher support in learning, class participation, etc. As can be seen from the content of these techniques, they are completely focused on the socio-psychological aspects of the educational process and do not even attempt a systematic study of the educational environment. Same can be said about R. Mohs's Classroom Environment scale.

The International School-Age Care Environment Rating Scale (SACERS), developed by the Universities of North Carolina and Montreal (Harms, 1996), includes forty-nine indicators grouped under the headings: interior space and furnishings, health and safety, activities, interaction, curriculum, staff development, and special needs. As E.V. Ivanova, who is an active popularizer of the SACERS methodology, admits, “The authors of SACERS adopted ideas from numerous resources. Rather than offering a specific philosophy of peer review, the SACERS scale is based on criteria of the adequacy of the educational environment to the age features of children and the school curriculum” (Ivanova, 2016). This methodology leaves an impression of being eclectic, despite its undoubted practical utility.

The advantage of the method is the possibility to involve external experts as well as students themselves, teachers, and parents. SACERS test is a part of an expert complex created based on Early Childhood Environment Rating Scales (ECERS), which also includes Family Day Care Rating Scale (FDCRS) and Infant/Toddler Environment Rating Scale (ITERS). The given complex of expert techniques is used in educational practice in the USA, Canada and in some European countries, which allows to conduct the comparative research.

S. Manuilov (Manuilov, 1997) reflected the problem of expanding the criterion base for assessing the quality of school environments and the creation of appropriate pedagogical tools.

The monitoring model of the educational process implemented in the logic of the environmental approach characterizes the level of implementation of pedagogical technology from goal setting to the result, as well as the teachers' skills.

The quality assessment model of educational services offered by E.V. Orlov includes three parameters: the environment of the educational process, its effectiveness, and customer satisfaction. The indicators of these parameters are based on regulatory requirements.

It is necessary to emphasize that all the presented developments are based on a synthesis of the collectivist, socio-psychological and spatial-subjective approaches and do not reflect a systemic view of the nature of personal development in a certain environment.

The purpose of the study is to develop an expert tool based on the ecological-psychological approach for the system analysis and organization of the environment of personal development and its validation.

Research hypothesis is the assumption that the following vector model of personal development environment, developed based on the typology of “nurturing environments” by J. Korczak. Korczak in the logic of the ecological-personal approach, is an effective expert-project tool capable of methodologically providing a systematic expert analysis of the pedagogical quality of environments, as well as pedagogical design of personally developing environments and monitoring their development.

2. Method of vector modeling of personality development environment

2.1. Expert Questionnaire

The work of Janusz Korczak "How to Love a Child" first published in 1919, characterizes four types of nurturing environments: *dogmatic, ideological, serene consumption*, and *external gloss* & *career*. Qualitative analysis showed that according to J. Korczak's typology, dogmatic environment promotes the formation of a dependent and passive personality; ideological - formation of a free and active personality; serene consumption - formation of a free, however, passive personality; career environment - formation of an active, but dependent personality.

The developed method of vector modeling of personal development environment (Yasvin, 1997; Yasvin, 2000) provides construction of a coordinate system that consists of two axes: *freedom-dependence* and *activity-passivity*. It is necessary to answer six diagnostic questions based on the pedagogical analysis of this environment to build a vector corresponding to this or that type of environment in the coordinate system.

With the help of three questions, it is possible to determine whether given environment provides opportunities for the independent development of the personality and, accordingly, three questions provide opportunities for the development of personality's activity. Each question can be answered by ticking one point on the corresponding scale (activity, passivity, independence, or dependence). *Activity* is defined as having such properties as pro-activity, aspiration to achieve something, persistence in this aspiration, the ability of a person to fight his/her interests, the ability of a person to defend his/her interests, etc.; respectively, *Passivity* can be considered as zero activity. *Freedom* is associated with independence of judgment and actions, right to choose. *Dependence* is understood as obedience, subordination, and adjustability.

Diagnostic questions and interpretation of answers:

The *Freedom - Dependence* dimension. Rate in terms of percentages.

1. *Whose interests and values are prioritized in this environment*: a) the personality; b) society (group)?

The priority of personal interests and values over public can be considered as an opportunity for the free development of the personality, accordingly, a score on the "Freedom" scale is given; if the priority of public interests is chosen, a score on the "Dependence" scale is given.

2. *Which person adjusts to whom in the process of interaction*: a) an adult (senior) to the child; b) a child to an adult?

If it is noted that in the given environment, the tutor adjusts to the child prevail (or, at least, there is an aspiration of tutor to try to adjust), correspondingly, a score on the scale "Freedom" is given; if it is stated that the child is forced to adapt to his or her tutors, then a score on the scale "Dependence" is given.

3. *Which form of parenting is practiced in the given environment*: a) individual; b) collective (group)?

Orientation of the environment to an individual form of upbringing is interpreted as the fact that the environment provides additional opportunities for the free development of an independent child, a score on the scale "Freedom" is given; if the environment prioritizes collective upbringing, a score on the scale "Dependence" is given.

For the *Activity - Passivity* dimension. Please estimate in percent-ages.

4. *Is punishment of the child practiced in this environment*: a) yes; b) no?

The absence of punishment is considered as a factor that contributes to the development of personal activity, a score on the scale of "Activity" is given, if there is a system of punishment in the educational environment (used both directly and indirectly) a score on the scale of "Passivity" is given.

5. *Does the environment encourage a person to take any initiative*: a) yes; b) no?

A score on the “Activity” scale is given if positive reinforcement of the initiative (both conscious and unconscious) can be observed in the environment in question, i.e., it is regarded as an additional opportunity to develop the activity; however, a score on the “Passivity” scale is given if the initiative shown can typically result in various kinds of inconveniences.

6. *Does the environment provide any positive feedback on any of the creative manifestations of the personality:* a) yes; b) no?

When the environment provides the conditions under which the creativity could be stimulated or could be evaluated, such an environment is conducive to the development of activity, a score on the scale “Activity” is given; if creative manifestations are ignored, as a rule, remain, unnoticed and unappreciated, then a score on the scale “Passivity” is given.

According to the assessment, the analyzed environment can be allocated to one of four basic types: *Dogmatic environment*, which promotes the development of passivity and dependency; *Career environment*, which promotes the development of activity, but also dependence; *Serene environment* that promotes free development, but also determines the formation of passivity; finally, the *Creative environment*, that promotes the free development of the active personality.

2.2. Analysis and graphical representation of the examination results

1. It is necessary to *fill in the table* and calculate the sum of percentages received for each of the directions of dimensions (“Freedom”, “Dependence”, “Activity”, and “Passivity”). Each amount received should be divided by 3 (rounded to the whole). See example (Table 1).

Table 1. Representation of the examination results

Questions	**Scale “Freedom”**		**Scale “Dependence”**	
	Answers	Percentages	Answers	Percentages
1	A	20	B	80
2	A	30	B	70
3	A	40	B	60
Total sum	90		210	
Indicator	30		70	
	Scale “Activity”		**Scale “Passivity”**	
	Answers	Percentages	Answers	Percentages
4	B	70	A	30
5	A	60	B	40
6	A	70	B	30
Total sum	200		100	
Indicator	67		33	

2. In order measure the percentage of the different types of environments, you should *multiply the values of the corresponding dimensions*, and divide the obtained result by one hundred.

Dogmatic environment (%) = “Dependence” values is to multiply by “Passivity” values and divide by 100 (rounded to integers).

Example: $70 * 33 : 100 = 23\%$.

Career Environment (%) = "Dependence" values should be multiplied by "Activity" values and divided by 100.

Example: $70 * 67: 100 = 47\%$.

Creative Environment (%) = "Freedom"" values should be multiplied by "Activity" values and divided by 100.

Example: $30 * 67: 100 = 20\%$.

Serene environment (%) = "Freedom" values should be multiplied by "Passivity" values and divided by 100.

Example: $30 * 33: 100 = 10\%$.

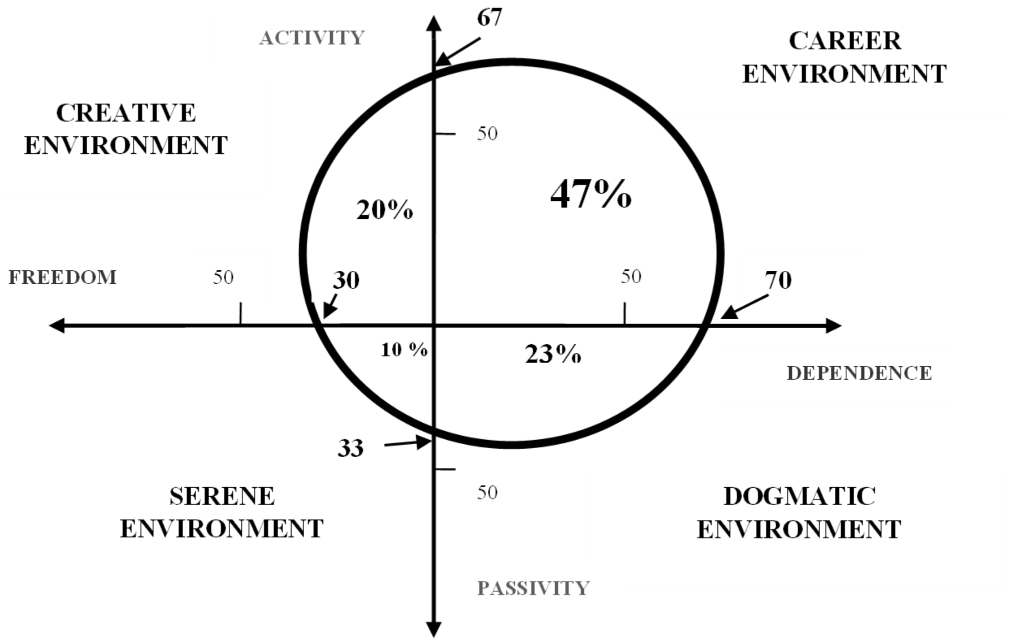

Figure 1. Graphically built ratio model of types of environments in the analyzed environment

3. *Graphically built ratio model* of types of environments in the analyzed environment (Figure 1.)

4. *The vector construction.* According to the answers to the diagnostic questions, the corresponding vector is constructed in the coordinate system, which allows to additionally characterize the environment. The responses to diagnostic questions are considered with no percentage value, only "A"or "B".

One of twelve theoretically vectors (three in each of the four sectors of the coordinate system), that models a certain type of personal development environment, can be obtained through a simple mathematical construction (Figure 2). For example, when analyzing any environment, we get three points on the "Dependence" scale and on the "Activity" scale, but zero points on the "Freedom" scale and on the "Passivity" scale. Such an environment can be called "Typical Career Environment" (Figure 3).

The other example shows that we have one point on the "Freedom" scale, two points on the "Dependence" scale, three points on the "Activity" scale, and zero points on the "Passivity" scale. As the scores obtained on the *Freedom-Dependence* dimension were distributed on different scales, it is necessary to obtain their sum, bearing in mind the character of each score ("+" or "-"): -1+2=+1, i.e., in the end one point on the "Dependence" scale should be taken into account.

Thus, such a vector forms a "career" environment, which stimulates high activity and involves a small degree of dependence. Such an environment can be

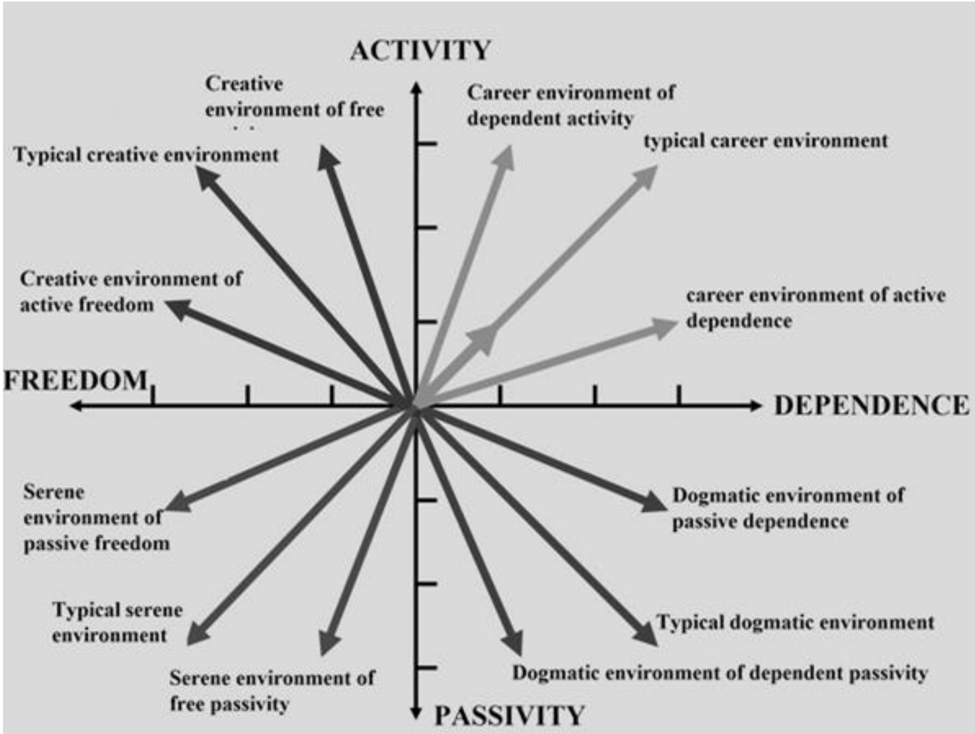

Figure 2. Total spectrum of environment types

referred to as the "career environment of dependent activity".

