Actual problems of creative activity and new cognitive possibilities: a transdisciplinary approach

Valeriy Mygal[1], Galyna Mygal, Stanislav Mygal

1 National Aerospace University Kharkov Aviation Institute

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

Digitalization of education and science is a unique opportunity for creative activity, as well as new problems of the functioning of complex dynamic systems, including the human body, in extreme conditions (technogenic, environmental, epidemics and wars). New tools are proposed, based on new phenomena, analogies and principles, as well as metamodels of thought structures and relationships between key sciences and their metasciences, the complementarity of which has cognitive and heuristic value.

It is shown that the heuristic significance of successful activity is associated with the emotional perception of the harmony of nature, the holographic nature of memory and the desire to generate useful ideas. The cognitive value of extreme principles in the natural sciences, in information theory, in psychology and design is considered. Attention is drawn to new possibilities for the use of signs and symbols, the versatility of which made it possible to propose:

• apply the diversity of signs and symbols in the natural sciences to bridge the gap between the humanities and science cultures;
• heuristic meta-models in the form of the Star of David, the complementarity of which increases their cognitive value;
• new tools for optimizing creative activity, the use of which contributes to the harmonization of interaction in the digital

environment.

It is proposed to unify the criteria for evaluating different types of creative activity (scientific, technical and artistic), which are aimed at solving the actual problems of the individual (health, safety and development of emotional intelligence).

Keywords: metasciences and metamodels, heuristic value, cognitive space, new universals, cognitive distortions, harmony and balance of relationships.

1. Introduction

Digitalization of education and science.It has created unique opportunities for creative activity (new materials, technologies and methods), as well as new challenges (cognitive, communication and mental). Problems are induced by the accelerated digitalization of different subject areas, which is accompanied by an increase in complexity (statistical, dynamic, structural, algorithmic and informational) (Mygal V., Mygal G. Mygal S. (a) 2022). The increasing complexity of special disciplines is accompanied by their differentiation. Their mathematization and theorization began to develop linear thinking, which limits the development of critical thinking. At the same time, the digitalization of natural sciences contributes to the exchange of methods and ideas, which leads to the development of interdisciplinary links and mutual enrichment. The complexity of the dynamic structure of information flows is increasing, which increases their uncertainty and limits the further development of learning technologies (Mygal V. et al. (f) 2020, Mygal V. et al. (b, c) 2021).

At the same time, the dynamic similarity of information flows of different nature (fractal signals, etc.) was revealed in different subject areas (Ashby W. Ross. (1947); Mygal V. et al., 2016, 2017, (a-c) 2018, (a, b) 2019, (d) 2020). This similarity opens up new possibilities for understanding the holistic and unity of knowledge, without which this understanding does not arise. In the 21st century, the number of unresolved problems in the sciences has increased, which is a consequence of the failure to implement the recommendations of UNESCO and the UN on the transdisciplinarity of education. There are especially many unsolved problems in the natural sciences and neurosciences (Wikipedia).

Mutual enrichment of the natural sciences.The exchange of research methods in the natural sciences made it possible to go beyond them and gain new knowledge. Simplifying the study of interdisciplinary relationships allows extreme principles of natural science, the geometric interpretation of which reflects the dualism of nature. Therefore, the generator of revolutionary ideas in physics, biology and chemistry has always been geometrization, which made it possible to streamline the world of structures (Loshak Zh., 2005). Common methods, structures and extreme principles of physics, biology and chemistry contribute to their convergence. Convergence is based on the principles of the natural sciences, the commonality of their models and the structures of different nature. This actualized the study of the relationship between the spatial and temporal properties of nanostructures. However, an increase in the spatial complexity of

structures is accompanied by an increase in temporal uncertainty. This has created new difficulties and problems that are most clearly manifested in the nanoworld.

Fruitfulness of interrelated concepts: environment, field and induction. These concepts are based on:

- revolutionary ideas in physics (A. Einstein, L. De Broglie, I. Prigogine), which were awarded Nobel Prizes;
- new methods in ergonomics-engineering psychology (Venda, V. F., Venda, Y. V. 1995);
- second-order cybernetics (Foerster 1974; Glasersfeld 1987).