Alternatively, it is possible to get zero points on the "Freedom" scale, three points on the "Dependence" scale, two points on the "Activity" scale and one point on the "Passivity" scale.

Since the scores obtained on the *Activity - Passivity* dimensions were distributed on different scales, it is necessary to obtain their sum, taking into account the character of each score ("+" or "-"): +2-1=+1, i.e., as a result one point on the "Activity" scale is taken into account. After that, the corresponding vector models the "career" environment, which promotes the development of a high degree of dependence and a low degree of activity – "career environment of active dependence". The similar picture of the possible modeling construction of vectors can be obtained in each sector of the system of coordinates.

Two points on the "Freedom" scale and one point on the "Dependence" scale can finally be obtained: +2-1=+1, and two points on the "Activity" scale and one point on the "Passivity" scale: +2-1=+1.

5. *"Social wind".*

It is it is clear that with the exception of rare cases of complete isolation of the personality from external social contacts (monastery, sect, village hinterland, etc.) the character of the personality's development, besides the dominant educational environment of the family or educational institution, i.e. "structure functioning environment", will be influenced either way through those or other interactions with other people, with society in general, i.e. "environment of living environment". In a real-life situation, the development of the personality is influenced, as a rule, not only by one type of environment, but several, particularly, "the influence of the street" will inevitably have an impact.

It is possible to model the effect of such influence by including a vector of influence of the broad social environment, called the "social wind", into the methodology. The social wind always "blows" in the direction

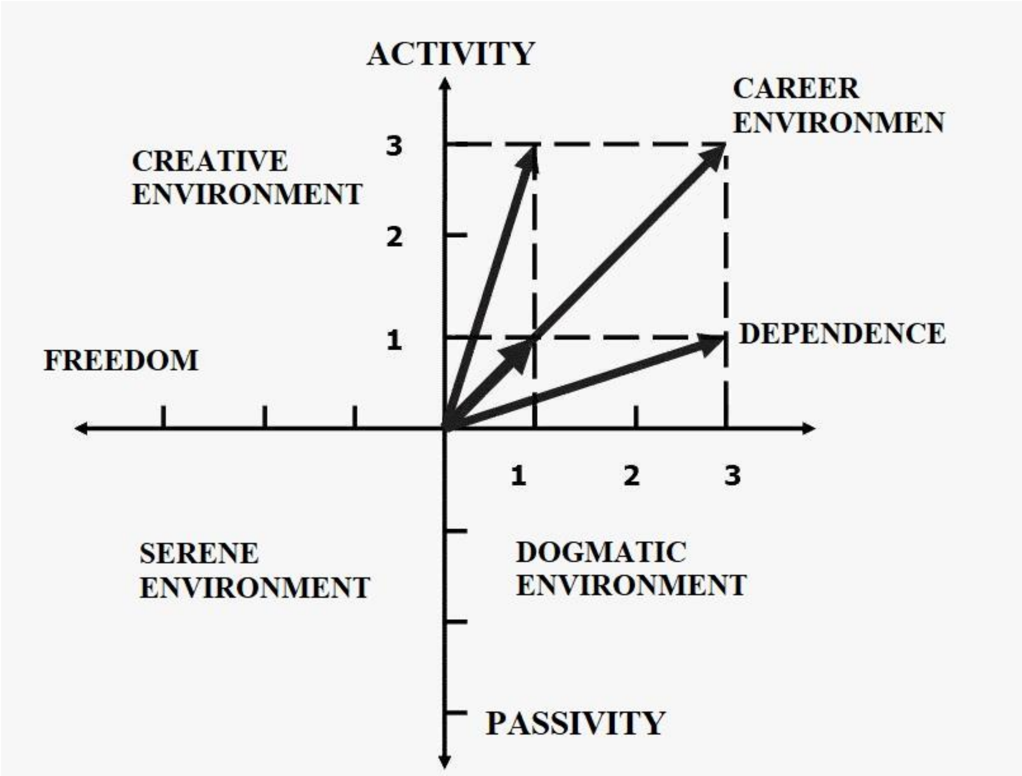

Figure 3. Example of the construction of educational environment vector models

of dependence and passivity and coincides in this respect with the vector that models the dogmatic environment.

Thus, it is necessary to somehow indicate the extent to which the vector of social influence shifts the result of the basic educational environment in the specified direction. If we consider that as a result of the "Social wind" the formed personality can be referred as a type adjacent to its basic educational environment in the direction of the increasing levels of dependence and passivity, then the vector obtained by such shift is considered as a "vector of personality" developed in this environment (Figure 4). It is important to note that in the conditions of a typical dogmatic environment the directions of vectors of this environment and the "Social wind" coincide, reinforcing each other, it is possible to say, there is a "resonance effect". Moreover, the direction of such a powerful influence "pushes" the personality to absolute passivity and absolute dependence, which is in "prison" conditions.

3.Results

3.1 The empirical studies of school environment perception

The conducted researches of school environment perception (Figure 5) during the period from 1993 to 2023 based on the method of vector modeling of environments which involved teachers and students of more than two thousand Russian schools, demonstrated that students (as well as qualified external experts) perceive the school environment mainly as "career" and "dogmatic", i.e., connected with the dimension "Dependence" (85 %). School teachers' answers to diagnostic questions are dominated by the attitudes that characterize the same school environment as "career" and "creative", i.e., connected with the *Activity* dimension (95%).

According to the results of research, the percentage of "creative" environment in

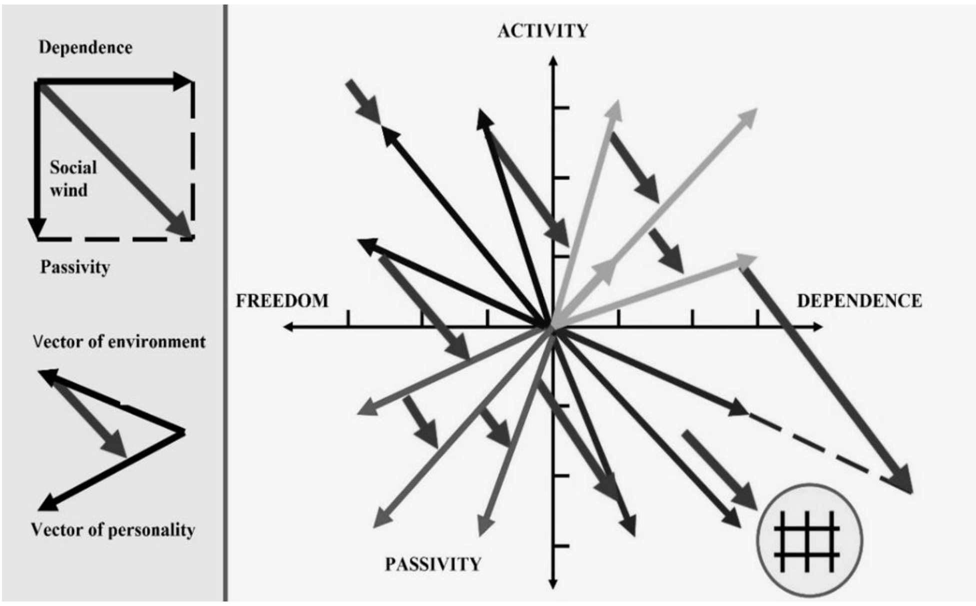

Figure 4. The nature of society's influence on the personality developing in different types of environments

schools does not exceed 15%, and in most cases, it is about 5-7% (Yasvin, 2019).

The teachers negatively deny the presence of any elements of a “serene” environment in their schools. It should be noted that a “serene” environment is the only environment in which a child can gain inspiration, dreams, and build his or her imaginative images of a desirable future. “Dogmatic” environment is also given a small place by the teachers in the evaluation of their educational practice. The teachers and students agree that the educational process at school takes about half of its course in a “career” type of environment. At that, what in the teachers' minds is perceived as a “creative” environment (“free” and “active”), is evaluated by the students as “dogmatic” environment (“passive” and “dependent”) which is radically opposite. As mentioned above, qualified experts also evaluate the school environment as predominantly "career dogmatic.

3.2. Environment studies at different levels of education

The comparison of school educational environment research results with the results of the analysis of preschool environments, conducted by us together with Yu.Yu. Kondrashina (Yasvin, 2019), and universities (Kaptzov, 2003; Nagornova, 2005) allowed us to see its dynamics at different stages of the educational process (Figure 6).

From the point of view of the developmental potential of the environment the most adequate is the environment of preschool institutions (72% on dimension *Activity*). Subsequently, a drastic increase in the share of dogmatic environment (by three times), primarily due to a decrease in the share of the creative environment is noted in the general education school. Further increase in the share of dogmatic environment (which forms a dependent and passive personality) is typical for bachelor’s education (76%), in which students must memorize the basics of science, staying entirely in the environment, which forms a dependent type of personality (94%). The structure of the educational environment becomes more balanced, similar to the structure of the school environment, only during the senior year of higher education, during the master's program. Nevertheless, the types of environments associated with the axis “Dependence” remain completely

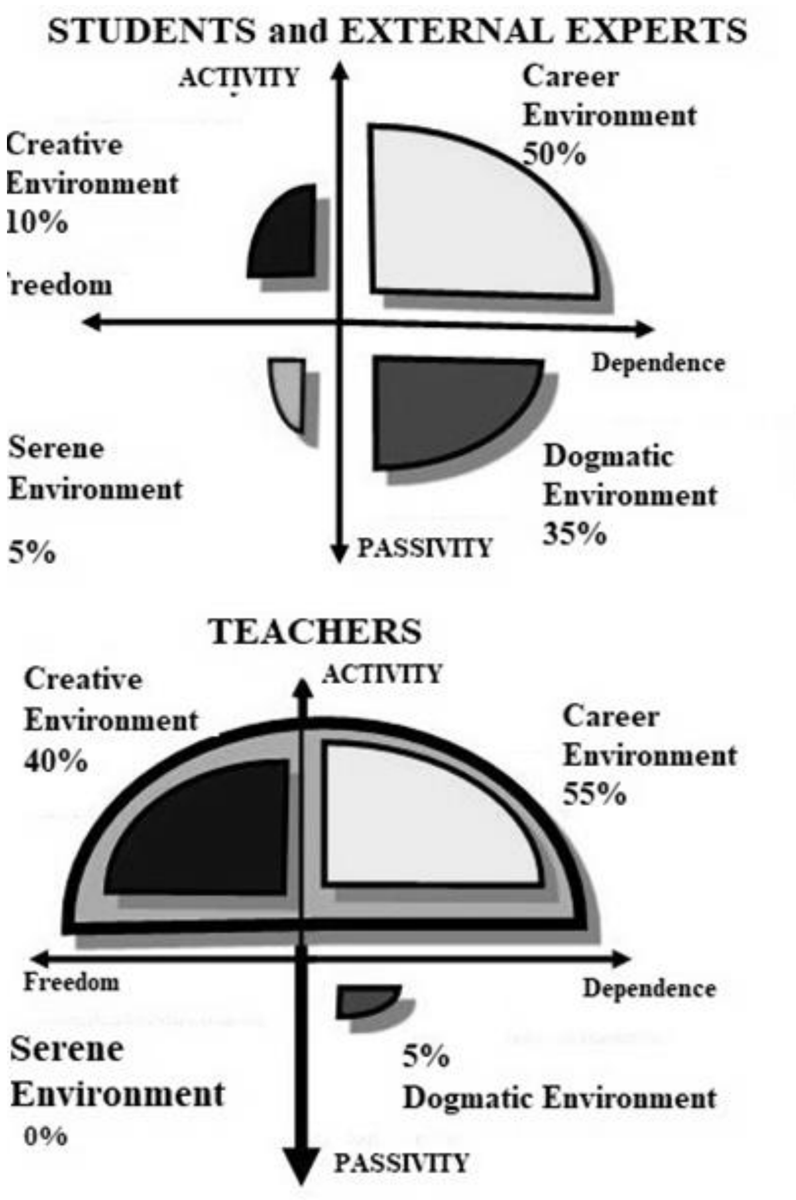

Figure 5. Evaluation of teachers', students', and external experts' perceptions of the school environment

dominant (86%). Thus, it is possible to conclude that, starting from general education school, students perform their educational activities in the "dogmatic" and "career" types of environments, fostering the formation of a dependent personality.