They are also fruitful in the humanities, art and design. The complementarity of these concepts is used in environment-oriented learning and professional activities. At the same time, despite the high achievements (science, nanotechnology, IT and artificial intelligence, digitalization of the economy and education), the cost of new disasters (pandemics, tsunamis, earthquakes, etc.) is increasing. New ideas and approaches in the field of security (ergonomics, human factors, theories of risk and viability) are expressed and actively developed through differentiation, theorization, mathematization and systematization (Parasuraman, Mehta 2013). However, the cause of more than 75% of man-made disasters is still the human factor, and the "price" of human activity is growing (Fedota, Parasuraman 2010). Therefore, the safety problems of the CDS and its elements, including humans, have necessitated the search for new ideas in practical ergonomics to solve urgent problems caused by digitalization and extreme conditions.

Cognitive aspects of information interaction. With the rapid integration of information and industrial technologies, human activity has shifted significantly toward cognitive load (Lee et al., 2017), while cognitive distortions have increased the cost of errors. Thus, the cognitive aspects of interaction in the digitized world are paid attention to in the works (Mygal, V. Mygal, G. Mygal, S. (a, b) 2022). Today, information interaction is determined not only by the development of thinking in the family, school and university, but also by the era of digital technology, which is mediated by the screen. In the 21st century, the new generation is dominated by:

- breathtaking quality of instant contact;
- unlimited flow of information;
- virtual games and virtualization of personal life.

Accordingly, the cognitive essence of a person changes — a schoolchild, a student, an employee, an operator, a designer, a manager. Therefore, for science and education, it has become very relevant to search for new ideas to solve the problems of cognitive distortions that are acquired in the course of activity and are inherent in each individual, as well as hidden genetically inherited ones (Mygal V., Mygal G., (a, c) 2021; (a, b) 2022).

Key causes of problems. The digital code form of interaction affects human cognition, and its apparent effectiveness hinders the way we relate, feel and think. The accumulation of hidden contradictions and interdisciplinary conflict is the main cause of systemic problems in science and education. As a consequence, the influence of the human factor on the safety and viability of complex dynamic systems (CDS) under extreme conditions (Mygal V. P., Mygal G. V. and Mygal S. P. (c) 2021). In our opinion, the key causes of these systemic problems are:

- accelerated digitalization of education and science;
- increasing information complexity of science, technology and education;
- dominance of linear (binary) thinking in problem solving.

In the circular economy of the 21st century, industries, governments and even consumers are increasingly recognizing the intuitive value of cyclical principles. Therefore, it is necessary to develop not only logical (mathematical) thinking in the process of activity, but also emotional intelligence on a natural scientific basis. In our opinion, semiotics, which combines humanitarian and natural science cultures, deserves special attention.

Relevant goals of the work:

1. To create a hybrid cognitive environment, activities that promote creativity and do not affect mental health.
2. Optimization of interaction in a digitized environment, where comfortable activity is due to the natural dynamics of adaptive processes responding to external and internal influences.
3. Stimulation of the emotions of individuals in the process of fruitful creative activity, which contributes to the accumulation of successful experiences.

The complementarity of these goals can be achieved in a hybrid environment in which information flows of different nature have a similar dynamic structure, common signs and symbols, which will increase the reliability and safety of human activity in extreme conditions.

2. Problems induced by accelerated digitalization

Unresolved issues. Despite the unique opportunities for researchers in the 21st century, the number of unsolved problems in physics, mathematics, biology, psychology, philosophy and other sciences is rapidly increasing. This is due to the mathematization and theorization of sciences with the help of which it is impossible to solve the problem of transient processes and states. The urgency of the problems of change was foreseen by the British publicist Alvin Toffler in the book “Future Shock”, which was written back in the 1970s. He wrote, Nobel laureates, hippies, psychiatrists, doctors, businessmen, professional futurists, philosophers, and educators have voiced their concerns about change, their anxiety about adaptation, their fears about the future. From this experience, I drew two disturbing conclusions. First, it has become clear that future shock is not a distant potential danger, but a real disease from which an increasing number of people are already suffering. This psychobiological state can be described in medical and psychiatric terms. This is the disease of change. Second, I was gradually dismayed by how little adaptability is actually known, both by those who are calling for change and creating large-scale change in our society, and by those who are supposedly preparing us to deal with that change. Serious intellectuals boldly speak of “education for change” or “preparing people for the future.” But we don’t really know anything about how to do it. Being in the most rapidly changing environment in which man has ever lived, we remain in a pitiful ignorance of how a person copes with problems.

We were looking for new ways to describe the transitional states of CDS elements, including the human body, based on

the idea of a single cognitive space, namely:

- carried out an analysis of the transition states of inanimate objects (Mygal V. P., Klymenko I. A., and Mygal G. V., 2017, 2018);
- proposed integrative measures of human operator transient states (Mygal V. P. and Mygal G. V. (b, c) (2020);
- established the characteristic features of the transition states of CDS (Mygal V. P. and Mygal G. V. (d, e) 2020).

Interrelation of problems of education and science.Digitalization creates not only new opportunities, technologies and methods, but also problems, the cause of which is:

- increasing complexity (statistical, dynamic, structural, algorithmic and informational) that affects security (physical, functional and informational);
- accelerated digitalization of various subject areas, which is accompanied by their mathematization, theorization and digital modeling;
- the emergence of new metasciences (metapsychology, metachemistry, metabiology, etc.), the development of which is limited by cognitive problems.

They are a consequence of the differentiation, fragmentation and segmentation of the special sciences. Meanwhile, the mutual enrichment of the natural sciences contributes to interdisciplinary connections, leading to their convergence. The escalating complexity of computer science and other specialized disciplines has begun to constrain the cognitive possibilities of online learning. The cognitive problems of digitalization are considered in the works of (Mygal V. P., Mygal G. V., and Balabanova L. M. (a) 2019; Mygal V. and Mygal G. (b) 2019). The increasing complexity of the dynamic structure of the information flow and its uncertainty limits machine and deep learning (Mygal V. P. and Mygal G. V. (c, e) 2020; Mygal V. et al. (f) 2020).

3. Individuality of thinking and universality of creative activity tools

Features of thinking in science, art and design.They make it possible to overcome the complexity of interdisciplinary barriers induced by digitalization. Indeed, only through the development of design thinking, designers have the freedom to create innovative solutions. In Designerly Ways of Knowing, Nigel Cross (2007) says: "…the ability to design is, in fact, one of the three main types of human intelligence (mental, emotional and social) that influences the choice of strategy.

Design, science and art are in an AND, not an OR relationship, creating incredible human cognitive abilities:

- Science – looking for similarities between things that are different;
- Art – finding differences between things that are similar;
- Design – creating a possible "whole" from impossible "parts".

Their complementarity allows generating ideas and visualizing dreams and transforming them into heuristic models.

The connection of the individual's worldview with the perception of nature The scientific and philosophical outlook

of an individual forms the perception of the nature and features of thinking in the subject area. Purposeful interaction with nature, culture and the digital world at various levels of knowledge in parallel with binary analysis develops intuition and intelligence. Basic mental operations (analysis – synthesis – comparison) make it possible to find common features and properties in information flows of various nature and predict the functioning of objects in extreme conditions (Mygal V.P., Mygal G.V. and Mygal S.P. (c) 2021). On the one hand, language is a tool of science, culture and evolution, and on the other hand, the cognitive capabilities of an individual are determined by:

- Intuition, experience and emotional intelligence;
- natural-scientific worldview, which forms in the process of activity;
- perceptions of culture (art) by researchers, technologists and designers.

However, theorists continue to invent new names for old concepts and confuse them more and more. As A. Poincare noted, "... everything that a scientist actually creates is the language with which he proclaims it." Creativity, as the ability to generate new and useful ideas, is closely related to memory encoding, storage and retrieval of information (Poincaré 1990).

Heuristic thinking and cognitive flexibility. Successful human activity, which is aimed at understanding the phenomena of nature, forms heuristic thinking. By developing the cognitive abilities of students, the digitalization of education has created new difficulties, problems and logical contradictions. Thus, using formal logic, researchers run into the trap of recursion. It underlies a significant part of the paradoxes and logical contradictions. Consequently, language and abstract thinking create limitations and traps that lead to problems, conflicts, and destructive behavior.