4. Discussion

It is necessary to emphasize that the classification of educational spaces based on the system of coordinates was proposed by R.E. Ponomarev (Ponomarev, 2003), who identified the educational space dimensions: *External Organized – Internal not Organized*, *Conscious – Unconscious*, and *Individual – Group*. Given classification includes the following educational spaces: free (unorganized conscious), manipulative (organized unconscious), natural (individual unorganized unconscious) and uthoritarian (group organized conscious).

Based on the method of vector modeling, the classification of educational spaces by R.E. Ponomarev can be correlated with the typology of educational environments by J. Korchak: free space is an ideological (creative) environment, manipulative space is a career environment, natural space is a serene environment, authoritarian space is a dogmatic environment.

The method of vector modeling of educational environments also provided a comparative analysis of a number of pedagogical models and typologies and established complementarity between them: the typology of the educational environment by J. Korchak (Korczak, 1990), school types of students P.F. Lesgaft (Lesgaft, 1991), the model of the "cultural-historical school" of V.V. Rubtsov (Rubtsov, 1996), the types of organizational cultures of pedagogical teams according to K. Cameron and R. Quinn (Cameron & Quinn, 2001), as well as to develop a typology of teachers' "pedagogical positions" complementary to these pedagogical developments (Yasvin, 2019) (Table 2).

The developed method of educational environments vector modeling enables researchers to conduct the historical and pedagogical analysis of both educational systems implemented in practice and their projects (Figure 7).

The method of educational environment vector modeling for the analysis of classical educational systems (Yasvin, 2019) has been successfully used for 30 years in the process of teaching the course "History of Pedagogy" to organize practical work of students, the students build appropriate modeling vectors based on independent analysis of primary sources and further group historical and pedagogical discussion.

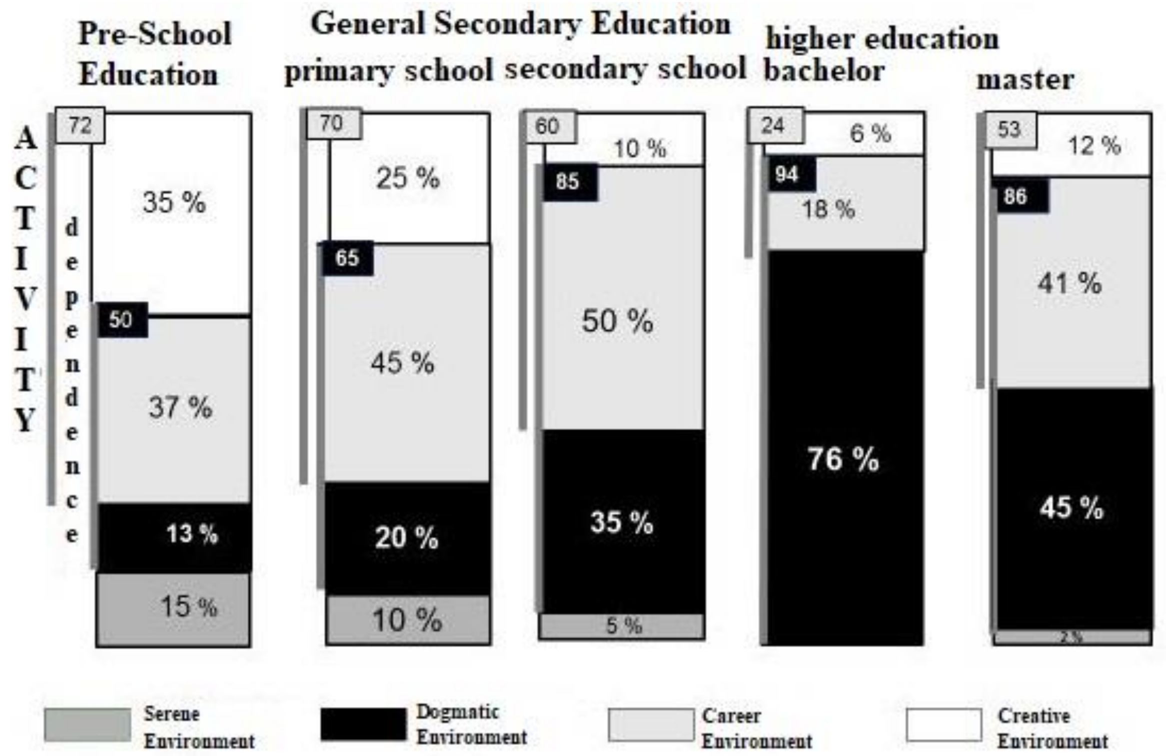

Figure 6. The pattern of educational environments at different stages of education

4. Conclusion

Formation of a unified theory of environmental approach in pedagogy and educational psychology based on the environmental-personal concept of developing educational environment creates the preconditions for the formation of a field of research as environmental psychological pedagogy, the subject of which is the study of the influence of environmental conditions on personal development and teaching design environment as a set of opportunities for personal development. Research problems of environmental psychological pedagogy can be associated primarily with a structural and content analysis of the environment of personal development, the study of environmental factors in personal development, the study of psychological mechanisms of personal development in the educational environment, a comparative analysis of different educational environments, humanitarian assessment of educational environments, typology of educational environments, the study of perception of educational environments, study of subjective relations in the educational environment; design of innovative educational environments; pedagogical organization of effective educational environments, etc.

The method of vector modeling of the personal development environment based on the typology of "educating environments" by J. Korczak is universal and makes it possible to analyze the personal development potential of different local environments such as school, family, club, sports, volunteer, informal youth associations, neighborhood environment, etc., as well as environments developed by prominent teachers of the past and the present in the process of historical and pedagogical analysis of their educational systems.

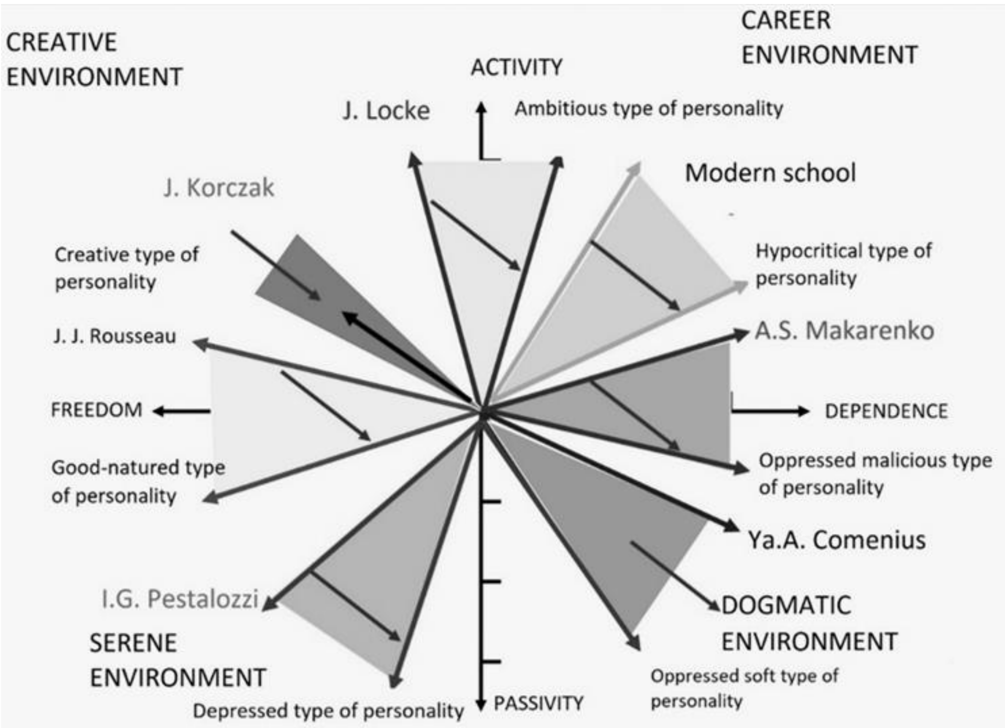

Figure 7. Comparative analysis of classical pedagogical concepts and modern school based on vector modeling of the personality development environment

Table 2. Complementarity of various pedagogical models and typologies based on the vector modeling method.

Type of environments by Korczak	Educational space for Ponomarev	Vector model of the environment	Student type according to Lessgaft	The pedagogical position of the teacher	Examples of models of educational systems	The stage of the educational process according to Rubtsov	Type of organizational culture by Cameron & Quinn
Environment of serene consumption	Natural educational space	The serene environment of passive freedom	Good-natured	Waiter	Free upbringing by J. J. Rousseau	School of Mythmaking	“Family” (“clan”) organizational culture
		The serene environment of free passivity	Depressed	Shepherd	Education of poor rural youth according to I.G. Pestalozzi		
Dogmatic Environment	Authoritarian educational space	Dogmatic environment dependent passivity	Oppressed soft	Conductor	Great didactics Ya.A. Comenius	School-workshop	“Bureaucratic” organizational culture
		Dogmatic environment passive dependence	Oppressed malicious	Commander	Collective education of a citizen according to A.S. Makarenko		
Environment of external gloss and career	Manipulative educational space	Career environment active dependence	Hypocritical	“Boss”		School-laboratory	“Productive” (“market”) organizational culture
		Career environment of dependent activity	Ambitious	Trainer	The education of a gentleman according to J. Locke		
Ideological environment	Free educational space	Creative environment of free activity	Normal (perfectly presented)	Expert		Project School	“Innovative” organizational culture
		Creative environment of active freedom		Consultant	Humane Pedagogy J. Korczak		

Highlight:

- Dogmatic environment contributes to the formation of dependent and passive personality.
- Creative environment leads to the formation of free and active personality.
- Serene environment leads to the formation of free, however, passive personality.
- Career environment contributes to the formation of active, but dependent personality.

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The Role of the Amplitude Decay for the Evaluation of Major and Minor Chords in Amateur Listeners and Professionals

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Abstract: Many studies within the framework of the Western music psychology demonstrate the ability of non-musicians to recognize major and minor musical scales. The aim of this work is to study the ability of subjects to evaluate the emotional valence of major and minor triad chords based solely on their tonal characteristics, as well as to find out what differentiates musicians from non-musicians in recognizing emotions caused by isolated musical chords, both generated and real. The study involved 103 subjects. The stimuli consist of three groups of generated major and minor triad chords and one group played on the piano. For the evaluation of stimuli, two sets of unipolar and bipolar scales formed on the basis of the previous free descriptions are used. The specific attenuation pattern of the signal's intensity (i.e., sustain, decay and release segments of the amplitude envelope) is the decisive factor for major and minor chords perception. Without it, amateurs are unable to estimate the differences between the chords while its presence almost equates amateur listeners and professionals in their evaluations. Although, the latter are able to distinguish the chords based solely on the tonal structure, the presence of the amplitude decay influence their perception by either enriching it more than two times or considerably impoverishing it, depending on the familiarity of the attenuation pattern.
Keywords: Music Perception, Emotional Valence, Chords, Tonal Structure, Amplitude Envelope

1. Introduction

The contemporary understanding of the semantic space of music in cognitive musicology and music psychology may be summarized as consisting of 3 dimensions: "Active - Passive" associated with temporal characteristics; "Happy - Sad" associated with tonal characteristics, particularly with minority and majority; and "Tension - Relaxation" associated with the systemic interaction between musical composition characteristics and a generalized evaluation of music experience (Reybrouck et al., p 5, 2018). The major and minor musical scales, important for the evaluation of emotional valence, became the basis of the Western musical system during the Baroque epoch, and up to this day most of the popular music is created basing on these two musical scales. They have been studied for more than a hundred years in music psychology, but the psychological mechanisms of perception and emotional evaluation of these two sound combinations are not yet completely clear, and have no single accepted explanation (Bowling, 2013).