The ability not only to perceive information, analyze data and make decisions, but also to think, visualize and fantasize on the basis of cognitive flexibility of thinking. Therefore, in psychology, cognitive flexibility is identified with emotional intelligence, which is an important part of mental health. The cognitive aspects of digitalization are considered by us in 22 works (Mygal V. et al., 2016-2023), in which attention is drawn to the relevance of the cognitive problems of digitalization. Cognitive distortions, with the help of which the brain convinces us of something that is not true, are a kind of trap of consciousness. They influence the decisions made in extreme conditions and are the main reason for the manifestation of the human factor in the 21st century.

Recursive thinking as a barrier. Recursion is used in various special fields of knowledge - linguistics, logic, physics, mathematics and computer science. In its purest form, recursion is noticed by psychologists-physiologists, who have long used such a speech blocking mechanism for research on language and thinking. Psycholinguist Stephen Krashen put forward five hypotheses, one of which in the form of the "Grammar Monitor Hypothesis" follows from the laws of logic, mathematics, psychology, and physiology. And only the fragmentation and segmentation of the sciences and the increasingly narrow specialization of scientists do not allow us to notice this. In particular, millions of people continue to try to learn a language using a language description of a language (grammar), not noticing that they fall into the logical trap of recursion without a chance to get out of there. When you don't know how to construct a sentence in another language to express what you want, you can't say it. But once you've learned the rule and know how to build that sentence, you still can't say it because the area of the brain that should control this action is occupied with thoughts about how to do it (rules)

(Krashen 1977). Consequently, the recursion of consciousness is a barrier to the development of creative thinking, and for programmers, recursion is self-evident, which is not at all the case in other areas of science and activity.

Cognitive dualism. Neurosciences (neuroergonomics, neuropsychology, etc.) have established those cognitive problems depending on the psychophysiological state of a person. Therefore, the study of activities in the digital world limits many cognitive problems. The key problems for cognitive perception are:

- presentation and analysis of little formalized information;
- studying the features of thinking and identifying cognitive distortions;
- perception of a variety of sources of information.

They give rise to contradictions between the style of thinking and the methods of processing, displaying and analyzing information, and are also due to the complexity of discrete thinking, which is based on intuition. Therefore, when implementing individual scenarios of adaptation to external influences, a person intuitively uses the flexible logic of antonyms. Obviously, cognitive dualism is associated with an intuitive search for a spatio-temporal balance between extremes. The duality of perception of nature, individuality of thinking and functional asymmetry of the cerebral hemispheres determines the features of cognitive activity (Haken 1995, 2003).

Analysis of triads reflecting the evolution of a synergistic system. Such a system is characterized by the exchange of energy and matter with the environment, which is due to the desire of the system to maximize the use of external energy. This determines the selection of new efficient ways of using energy, matter and information. Therefore, it is important to use the Darwin triad (variability, heredity, selection) for the system analysis of synergetic systems of any nature and evolution algorithms, as well as for the educational process. Indeed, transition states are associated with the continuous formation of new forms of organization (structures) and their subsequent destruction (inclusion in a hierarchical structure) through a sequential transition from one state to another. Therefore, transition states reflect the variability of the system. Heredity connects the past with the future through the preservation of structural features, which reflects the influence of the past on the future through the action of feedback characteristic of open systems.

Triad of natural colors. The degree of information distortion under external and internal influences depends on the psychophysiological state of a person, which psychologists determine using Luscher color tests. Note that I. Goethe developed the theory of the natural circle of colors for 40 years and considered it his greatest achievement (Johann Wolfgang von Goethe 1840). He showed that from the basic three colors (blue, red, yellow), any color can be obtained by mixing them in different proportions. It is important that the primary colors in the form of a triangle, and the colors of the first order in the form of an inverted triangle are spatially balanced and form a hexagram, the boundaries of which look like the Star of David.

Based on the fact that the triad of colors was used to obtain the first color photograph (J. Clerk Maxwell 1861), it can be assumed that the connection between the holographic nature of memory and thinking is based on different types of holography (dynamic, color, acoustic, etc.). Therefore, the cognitive metamodel of thinking reflects the features of thinking in a given field of knowledge (see Figures 1-3).