The interest of scientists in this topic is explained by the ability of significantly

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different groups of listeners to associate the major and minor musical scales with different poles of emotional valence, as it was shown in many studies (see Parncutt, 2014). This result was obtained on the samples of listeners without musical background (Bakker & Martin, 2015), musicians (Kuusi, 2015), children (Thompson & Opfer, 2014), adults with amusia (Gosselin et al., 2015), elderly people (Bones & Plack, 2015), and representatives of non-Western musical culture (Okhova & Poudeh, 2015, Virtala, Tervaniemi, 2017; Fang et al., 2017).

Generally, whole compositions or their fragments are used in music psychology as the stimuli for evaluation of emotional valence. In this case the tonal component of a stimulus interacts with its tempo, rhythm, manner of playing and other variables – they all are blended in the evaluation of a musical composition or melody.

The approach that is based on the estimation of whole compositions revealed stability of such estimations but it makes little headway towards the understanding of this phenomenon's mechanisms. Indeed, in the case of the perception of a whole musical composition, the evaluation of music as "happy" or "sad" may take place due to various factors: the context and background of perception, the structure of the composition, the style of performance, tempo characteristics (Almayev & Skorik, 2015), sound intensity characteristics (subjective loudness), lyrics, etc.

Listeners can evaluate the valence of music emotions not only in the case of a whole composition or its segments but also in the case of an isolated chord or pitch. In the case of the evaluation of a separate chord, the temporal component is minimized, but the tonal component remains in the form of pitches' interrelation to each other. The approach that is based on the evaluation of isolated characteristics allows experimental control of any isolated factor and thus answers the question: what makes it possible for subjects to differentiate basic emotions at each level of consideration — tonal, temporal and etc.?

The study of isolated major and minor chords' perception can provide information about the psychological and psychophysiological mechanisms of tonal perception (Lahdelma & Eerola, 2016; Skorik et al., 2018).

In addition to isolated musical sounds, it looks appropriate to use digitally generated stimuli (Kunavin & Sokolova, 2014; Almayev & Skorik, 2016; Skorik & Almayev, 2018). In this case the researcher can control almost every characteristic of an acoustic event independently, from the specific performing style to music instrument's timbre to sound-producing characteristics, etc.

The most common explanation for the polarity of evaluation as major and minor is the consonance and dissonance concept wherein the listener perceives certain combinations of pitches as annoying, and others as calming due to the cultural conditioning. If the psychological mechanism for evaluating the valence of emotions is based on an evaluation of frequencies of pitches and their ratios, it's expected that generated major and minor chords will convey the valence of emotions of chords as well as the "natural" ones (produced by professional performers) do this. If tonal characteristics are not sufficient, then there are other mechanisms for emotional response which cannot be reduced to the frequencies of sound components.

Of all the available arts, music is the best in directly conveying the basic emotional component (Argstatter, 2016). How can listeners judge musical sounds as happy or sad? At what other characteristics of acoustic events (beyond the tonal) is their perception focused? The study of the emotional valence of music estimation mechanisms is relevant not only in the context of the music perception theory but also in the broader context of non-verbal (or "non-lexical," to put it more exactly) communication components –

that is how information is transmitted without the usage of linguistic signs. Can similar mechanisms work in the case of non-verbal communication, i.e., how do pre-lexical, prosodic phenomena transmit emotions?

The general hypothesis of the study: the mechanisms for the evaluation of the emotional valence of musical sounds are different for musicians and non-musicians. We also suggest that the attenuation of chords' intensity (i.e., a specific profile of decay, sustain and release segments of the amplitude envelope) is an important condition for the evaluation of emotional valence.

The present studies were conducted from 2015 to 2018 for the first time on the Russian sample and their preliminary results were announced in several conference reports (Almayev & Skorik, 2016; Almayev et al., 2017; Skorik et al., 2018); the paper that is presented below is based on the most complete and verified data.

(A) THE FIRST STUDY

This study consisted of two parts: preliminary and main. The goal of the preliminary part was to work out, on the basis of content analyses, a set of subjective scales that fits specific stimuli best of all. In the main part of the study, other subjects evaluated the stimuli based on the set of scales developed in the preliminary part.

A 2. Data and Methods

A 2.1. Subjects

At the preliminary stage of the first study, 20 people without musical education or experience playing musical instruments were involved (50% males and 50% females; the average age was 28.6 ±5.24 years) .

A 2.2. Method

Natural scale major and minor triad chords served as the base for the stimuli material. Using CoolEdit Pro 2.0 audio editor, the sinusoidal rectangular triad chords (see Fig. 1 and Fig. 2) were generated without attenuation from pitches A (A5 - 880 Hz), B (B5 - 987.77 Hz) of the second octave and C (C6 - 1046.5 Hz), D (D6 - 1174.7 Hz) of the third octave. The duration of each sound was 3 seconds. The volume was equaled taking into account the equal-loudness contour and sound level meter, and was about 70 dB.

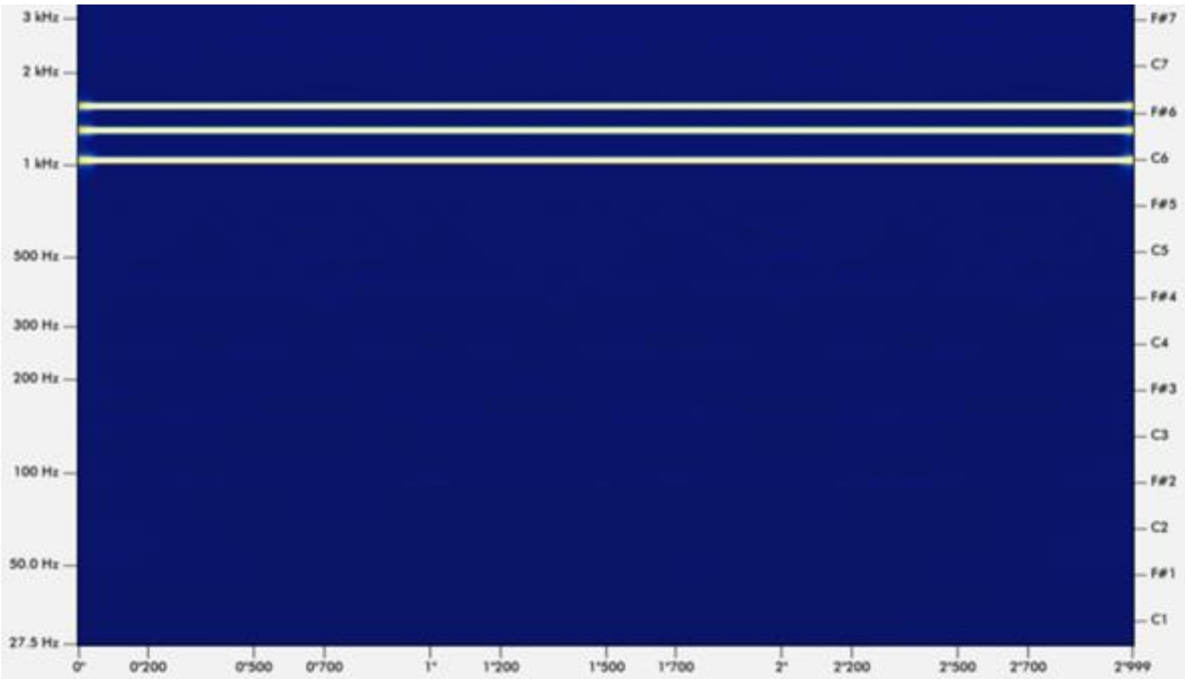


Figure 1. The spectral view of the generated major chord without attenuation from the note C of the third octave consisting of three pitches: the tonic C (C6 - 1046.5 Hz), the major third E (E6 - 1318.5 Hz) and the G (Sol) quint (G6 - 1568 Hz).

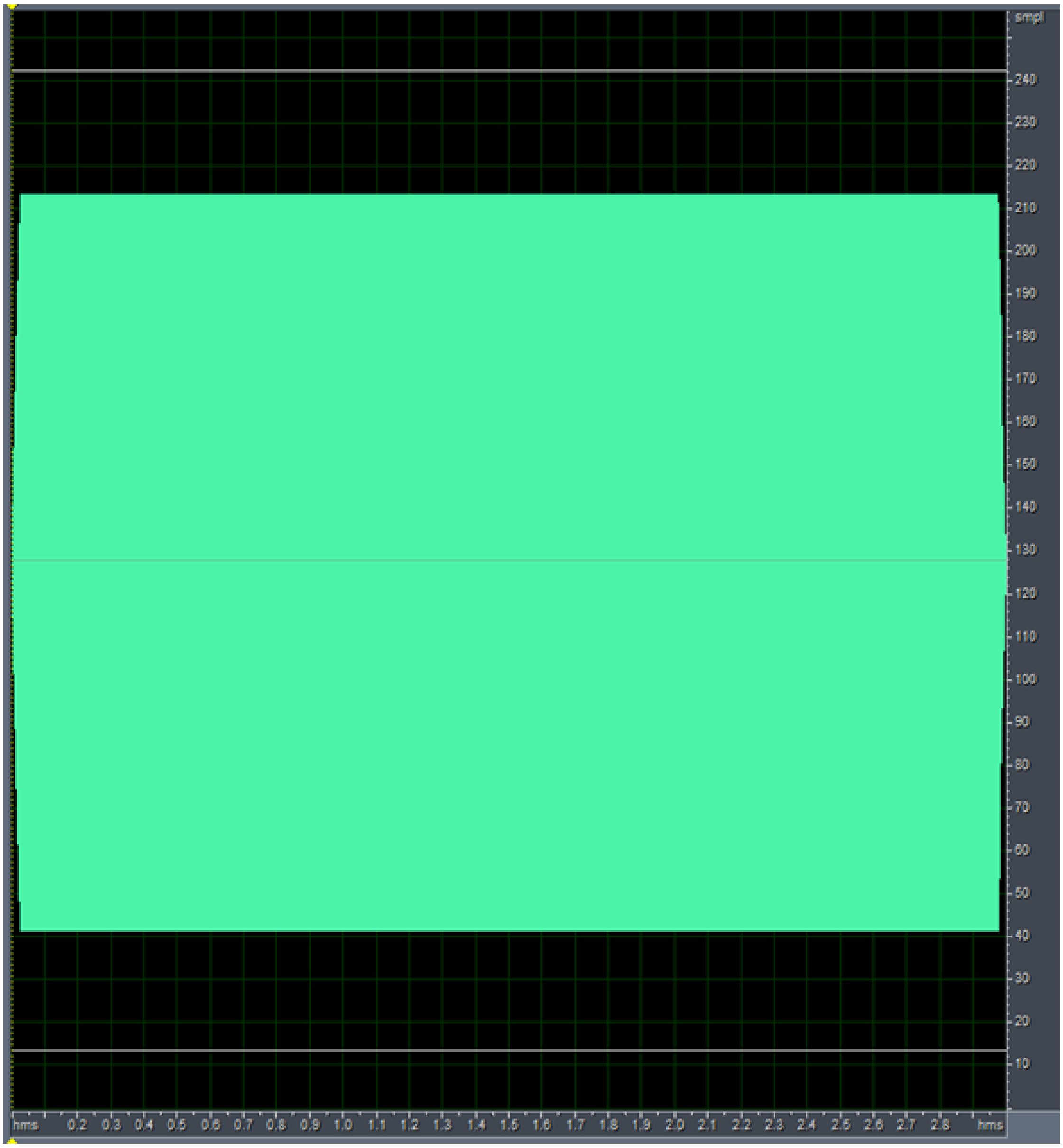


Figure 2. The amplitude view of the generated major chord without attenuation from the note C of the third octave. The first and last 30 *ms* were smoothly muted to avoid "clicks" when the stimuli were turned on and off.

A 2.3. Procedure

The study was conducted in a soundproof room. The subjects were placed in a chair in front of loudspeaker that was reproducing experimental stimuli. The distance from the loudspeaker to the chair was 1.5 m. Triad chords were presented in a randomized experimental design sequence.

In the first part of the study subjects were presented with 8 generated stimuli (4 major and 4 minor, created from 4 tonic pitches) and then with all of their pairs (a total of 32 pairs). The subjects orally evaluated the presented sounds in a free form. A similar assessment procedure was used in the studies of B. Willimek and D. Willimek (2017). Communications proceeded via microphones and were recorded. The following instruction was read out loud:

Instruction. In this study you will listen to sounds and evaluate them. After you have listened to the sound, answer the following questions out loud:

- *What associations did the sound cause?*
- *What emotions and feelings did the sound cause?*
- *What corporeal sensations did you have while listening to the sound?*
- *After answering the questions out loud, say "next sound" out loud.*
- *A total of 8 sounds will be presented to you. Then you will hear their pairs.*

Based on the content analysis of the most frequent subjects' responses, a semantic differential (Likert-type scales) was created consisting of 23 bipolar scales (see Table 1).

Table 1. Scales for subjective evaluation in the first study.

№	Semantic differential scales	
1	Low sound	High sound
2	Unpleasant	Pleasant
3	Ringing	Smooth
4	Relaxation	Tension
5	Indifference	Desire to do something
6	The sound moves away from me	The sound moves to me
7	The sound turns left	The sound turns right
8	Slow	Fast
9	Light	Heavy
10	Close	Far away
11	Dark	Light
12	Younger	Older
13	Quiet	Loud
14	Narrow	Wide
15	Calm	Anxious
16	Passive	Active
17	Sad	Happy
18	Nothing will happen	Something will happen
19	Cold	Warm
20	Negative	Positive
21	Female	Male
22	Boredom	Interest

Regarding the nature of the stimuli more than 90% of associations were with old / cheap / toy/ 8-bit synthesizers / PC-games / gamepads.

The main part of the study was attended by 30 subjects (50% are men, 50% are women; average age is 27.6 years; SD is 5.35) without musical education and experience of playing musical instruments, who evaluated triad chords by using a previously created semantic differential (Likert-type scale). Pairs of stimuli were not presented in the main part of the first study.

In the main part of the study subjects evaluated 8 triad chords in randomized experimental design sequences, presented in a soundproof room with the following.

Instruction: In this study you will evaluate the sounds. After you listen to the sound, evaluate it using the properties that are written on a list in front of you. Each pair of properties describes a feature, the value of which can be determined on a 7-point scale (from -3 to +3). Circle the number which, in your opinion, most accurately characterizes the expression of the proposed feature. After completing the questionnaire, say "next sound" out loud. In total 8 sounds will be presented to you.

After reading the instructions the experimenter left for the next room and began administering the stimuli. During the study, the subjects filled in 8 forms of semantic differential, corresponding to the total number of sounds. The experiment with one subject took from 20 to 40 minutes depending on the speed of filling out the forms.

A 3. Results

A Wilcoxon T-test reveals differences between estimations of minor and major triad chords within the three scales (see Table 2).

Table 2. The values of Wilcoxon T-test for three scales at which significant differences were identified for major and minor chords evaluations.

Scale	Valid N	T	Z	p-value
Boredom / Interest	85	1257.5	2.497605	0.012504
Narrow / Wide	87	1424.5	2.071755	0.038289
Passive / Active	89	1277.5	2.966203	0.003015

In the scales where differences were revealed, major triad chords were evaluated by subjects as more "narrow", "passive", and "boring", while minor triad chords as "wide", "active", and "interesting".

The stimuli from the preliminary study were also presented to three participants who could be described as semiprofessionals: one female aged 22, education – musical college, performs regularly in an orchestra (clarinet), and two males aged 50, one pianist with a conservatory level education but performing irregularly, and one professor of aesthetics with an amateur level of performance (bass-guitar). The main question to them was to identify the nature of presented sounds. The female participant succeeded in this task at about tenth attempt and consequently named the chords. Both of the men identified the nature of the stimuli implicitly by saying that some pairs of them could form harmonies, nevertheless, neither of them, despite their superior level of education in the field, could name the chords explicitly, instead calling them "some synthesized sounds".

(B) THE SECOND STUDY

B 2.1. Subjects

In order to elaborate the new set of subjective scales, the first group of subjects consisting of 10 people (among them 40% are men; average age is 28.1± 5.24 years) were involved, who evaluated four groups of stimuli (32 sounds) by using the method of free description. The subjects had no musical education or skills in playing musical instruments, except for two subjects, who studied at music schools for 3 years.

The sample of the main part of the second study is 43 subjects. They are divided into two groups:

29 non musicians (51.72% male, 28.28% female; mean age is 26.7 years; SD is 5.8 years) without any musical education or skills in playing on musical instruments;

14 professional musicians (57.1% male, 42.9% female; average age is 28.2 years; SD is 8.29 years); all subjects in the second group studied music, 8 of them received higher levels of musical education, 2 subjects graduated from music schools, 4 subjects studied music on their own and with the help of a tutor. Of the 8 subjects who had higher levels of music education, four subjects graduated from an entertainment-jazz faculty and 4 subjects graduated from a faculty of classical music. The criterion of professionalism was earning at least half of their income by the means of activities connected to performance, editing and/or composing music; thus, the regularity of respected activities was emphasized.

The subjects from the first group participated in an elaboration of the new set of subjective scales, while the second group was engaged only in the evaluation of the sounds according to the previously created semantic differential.

B 2.2. Method

Four groups of sounds were created (see Figure 4 and Figure 5):

(1) The first group (taken from the first study) included 4 major and 4 minor triad chords from the tonic pitches of the second and third octaves, generated without intensity's attenuation (A5 – A; H5 – B; C6 – C; D6 – D). The sound was based on generated sine waves.

(2) The second group was 4 major and 4 minor triad chords generated with linear attenuation from the tonic pitches of the second and third octaves (A5 – A; H5 – B; C6 – C; D6 – D). The sound was based on generated sine waves. In this group of sounds the attenuation was linear, decreasing evenly from the beginning of the sound to the end.

(3) The third group consisted of 4 major and 4 minor MIDI triad chords generated with attenuation from the tonic pitches of the second and third octaves (A5 – A; H5 – B; C6 – C; D6 – D). The sound was based on the *Electric Piano timbre* from the MIDI sounds bank. The amplitude envelope of these stimuli is characterized by a pronounced attenuation to 100-150 msec, and then by the one closer to the linear attenuation until the end of the stimulus.

(4) The fourth group was 4 major and 4 minor triad chords from the tonic pitches of the second and third octaves (A5 – A; H5 – B; C6 – C; D6 – D), taken from the professional Yamaha sound bank, corresponding to the natural sounds caused by pressing keys on a concert piano. The amplitude envelope of the sound in this group of stimuli is a type of inverse or inverse power dependence with a sharp attenuation of intensity within the first 150-200 msec, and then - with the long gentle slope until the end of the stimulus.

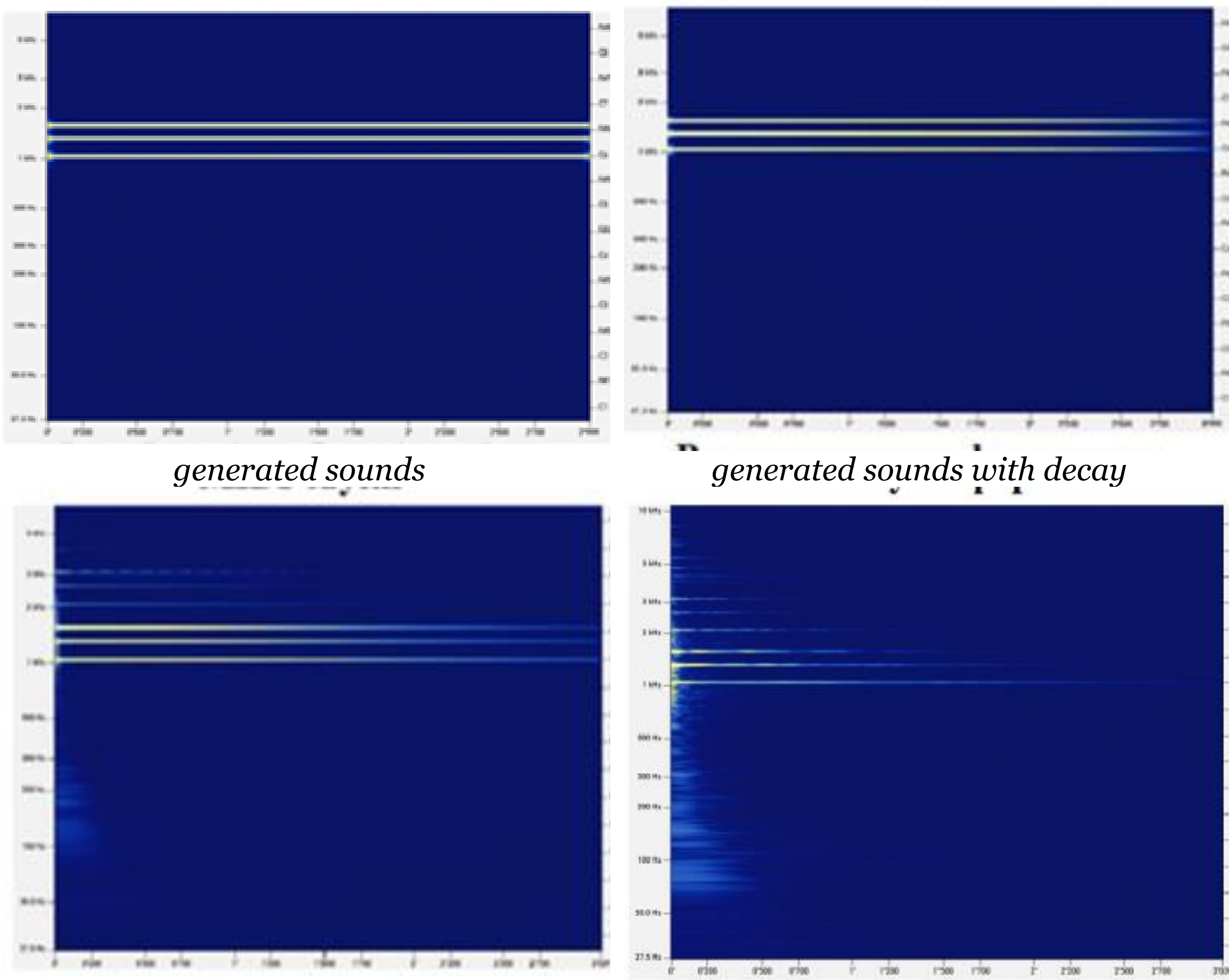
32 chords were presented to subjects in the first part of study. The following instruction was read out loud in advance:

In this study you will listen to sounds and evaluate them. After you listen to the sound, answer the following questions out loud:

- *What associations did the sound cause?*
- *What emotions and feelings did the sound cause?*
- *What corporeal sensations did you have while listening to the sound?*

After answering the questions out loud, say "next sound" out loud. In total you will be presented with 32 sounds.

For the main part of the second study, an extended set of subjective scales was elaborated, on the basis of the one from the first study. Content analyses of the descriptions of new groups of sounds were repeatedly conducted, on the basis of the most frequently encountered definitions. In addition to content analysis, descriptions of major and minor keys from musicology were adopted (Kolchinsky et al., 2017). As a result, a semantic differential was developed consisting of 35 scales, including 29 unipolar scales and 6 bipolar ones (see Table 3).



generated sounds *generated sounds with decay*

MIDI sounds *real piano sounds*

Figure 4. The spectral view of 4 groups of major chords from the note C of the second octave, consisting of three pitches: tonic C (C6 - 1046.5 Hz), major third E (E6 - 1318.5 Hz) and the fifth G (G6 - 1568 Hz). Upper left –no attenuation, upper right – linear attenuation, lower left – midi type, low eight – real type.

The study was conducted in the soundproof room. The following printed *instruction* was given to the subjects:

In this study, you will be presented with sounds. After listening to each sound, evaluate the strength of properties that are written on the sheet in front of you. The expression of each property can be determined on a 7-point scale (from zero to six). The value "zero" means the absence of this property in the presented sound, and the value "six" indicates the maximum expression of the property in the presented sound. Circle the number which, in your opinion, most accurately describes the expression of the proposed property. After you fill out the list, say "next sound" out loud. In total you will be presented with 32 sounds.