Evolution of ideas and research methods of a physicist-materials scientist-metaphysicist. Discovery of new phenomena in semiconductor compounds (optically sensitized photosensitivity (Gavrikova, Migal, Rvachev 1975), inversion of IR photoconductivity (Gavrikova, Migal, Rvachev 1976), anomalous thermal conductivity (Komar, Migal, Chugay 1993), fifth-order dynamic symmetry (Migal 1998), second-order effects that are not inherent in cubic crystals (morphic effects (Nay, Dzh. 1967) – optical activity, pyroelectric effect (Zagoruiko, Komar, Migal 1995) contributed to the successful solution of actual problems of physical materials science, as well as:

- development of new methods for studying the structure of crystals and residual stresses (21 patents);
- study of signatures of technologically inherited states in crystals (Migal V.P. 2002);
- development of methods for predicting radiation and radiation resistance of smart materials (know-how).

Philosophical understanding of the evolution of research methods and the formation of metaphysical thinking based on the complementarity of the natural sciences and their metasciences contributed both to the further development of research methods and the birth of “fresh” ideas within the transdisciplinary approach.

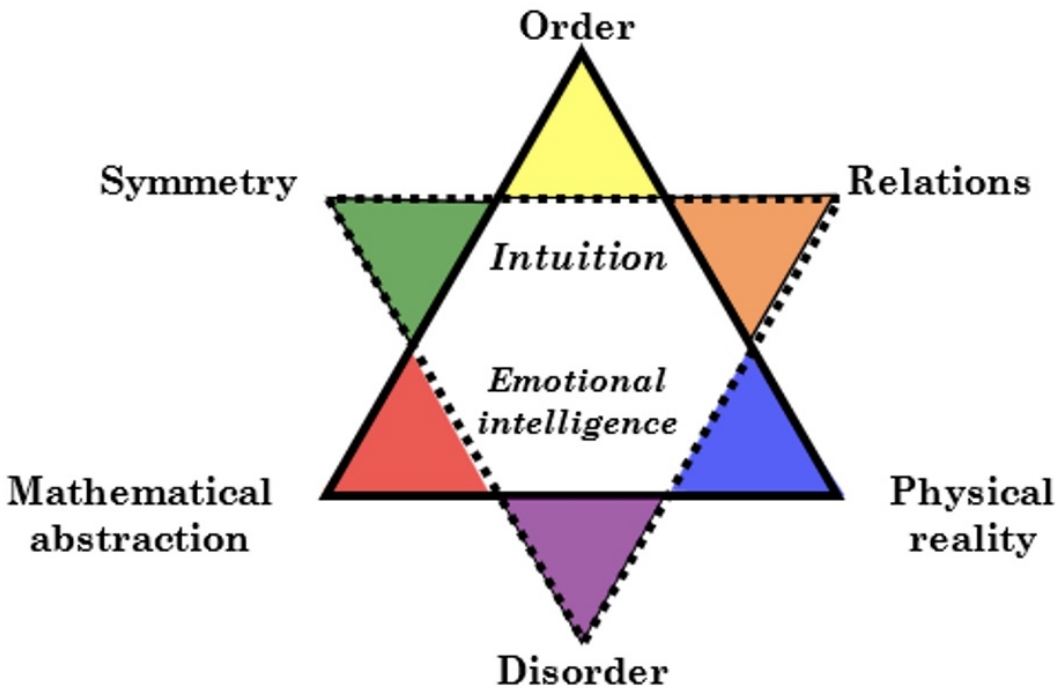

Fig. 1. Cognitive metamodel of the structure of systemic thinking through conjugated triads

In the figure, the combination of harmonious colors located side by side strengthens them, and the combination of less harmonious colors leads to disharmony. Aesthetic perception of natural colors contributes to the development of intuition. Emotional intelligence and intuition are associated with successful experiences in solving real problems.

Evolution of research methods of an ergonomist - an engineering psychologist - an ergonomist of extreme environments. With intense activity, a person loses his mental balance, which he seeks to restore. Therefore, for systems

thinking, the static/dynamic relationship is important. Whereas doubts allow us to assert with certainty, i.e., the ratio of negativism/positivism is important. When generalizing, the evolution/involution relation is important. Their balance is affected by emotional coloring and perceptual time, which does not coincide with natural time and is included in the organization of the human psyche. On this basis, the cognitive metamodel of the structure of systemic thinking is presented in the form of conjugated triads (see Fig. 2). Its synthesis was facilitated by the results of studying the functional states of the operator using:

- new ways of retrieving information (patents);
- transformation of electrophysiological signals into signatures of the cognitive space (Mygal V. P. and Mygal G. V. (c) 2016; Mygal V. P., Mygal G. V. and Balabanova L. M. (g) 2019; Mygal V., Mygal G. (c, e) 2020; Mygal V. and Mygal G. (a, b) 2021);
- methods of differential-integral diagnostics of functional state of humans (Mygal G., Protasenko O. 2020-2023).