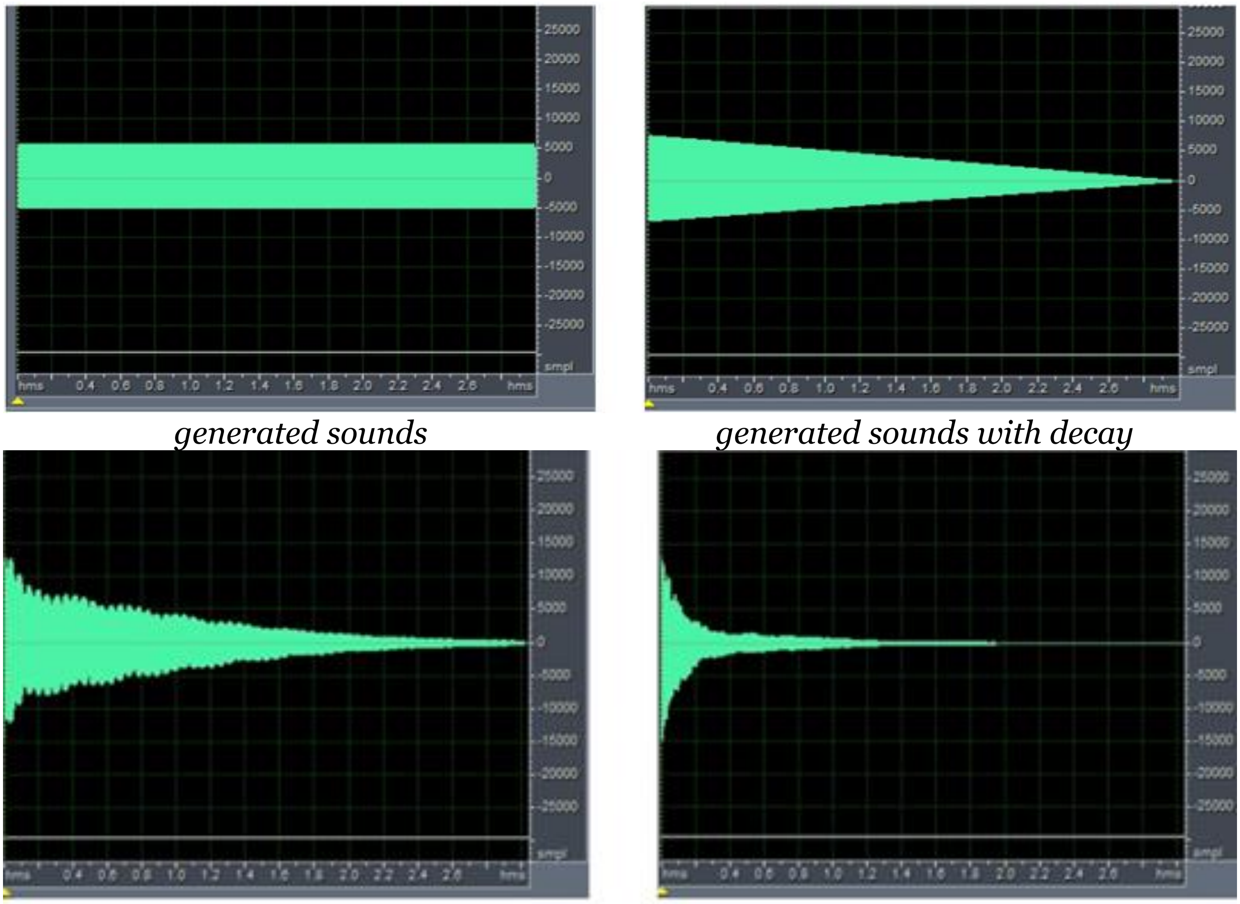
The further procedure is similar to the first study. The experiment with one subject lasted from 50 to 90 minutes, and in the musicians' sample – from one to two hours, depending on the speed of filling in the blanks by them.

After reading the instructions, the subjects were allowed to look at the scales of the semantic differential and ask questions about them. In the sample of musicians there were no questions about the scales. Non-musicians pointed to "Not Major/Major" and "Not Minor/Minor" scales. The experimenter suggested that they should provide associations on these scales. They associated "Not Major/Major" scale with a representative of elite youth. "Not Minor/Minor" scale was difficult for them to provide an association to, so they were offered to rate it as the opposite of "Major". After the end of the study the experimenter also separately questioned non-musicians on what they know about major and minor keys and chords. Of the entire group of non-musicians, only three subjects were able to associate these concepts with music, but none of them defined them.

B 3. Results

B 3.1. Statistical differences in the evaluation of major and minor chords

A Wilcoxon T-test was used to reveal the differences in estimations of major and minor chords. Significant differences in the ratings of major and minor chords were found in all conditions, with the exception of the ratings of non-decayed generated sounds by non-musicians. This test reveals the presence of differences, but not the direction of evaluations. The subjects could distinguish major from minor triad chords, but ascribe them to a different pole compared to what is usually expected, i.e., they could evaluate a major chord as sad and a minor chord as happy. Generally, in this study the expected poles of evaluations are not inverted, although with a few exceptions. For example, contrary to the expectations non musicians evaluated the minor second type attenuation stimuli as more "positive", which doesn't correspond to the traditional description of the minor as the "sad" scale.



generated sounds *generated sounds with decay*

MIDI sounds *real piano sounds*

Figure 5. The amplitude view of 4 groups of major chords tonic C5. The upper left – the first group – no attenuation. The upper right –the second group – linear attenuation. The lower left –the third group – MIDI amplitude envelope. The lower right –the fourth group – real piano chord amplitude envelope.

Table 3. Unipolar and bipolar semantic differential scales for triad chords evaluation

№	Scale	Unipolar	Bipolar
1	Unpleasant/Pleasant	X	
2	Not tensing / Tensing	X	
3	Don’t want to do something / Want to do something	X	
4	Not heavy / Heavy	X	
5	Not light / Light	X	
6	Not active / Active	X	
7	Not anxious / Anxious	X	
8	Not happy / Happy	X	
9	Not sad / Sad	X	
10	Not expected that something will happen / Expected that something will happen	X	
11	Not warm / Warm	X	
12	Not Major / Major	X	
13	Female / Male		X
14	Not interesting / Interesting	X	
15	Don’t want to mute / Want to mute	X	
16	Not Natural / Natural	X	
17	Languid / Cheerful		X
18	Pessimistic / Optimistic		X
19	Not energetic / energetic	X	
20	Unsure / Sure	X	
21	Not Asking / Asking	X	
22	Not Exciting / Exciting	X	
23	Don't want to help him / Want to help him	X	
24	Not cold / Cold	X	
25	Not Minor / Minor	X	
26	Not Musical / Musical	X	
27	Not good / Good	X	
28	Not hysterical / Hysterical	X	
29	Not Angry / Angry	X	
30	Negative / Positive		X
31	Not boring / Boring	X	
32	Not relaxing / Relaxing	X	
33	Not working properly / Working properly	X	
34	Quiet / Loud		X
35	Young / Old		X

Table 4. Statistically significant differences in the Wilcoxon T-test between evaluations of minor and major triad chords for a sample of non-musicians for all 4 groups of sounds (I - generated without attenuation, II - generated with a linear attenuation, III – MIDI sounds, IV - real sounds)

Non-musicians	**Stimuli type**			
Scale	I	II	III	IV
Unpleasant / Pleasant	n.s.	n.s.	n.s.	n.s.
Not tensing / Tensing	n.s.	n.s.	n.s.	.037883
Don't want to do something / Want to do something	n.s.	n.s.	n.s.	n.s.
Not heavy / Heavy	n.s.	n.s.	n.s.	.000651*
Not light / Light	n.s.	n.s.	n.s.	.000199**
Not active / Active	n.s.	n.s.	n.s.	n.s.
Not anxious / Anxious	n.s.	n.s.	n.s.	.000410*
Not happy / Happy	n.s.	n.s.	n.s.	.000010***
Not sad / Sad	n.s.	n.s.	n.s.	.000011***
Nothing will happen / Something will happen	n.s.	n.s.	n.s.	n.s.
Not warm / Warm	n.s.	.044	.045	.000106**
Not Major / Major	n.s.	n.s.	n.s.	.000313*
Female / Male	n.s.	n.s.	n.s.	n.s.
Not interesting / Interesting	n.s.	n.s.	n.s.	.012518
Don't want to mute / Want to mute	n.s.	n.s.	n.s.	.015222
Not Natural / Natural	n.s.	n.s.	.044	n.s.
Languid / Cheerful	n.s.	n.s.	n.s.	*.058050*
Pessimistic / Optimistic	n.s.	n.s.	n.s.	.000059**
Not energetic / Energetic	n.s.	n.s.	n.s.	.024844
Unsure / Sure	n.s.	n.s.	n.s.	.002164
Not Asking / Asking	n.s.	n.s.	.021	.030679
Not Exciting / Exciting	n.s.	n.s.	n.s.	n.s.
Don't want to help him / Want to help him	n.s.	n.s.	n.s.	.035131
Not cold / Cold	n.s.	.012	n.s.	.000851*
Not Minor / Minor	n.s.	n.s.	n.s.	.002246
Not Musical / Musical	n.s.	n.s.	n.s.	.961166
Not good / Good	n.s.	n.s.	n.s.	.000314*
Not hysterical / Hysterical	n.s.	n.s.	n.s.	.022015
Not Angry / Angry	n.s.	.016	n.s.	.011046
Negative / Positive	n.s.	.025	n.s.	.000048**
Not boring / Boring	n.s.	n.s.	n.s.	n.s.
Not relaxing / Relaxing	n.s.	n.s.	n.s.	.042932
Not working properly / Working properly	n.s.	n.s.	n.s.	.024300
Quiet / Loud	n.s.	n.s.	n.s.	n.s.
Young / Old	n.s.	n.s.	n.s.	.026731

n.s. – non significant
Italic – tendency,
** – Bonferroni correction for 35 measures at p<.05,*
*** – the same at p<.01,*
**** – the same at p<.001.*

Table 5. Statistically significant differences in the Wilcoxon T-test between evaluations of minor and major triad chords for a sample of musicians for all 4 groups of sounds (I - generated without attenuation, II - generated with a linear attenuation, III – MIDI sounds, VI - real sounds)

Musicians	**Stimuli type**			
Scale	I	II	III	IV
Unpleasant / Pleasant	.006662	n.s.	.0054859	.039044
Not tensing / Tensing	*.051298*	n.s.	n.s.	n.s.
Don't want to do something / Want to do something	n.s.	n.s.	*.0507406*	n.s.
Not heavy / Heavy	n.s.	n.s.	.0245646	n.s.
Not light / Light	.009252	n.s.	.0008613*	.000178**
Not active / Active	n.s.	n.s.	.0152603	.002350
Not anxious / Anxious	.000422*	n.s.	.0018495	.000011***
Not happy / Happy	.000858*	.016	.0000017***	.000006***
Not sad / Sad	.001593	n.s.	.0000004***	.000001***
Nothing will happen / Something will happen	n.s.	n.s.	n.s.	n.s.
Not warm / Warm	.020372	.039	.0139637	.000146**
Not Major / Major	.000051**	.002	.0000003***	.000001***
Female / Male	n.s.	n.s.	.0156959	n.s.
Not interesting / Interesting	n.s.	n.s.	.0472738	n.s.
Don't want to mute / Want to mute	n.s.	n.s.	n.s.	.038204
Not Natural / Natural	n.s.	n.s.	n.s.	.028645
Languid / Cheerful	n.s.	n.s.	.0003674*	.002162
Pessimistic / Optimistic	.011288	.004	.0000024***	.000037***
Not energetic / Energetic	*.051403*	n.s.	.0000933**	.000605*
Unsure / Sure	*.066575*	n.s.	.0002331**	.002584
Not Asking / Asking	.004287	.017	.0000336**	.000061**
Not Exciting / Exciting	n.s.	n.s.	*.0574366*	.004044
Don't want to help him / Want to help him	.000437*	.047	.0070508	.018243
Not cold / Cold	.000054**	n.s.	.0000028***	.000176**
Not Minor / Minor	.000182**	.008	.0000001***	.0000001***
Not Musical / Musical	n.s.	n.s.	n.s.	n.s.
Not good / Good	n.s.	.013	.0066173	.002349
Not hysterical / Hysterical	.048354	n.s.	n.s.	.026748
Not Angry / Angry	.004924	n.s.	.0249653	.048309
Negative / Positive	n.s.	n.s.	.0007896*	.000055**
Not boring / Boring	n.s.	n.s.	.0048445	n.s.
Not relaxing / Relaxing	.031273	.015	n.s.	.040688
Not working properly / Working properly	n.s.	n.s.	n.s.	n.s.
Quiet / Loud	n.s.	n.s.	*.0504039*	.005490
Young / Old	n.s.	n.s.	n.s.	.000437*

n.s. – non significant
Italic – tendency,
** – Bonferroni correction for 35 measures at p<.05,*
*** – the same at p<.01,*
**** – the same at p<.001.*

B 3.2. Factor analysis

A factor analysis was conducted, with an extraction of the main components, and the "Varimax", raw values method of rotation. According to the results of the Scree test, in the sample of non-musicians 4 factors are identified, explaining 52% of the variance of subjects' evaluations.

The first factor "General tension" explains 29.35% of the variance. Factor loadings are shown in Table 6. The second factor, "Activation," explains 11.45% of the variance. Factor loadings are shown in Table 7. The third factor "Minor" explains 6.1% of the variance. Factor loadings are shown in Table 8. The fourth factor «Major» explains 4.46% of the variance. Factor loadings are shown in Table 9.