By linking the ideas of assessing the transitional states of a person (fatigue, stress, functional breakdowns, etc.) with the theory of viability (Bogdanov 1989), we were able, through the geometrization of ergonomic studies, to use the universal concepts of symmetry and area as the main indicators of balance and harmonies of cognitive graphic images (signatures of the first and second order), which integratively reflect the viability of the system (Mygal V., Mygal G. 2017-2023).

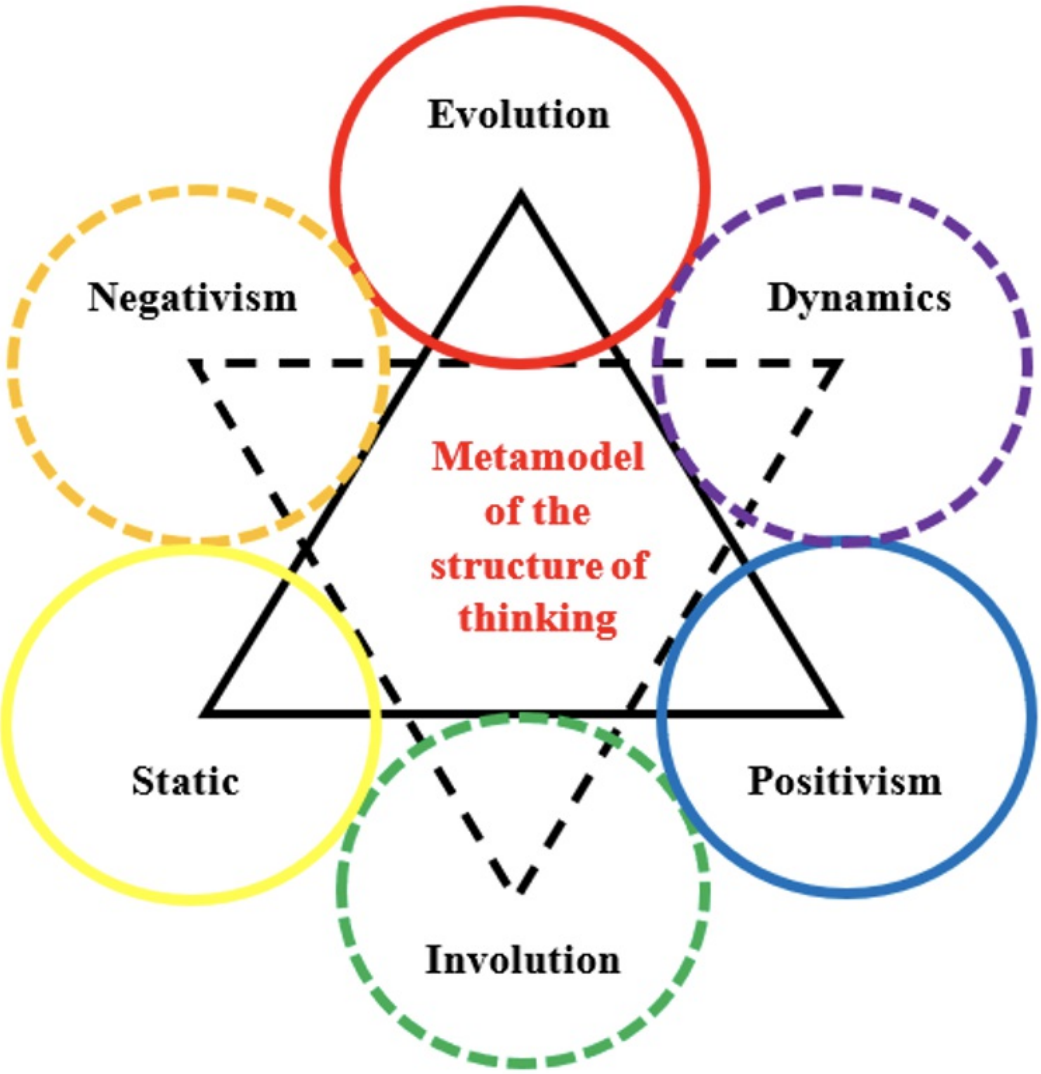

Fig. 2. Cognitive metamodel of the structure of systemic thinking through conjugated triads

In general, the developed approach to revealing the hidden individuality of objects of animate and inanimate nature and universal means of its implementation provide qualitatively new opportunities for diagnosing systems, coordinating human-computer interaction (Mygal G., Protasenko O. 2018 – 2022) and ensuring machine-machine interaction in cyber-physical systems (Mygal V. and Mygal G. 2020, 2021, 2022).

It turned out that digitalization and automation of technologies and CDS in themselves do not guarantee the safety of their operation (Illiashenko O., Mygal V., Mygal G., Protasenko O. 2021). There are features of human cognitive perception of information that determine the effectiveness of human-computer interaction. The intersection of problems is due to the relationship of between the psychological characteristics of a person, his psychophysiological limitations and capabilities, as well as awareness and desire to use their resources and knowledge (Mygal G., Protasenko O. 2020, 2021).

The fruitful activity of the designer, which is based on the principles of design, methods of system analysis, the principles of bionics. Diversity of creative work in the fields of: furniture design (Mygal S. P. 1999, 2017), pharmacy design (Migal' S., Vvedens'kij I. & Vasil'eva V. 1974), environmental design, ethnodesign and biodesign at the dawn of

post-industrial society contributed to the development of systems design and the evolution of a systems approach to design (Mygal S. P. et al. 2012). The socio-cultural design methodology includes artistic, technological and design thinking (Mygal S. P., Dyda I. A., Kazantseva T. S. 2014). This has allowed for a holistic approach to design philosophy that draws on anthropology, ethnography, psychology, and engineering (Myhal S., Kazantseva T. 2014). It is important that design is a holistic system of professional thinking, which is able to generate ideas in the direction of maximum streamlining of human life in accordance with its needs and aesthetic norms of the era. Therefore, the development of design thinking is based on:

- philosophy of innovation focused on human needs and motivation of design as a special design and artistic activity, based on the natural sciences, technical, humanitarian knowledge of the individual;
- principles of human-centered systems design thinking;
- orderliness of the set of structural elements and functional loads of the organized space.

The design thinking cycle involves observing to discover unmet needs within the context and constraints of a given situation, setting scope and scope for innovation, generating ideas, testing, and finalizing solutions.