According to the results of the Scree test, in the sample of musicians 3 factors were identified explaining more than 63% of the variance of subjective estimations. The first factor "Extended semantic description of major/minor" explains 36.16% of the variance. Factor loadings are presented in Table 10. The second factor "Extended Generalized tension" explains 16.59% of the variance. Factor loadings are presented in Table 11. The third factor "Affiliative Excitement" explains 9.39% of the variance. Factor loadings are presented in Table 12.

Table 6. Factor loadings of the first factor in the sample of non-musicians (values of more than 0.7 and less than -0.7 are highlighted)

Factor 1	Factor loadings
Unpleasant / Pleasant	**.79**
Not good / Good	**.79**
Negative / Positive	**.77**
Not light / Light	**.71**
Not happy / Happy	**.71**
Not relaxing / Relaxing	.68
Pessimistic / Optimistic	.67
Not interesting / Interesting	.64
Not musical / Musical	.64
Not Natural / Natural	.58
Not working properly / Working properly	.37
Not warm / Warm	.7
Not cold / Cold	-.51
Not boring / Boring	-.55
Not Angry / Angry	-.65
Not heavy / Heavy	-.66
Not tensing / Tensing	**-.7**
Don't want to muffle it / Want to muffle it mute	**-.71**

Table 7. Factor loadings of the second factor in a sample of non-musicians

Factor 2	Factor loadings
Not energetic / Energetic	**.82**
Unsure / Sure	**.74**
Not Exciting / Exciting	**.71**
Not active / Active	.68
Quiet / Loud	.51
Sluggish/Cheerful	.8
Not sad / Sad	-.38

Table 8. Factor loadings of the third factor in the sample of non-musicians

Factor 3	Factor loadings
Not pleading / Pleading	.61
Don't want to help it / Want to help it	.61
Not minor / Minor	.53
Not expected that something will happen / Expected that something will happen	.52
Not hysterical / Hysterical	.48
Not anxious / Anxious	.46
Don't want to do something / Want to do something	.44

Table 9. Factor loadings of the fourth factor in a sample of non-musicians

Factor 4	Factor loadings
Female / Male	**.71**
Young / Old	.55
Not major / Major	.37

Table 10. Factor loadings of the first factor in the sample of musicians

Factor 1	Factor loadings
Pessimistic / Optimistic	**.86**
Not warm / Warm	**.77**
Not good / Good	**.76**
Not Major / Major	**.75**
Negative / Positive	**.74**
Unpleasant / Pleasant	**.73**
Not light / Light	**.71**
Languid / Cheerful	.68
Not energetic / Energetic	.67
Not working properly / Working properly	.61
Unsure / Sure	.59
Not relaxing / Relaxing	.54
Not Exciting / Exciting	.47
Not natural / Natural	.47
Not happy / Happy	.8
Not interesting / Interesting	.7
Don't want to mute / Want to mute	-.7
Not heavy / Heavy	-.54
Young / Old	-.57
Not tensing / Tensing	-.59
Not angry / Angry	-.63
Not cold / Cold	-.66
Not boring / Boring	-.67
Not anxious / Anxious	-.68
Not sad / Sad	-.68
Not minor / Minor	**-.73**

Table 11. Factor loadings of the second factor in the sample of musicians

Factor 2	Factor loadings
Not active / Active	.55
Quiet / Loud	.51
Nothing will happen /Something will happen	.49
Not hysterical / Hysterical	.45
Female / Male	.23

Table 12. Factor loadings of the third factor in the sample of musicians

Factor 3	Factor loadings
Don't want to help it / Want to help it	**.71**
Not pleading / pleading	.55
Not Musical / Musical	.49
Do not want to do something / Want to do something	.46

4. Discussion

The results of the first study show that the subjects without a musical education cannot differentiate the emotional valence of the major and minor triad chords on the basis of tonal characteristics alone. The scales for which sounds were differentiated, are either not associated in scientific literature with the recognition of major and minor keys (“Narrow / Wide”), or their estimations are inverted (in the scales “Passive / Active” and “Boredom / Interest” the major is both “passive” and “boring”). For the full perception of musical sound filled with emotional semantics, other characteristics besides the tonal are required. They were revealed in the second study, when non-musicians first recognized emotional valence of generated sounds in the case of linear attenuation (“Negative / Positive” scale). In this case, the estimations are again inverted, as minor triad chords are evaluated as positive. It is worth paying attention to the scale "Not warm / Warm" within the comparison of the second and the third group of sounds. Non musicians can differentiate major and minor chords both generated with a linear attenuation and MIDI by this scale. Nevertheless, in the second group of sounds their estimations are inverted, and in the third group they correspond to cultural expectations. These two groups of sounds differ in the nature of attenuation (in the case of MIDI it is not linear and closer to the inverse power dependence), as well as in the presence of overtones in MIDI, although they are less expressed than in real sounds of musical instruments. We can assume that the presence of attenuation (albeit linear) is the basis for the appearance of emotional semantics of a sound, but it is not sufficient for the correct recognition of polarity of emotions. In their turn, the overtones complement the attenuation, allowing correct recognition of the emotional valence direction.

Professional musicians are able to cope with the task already in the group of triad chords generated without intensity attenuation. They also demonstrate increase in the accuracy of major and minor recognition from the first to the third and fourth group of sounds, with the exception of hardly ever heard second group of the sounds. The average time it took musicians to accomplish the task was longer than that of non-musicians. Several subjects in this group spent more than two hours filling out the semantic differential, while all of them were subjectively more tired. All of the participants of the professionals group noted that sounds consisted of major and minor chords.

The data can be interpreted as indicating the presence of different psychological mechanisms of major and minor chords perception within the samples of non-musicians and musicians. People with musical education and experience in playing musical instruments can differentiate major and minor chords and correctly evaluate their valence basing exclusively on the tonal component. Unlike them, non-musicians need the presence of intensity attenuation as well as the overtones for the correct emotional valence connotation. Nevertheless, in the case of the real piano sounds both groups show similar results.

The role of the sound intensity attenuation in recognition of major and minor triad chords is the decisive one. Its presence first makes possible for non-musicians to distinguish between major and minor keys and enhance corresponding capabilities in professionals in up to 2.6 times. It is impossible to distinguish major and minor keys basing solely on the tonal component without special professional education and training. Moreover, training of a semiprofessional level with the lack of regularity may be not sufficient. Presence of amplitude envelope that is specific for musical sounds almost equals abilities of non-musicians and professional musicians in recognition of the major and minor chords. A linear attenuation of the sound's intensity influences non musicians and music professionals differently: it helps the first and confuses the last.

Results of this research confirm the data of several studies on the ability of non-musicians to correctly differentiate major and minor keys. Our work clarifies the role of amplitude envelope in this phenomenon.

Declaration of conflicting interests: The Authors declare that there is no conflict of interest.

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Highlights:

- Aim is to study subjects' ability to evaluate emotional valence of chords based on their tonal and amplitude characteristics.
- Stimuli consist of generated and played by piano major and minor triad chords.
- The total of 103 amateurs/non musicians and professional musicians participated.
- Set of subjective scales was used for the evaluation of stimuli.
- Amplitude decay is crucial for the perception of emotional valence of chords in non-musicians.
- Professional musicians are able to perceive chords emotional valence without amplitude decay.
- Amplitude decay enhances perception of chords emotional valence in professionals.

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BOOK REVIEW

Kharlamenkova N.E. Psychology of Personality: from Theory to Scientific Evidence. M.: Publishing House "Institute of Psychology RAS", 2023

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Abstract: Monograph N.E. Kharlamenkova is aimed at educating a research culture. It is emphasized that the scientific fact should be interpreted at different levels of generalization. Otherwise, empirical knowledge runs the risk of remaining fragmented and useless. The book has many merits, among which there is a discussion of the problems of norm and pathology, nomothetic and idiographic methods in personality psychology. The monograph is distinguished by a very balanced vision of how scientific research should be conceived, carried out and understood.

Keywords: Scientific Fact, Personality, Nomothetic Method, Idiographic Method, Norm, Pathology, Stress, Coping

Modern science is characterized by a high level of differentiation, which is reflected in both research practices and training programs for psychologists. As a result, we often must deal either with extremely detailed research without understanding its value for science or practice, or with "narrow" specialists who turn out to be incompetent in a related field of knowledge. There is a lack of understanding of each scientific fact interpreted at different levels of generalization, leaving empirical knowledge at risk of remaining fragmentary and useless.

To understand and accurately interpret a scientific fact, the logic of its generation must be reproduced over time from its conception to its realization, and then interpreted in the context of the other facts. Such precise process requires a wider outlook and scale of thinking of the cognitive subject. We believe that the book reviewed is designed to develop a research culture.

N.E. Kharlamenkova, being one of highly qualified researchers in a rapidly developing field that might be called "psychology of personality under stress", possesses a balanced outlook on the way scientific research should be conceptualized, conducted, and interpreted. Therefore, her expertise may be useful to researchers and practitioners.

The book consists of six chapters and more than 400 pages. Despite the overwhelming number of foreign references, N.E. Kharlamenkova prioritizes the Russian methodology, and she focuses on the views of the leading scientists of the past such as K.K. Platonov, L.I. Antsyferova, and K.A. Abulkhanova. There are many advantages of the book, such as discussion of the nomothetic/idiographic relationship in personality psychology, the history of the

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scientific school of personality psychology developed at the Institute of Psychology of the Russian Academy of Sciences, and discussion of the topic of scientific fact in psychology, which has not been common practice in Russia. The paper analyzes current studies carried out by N.E. Kharlamenkova herself or under her supervision: coping with life-threatening disease, children's and parents' relationship in adolescence, emotional violence, the role of social support in coping with difficult situations related to the disease. The complex and at times sensitive issues of normality and pathology in personality psychology are discussed with new data. The final chapter and the conclusion raise new questions and open up prospects for future research in personality psychology.

The book, which is written as a scientific monograph, can be recommended to a wide range of intellectually active people such as researchers, students of different levels of education, people mastering the psychology as a second career, as well as to readers who are interested in psychology.

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Reference

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Review of the Book by Pevneva A.N. “Rigidity and Psychological Well-Being: Integrative Approach”. Minsk: Publishing House “Maxim Tank Belarusian State Pedagogical University”, 2024

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Abstract: The article presents a review of A.N. Pevneva’s “Rigidity and Psychological Well-Being: Integrative Approach” monograph. An analysis of the most important sections of this subject area is presented, such as the problem of rigidity in the personality structure and the theoretical model of rigidity, its structural and functional characteristics. It is considered the cognitive, motivational, and emotional components of the psychological well-being of a person. Particular attention is paid to neurocognitions, which is one of the most progressive scientific areas that have a significant impact on the modern understanding of human mind. As evidence of the neurophysiological correlates of cognitive rigidity, data from studies using an electroencephalograph, i-tracker and polygraph are presented, making it possible to study the phenomenon of rigidity within the framework of symbolic, modular, and neural network approaches. The book is intended for psychologists, educators, as well as anyone interested in the phenomenon of rigidity.
Keywords: Rigidity, Psychological Well-Being, Personality, Cognitive Rigidity, Motivational Rigidity, Emotional Rigidity

The monograph “Rigidity and Psychological Well-Being: Integrative Approach” by A.N. Pevneva is the first scientific work in the Republic of Belarus that reveals the problem of rigidity in relation to the psychological well-being of a person. The scope of the phenomenological field and methodological complexity of the study determines the logic of presentation and structure of the monograph: from defining the research problem for rigidity and psychological well-being and their conceptual foundations to presenting the obtained empirical data on the above-mentioned phenomena.

The relevance of the stated problems in the monograph manuscript submitted for the review is determined by the growing interest to the phenomenon of rigidity as a bipolar cognitive-personal structure. The acceleration of socio-economic processes in society requires maximum adaptability and active mobility from the individual, and the constant development of one’s potential in difficult situations. According to the author, rigidity can not only hinder the adaptation of personality but also serve as a kind of “buffer” in conditions of turbulence of current changes.

The author’s methodological research is primarily aimed at conceptualizing the phenomenon of rigidity in the personality structure. The general conceptual approaches to the study of rigidity and psychological well-being as well as private empirical studies conducted by Russian and foreign psychologists over the last

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decades have been thoroughly analyzed. The output of the generalization for the results obtained is the author's conclusion about the need for developing a number of aspects because of methodological disunity, conceptual polysemy, methodological neediness of the studied phenomena.

The generalization of a wide range of study results for structural and functional characteristics of rigidity is presented by a detailed analysis of the structure and dynamics of rigidity development for the cognition subject as well as a more detailed comparative analysis of approaches to cognitive rigidity study. The data obtained organically complement the general model of rigidity in the context of cognitive-personal subject of cognition proposed on the basis of theoretical analysis which reveals the phenomenology, mechanisms and regularities of rigidity development as a result of the cognition process (in a broad sense) and problem solving (in a narrow sense). The necessity of distinguishing between Convergent Rigidity and Divergent Rigidity is substantiated.

The chapter of the monograph, which reflects the structural-hierarchical model of rigidity in the context of cognitive-personal development, deserves special attention. The neurophysiological correlates of cognitive rigidity, the results of the correlation of the cognitive component with the motivational component of rigidity, as well as the structural organization of its emotional component are described. As a result of the study, the phenomenon of rigidity is proposed to be considered as a bipolar construct in the context of "rigidity – flexibility" opposition with splitting subfields that completely changes the perspectives on rigidity as purely negative phenomenon.

The final part of the monograph reveals the psychological rigidity and psychological well-being of a personality. The results of neurophysiological correlates of cognitive rigidity of a personality with different levels of psychological well-being, the interrelation of emotional, motivational components of rigidity in correlation with psychological well-being of a personality are considered. The structural components of rigidity, presented above, act as significant predictors of psychological well-being of a personality.

In general, the monograph is characterized by the complex character of scientific material presentation, novelty and relevance of the subject matter. The extensive and detailed analysis of theoretical and experimental studies of rigidity, identification of its structural and functional characteristics, development of its structural and hierarchical model in correlation with the psychological well-being of a personality make a significant contribution to general psychology and personality psychology issues.

A.N. Pevneva's "Rigidity and Psychological Well-Being: Integrative Approach" monograph is a fundamental scientific work that analyzes the existing knowledge about rigidity and psychological well-being. The monograph significantly expands knowledge on general psychology, covering in detail the problem of rigidity in relation to the psychological well-being of the individual.

CRediT author statement:

The author has read and approved the final version and bear responsibility for all aspects of the publication.

Highlight:

- A conceptual model of rigidity is presented, which reveals the phenomenology, mechanisms, and patterns of its development.
- The need to distinguish between Convergent Rigidity and Divergent Rigidity is substantiated
- Rigidity is considered as a bipolar construct in the "rigidity-flexibility" continuum with splitting of subfields, which completely changes the view of rigidity as a purely negative phenomenon.
- It is shown that the structural components of rigidity are significant predictors of an individual's psychological well-being.

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Review of the book by E.V. Volkova & I.O. Kuvaeva "Coping intelligence: differentiation and integration approach" M.: Publishing House "Institute of Psychology RAS", 2023

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Abstract: The book is devoted to the develop a new approach to the understanding of Coping Intelligence. Coping Intelligence is defined by the authors as a special form of organizing the mental experience of overcoming difficult life situations. There is no doubt that this is one of the most promising areas of research on stress and coping, which unites the efforts of researchers from different branches of science working in this problem area (physicians, psychologists, psychophysiologists, biochemists, culturologists, linguists, etc.), and will make it possible to critically rethink the huge amount of empirical data on stress and coping, including the influence of culture and context, maintaining health, personality development, well-being, and, perhaps, will lead to the creation of a unified theory of Stress & Coping from the standpoint of the systems approach.
Keywords: Coping Intelligence, Experience of Overcoming Stress, Stress & Coping System

The book is devoted to the problem of the role of intelligence in the implementation of the human's coping behavior as one of the key factors in the productivity of human life. Despite the attention of researchers to this issue and its undoubted promise, it still remains poorly developed. The theoretical importance and the novelty of the ideas presented in the book are also related to the fact that, *firstly*, the authors develop a new approach to the understanding of Coping Intelligence (the term was proposed by A. V. Libina more than 10 years ago, but has not received proper theoretical development) as a special form of organization of mental experience and a measure of the effectiveness of the subject's Stress & Coping System, *secondly*, Coping Intelligence is viewed from the perspective of the Differentiation & Integration theory.

The structure of the book is designed to help the authors solve the problems and consider the phenomena under study at both the theoretical, methodological, and empirical levels. The book consists of two parts, divided into nine chapters.

The first part of the book is devoted to a theoretical analysis of basic concepts and the development of a Theory of Coping Intelligence. Based on the P. K. Anokhin's theory of functional systems, the authors introduce and develop the concept "Stress & Coping System" as a complex of components selectively involved in the coping process:

(1) Subsystem Stress, providing the construction of the image of the situation,

(2) Subsystem Coping, carrying information about the ways of action in a particular situation.

Fundamental dimensions of the Stress & Coping System are also addressed, such

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as (1) the causes leading to stress; (2) stress state; (3) consequences; (4) process, i.e. duration, intensity and stages of development of a stressful situation; (5) management of stressful situations and stressful conditions.

The authors analyzed through the prism of these ideas the most influential stress theories of H. Selye (Selye, 1956), R. S. Lazarus (Lazarus, 1985), Paul T. P. Wong (Wong (1993), and the Jan Strelau's theory of temperament (Strelau, 1996). An interesting illustration authors' idea is the manifestation of the fundamental dimensions of the Stress subsystem in a professional and organizational context. Very promising are the ideas about the sensitive periods of formation of the Stress & Coping System and its level organization, according to B. F. Lomov (Lomov, 2021), from the micro level to the level of the Collective Subject. The ideas of M. A. Kholodnaya and S. A. Khazova about the conceptualization (Kholodnaya & Khazova, 2017) of the stressful situation experience are being developed in the book. The verbal and semantic level of stress regulation is also considered.

The authors pay attention to the analysis of the biochemical level of the Stress & Coping System, namely, the biochemical and neuronal changes that occur during a stressful situation. Obviously, the Coping Intelligence Theory would be incomplete without the analysis of functional aspects of the Stress & Coping System. The authors emphasize the balance (equilibrium) of the interaction between various body systems based on a significant number of the newest sources. Based on a significant number of the latest sources, the authors identify such functions of the biological level of the Stress & Coping System as (1) balance of the interaction of various body systems, (2) plasticity, (3) maintenance of rhythm, (4) accumulation of experience (immunological memory of stressor), (5) reappraisal of experience, and (6) emotional regulation. Future research tasks are also outlined here: empirical testing of the neurochemical dynamic model of Coping Intelligence (in terms of the rate of restoration of neurochemical balance when overcoming stressful situations) taking into account individual differences.

The second and third chapters are devoted to the Coping Intelligence itself, which is defined as a measure of the organization of mental experience of overcoming stressful situations and as a measure of the productivity of the subject's behavior in stressful situations. We believe that the authors' ideas formulated in these chapters are of great interest and are undoubtedly new and original. It is rather difficult to enumerate all authors ideas. For example, the importance of generalizing and highlighting criteria for the productivity of coping behavior is emphasized, which include both traditional flexibility and variability, as well as congruence of resources and requirements of the situation, and innovative ones: the orientational basis of coping, the transfer of successful models of behavior to new situations, selectivity, and optimal rate of coping depending on the complexity of the stressor. In addition, the reader may be interested in Chapter 4 that discusses the influence of culture on the perception and understanding of stress. There is no doubt that this is one of the most perspective directions of research, even though studies on this topic that confirm the role of the sociocultural context of stress and coping are not new in Russian psychology, in particular, eight years ago there was published a monograph by T.L. Kryukova, T.V. Gushchina "Culture, Stress and Coping: Sociocultural Constructualization of Coping Behavior" (Kryukova & Gushchina, 2015). Nevertheless, empirical data on the perception of stress and its coping in different cultures, reflected in real language practice, will be of great interest and use to a great number of readers.

Part II reviews the methodological aspects of the study and presents the results of empirical research. The authors propose original tools for studying the conceptualization of stressful events, as well as analyze in detail the existing methods of research on coping behavior.

The authors present an extensive empirical data set that allows verifying the hypotheses and confirming the main provisions of the Coping Intelligence theory. In particular, the authors obtained significant data on the role of the measure of differentiated experience of coping with stressful situations in the expansion of the repertoire of coping strategies and their greater consistency, as well as on the influence of a person's ethno-cultural background on the peculiarities of conceptualization of stressful situations and coping.

One of the important applied results is the further development of methodological aspects of the study of stress and coping based on the achievements of modern psychological science, as well as a detailed description of the BARS Coping Intelligence method developed by the authors, which can become a convenient and reliable tool for predicting human behavior in real stressful situations, developing recommendations for managing stress and preventing stress-related disease risks. The material presented in the appendices is also extremely useful in practical terms: Atlas of the visual representation of stress (Appendix 3) or a description of the expert assessment method for studying the conceptualization of stressful situations (Appendix 2).

It is necessary to note the evident advantages of the book and the authors' conception presented therein, which attempts to integrate within a single theory the data of various sciences, and analyze the studied phenomena of intelligence from the perspective of both the psychology of stress and coping behavior, and the recent data of psychophysiology, biochemistry, medicine, as well as the ideas of culturology and linguistics, that, in turn, testifies in favor of the interdisciplinary approach of the authors. The study covers a variety of empirical material obtained by the authors themselves, that proves the viability and significance of their ideas, as well as a meta-analysis of studies on the subject, which is a valuable gift for aspiring researchers and all scientists working in these problem field. Finally, the authors share with the reader a great deal of their ideas, speculations, and opinions, though this fact has its downside: not all the ideas are sufficiently theoretically justified, and sometimes it seems to be a “sketch”, an outline for the further development of theoretical propositions.

Like any other new conceptions, the ideas formulated in the book “Coping Intelligence: a Differentiation and Integration Approach” are likely to cause doubt and even disagreement among readers. For example, it seems that the very concept of “Coping Intelligence” is not entirely strictly scientific, but rather a successful, rather vivid metaphor; and the definition given by the authors (p.4) provokes new questions:

(1) If Coping Intelligence is a special form of organizing the mental experience of overcoming difficult situations, are there probably other, “non-special” forms of its organization?

(2) Can there be “Non-Coping Intelligence”? If we refer to the studies of the authors who worked on the problem (Khazova, 2014; Kholodnaya & Aleksapolsky, 2010; Kholodnaya & Khazova, 2017; Kornilova, 2016), there is not much clear evidence, consistent data on the relationship between intelligence and productivity (e.g., flexibility) of coping.

(3) If Coping Intelligence is an ability, as follows from the text of the monograph, then, probably, it is the subject who copes? It is the subject that perceives and processes information, builds an image of the situation and regulates his or her own behavior, in relation to the requirements of the situation and his or her own capabilities?

Further, there is some misunderstanding the list of attributive properties of Coping Intelligence, some of which in the authors’ formulations can be attributed to the subject (for instance, “quality” or “subjectivity”), and some characterize the Stress & Coping System, for example, “substantiality” or “metricity”.

However, if the Stress & Coping System is the substratum of Coping Intelligence, as the authors state, then, in our opinion, this does not mean that all its properties are also properties of Coping Intelligence.

It should be noted that the reader finds it difficult to understand how the main concepts are related to each other "Mental Experience of Coping", "Coping Intelligence", and "Stress & Coping System". On the one hand, as the authors say, Coping Intelligence is a measure of the organization of the mental experience of overcoming stressful situations, on the other hand, it is also a measure of the productivity of the subject's behavior in a stressful situation, i.e., the higher it is, the higher the productivity of coping, and finally, on the other hand, it controls the Stress & Coping System. Probably, the authors believe that they have a consistent picture of the relationship between all with everything. The reader needs some help with it, for example, in the form of a scheme. In the conclusion the authors make a rather successful attempt to present their views in a systematic way. Finally, the theoretical propositions suggested by the authors need strict empirical verification, which is certainly a perspective of the research, despite the empirical material provided.

Perhaps, at the first reading we did not manage to "grasp" and appreciate all the ideas, and in some ways our views differ. Nevertheless, as a conclusion, it is important to emphasize that the difference in scientific views is especially useful and important because it provides the grounds and food for thought, reflection, and discussion. What is hoped is that it, in its turn, will unite the efforts of authors who work in this problem field, and will give an opportunity to critically rethink a huge amount of empirical data on human perception of stress, including the influence of culture, its course in a particular context, on coping with it from the standpoint of health preservation, development of human vitality and life productivity, and, possibly, will lead to the creation of a unified theory of Stress & Coping from the standpoint of the system approach.

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Highlight:

- The criteria for the productivity of coping behavior are:

(1) flexibility and variability of coping,
(2) congruence of resources and requirements of the situation,
(3) the orientational basis of coping,
(4) the transfer of successful models of coping behavior to a new situation,
(5) selectivity of coping,
(6) optimal rate of coping.

- Functions of the biological level of the Stress-Coping System are:

(1) balance of the interaction of various body systems,
(2) plasticity,
(3) maintenance of rhythm,
(4) accumulation of experience (immunological memory of stressor),
(5) reappraisal of experience,
(6) emotional regulation.

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