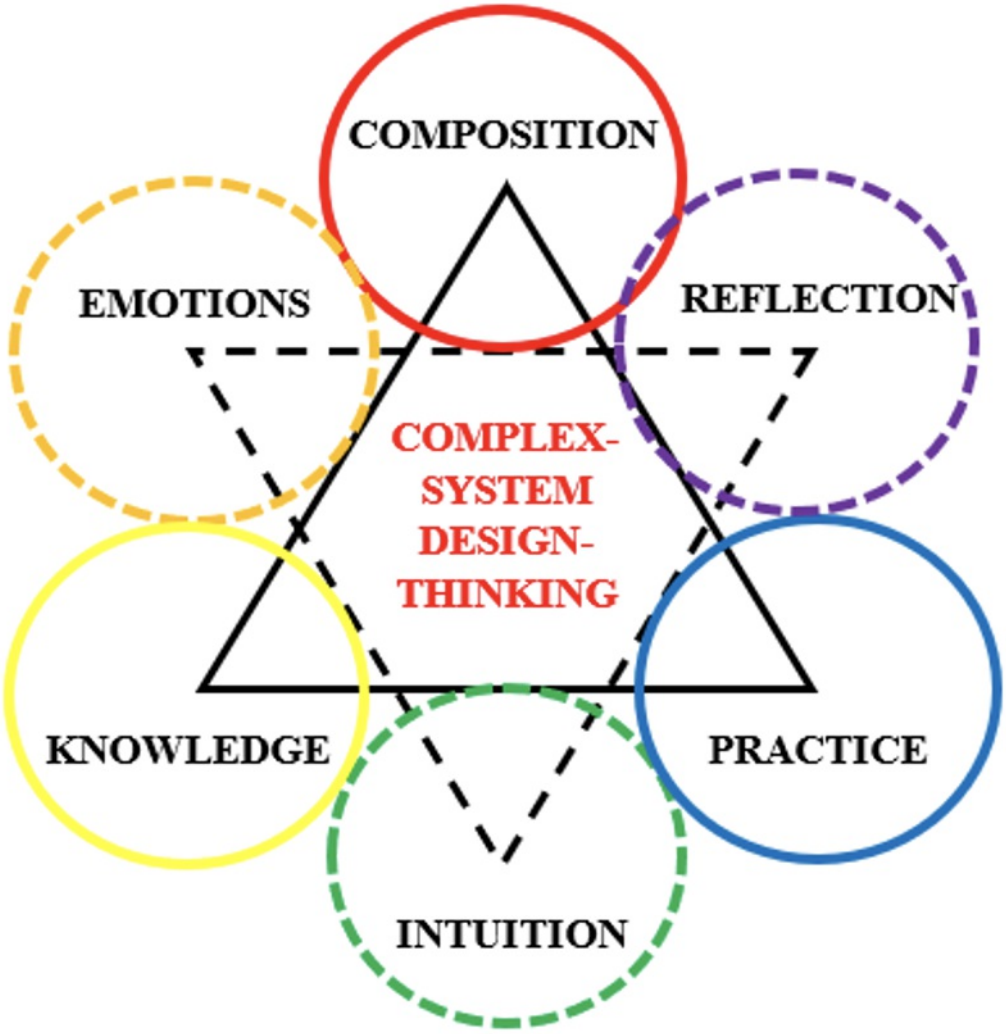

Fig. 3. Cognitive metamodel of the structure of systemic thinking through conjugated triads

The cognitive metamodel of the system thinking structure of an ergodesigner includes two conjugated opposites. On the one hand, there are creative components (knowledge – successful practice – compositional shaping, on the other hand, induced components (intuition – aesthetic reflection – emotions). Therefore, the structure of the cognitive metamodel looks like a Star of David, which allows us to give it a new interpretation as a universal code of a balanced creative-critical thinking.

The versatility of creative tools. It is associated with a triad of features – thinking, worldview and aesthetic perception of nature. The first feature – the use of natural colors according to I. Goethe emphasizes the triad of opposites (contrasts), namely:

- intuition forms a composition (image, work);
- knowledge promotes reflection;
- successful practice develops emotional intelligence.

The second feature is the ordering of the surrounding chaos into harmonious structures, which contributes to the formation of a balance of creative and critical thinking. At the same time, the symmetrical form of cognitive metamodels of the structure of thinking contributes to:

- the transition from the inseparability of knowledge and culture to unifying strategies of creative activity;
- erasing the boundaries between the methodologies of natural and social cognition;
- development of emotional intelligence.

The third feature – the aesthetic perception of the harmony of nature contributes to the development of intuition and critical thinking.

It is the similarity of the forms of cognitive metamodels of the structure of the authors' thinking that made it possible to overcome interdisciplinary barriers and successful creative activity.

4. Universals that expand the possibilities of creative activity

Metastudies. They are better known as metasciences, which use scientific methodology to study the problems of science itself. However, the information about metasciences in the Wikipedias of the USA, Germany and France is different. In our opinion, this is due to the history, culture and environment that form the peculiarities of thinking in a given country. Therefore, to discuss topical problems of science and education, it is necessary to search for new universals. For all types of creative activity, common thought processes are combination and analogization, which allow:

- identify new connections and properties;
- transfer the functions of one object to another;
- obtain new knowledge.

The basis of creative thinking is the synergy of the brain, when it generates new ideas based on the knowledge of

associated uncertainties, analog modeling and extreme principles, as well as the successful experience gained in the process of applying them.

From the complexity of algorithms to the simplicity of metamodels The increasing complexity of interaction in the digital world has led to the development of complex systems thinking (Mainzer 1994). The natural relationship between structure and functionality was considered in (French 2014, Mygal 2016), which opened up new possibilities for the study of NBICT (Roco M. and Bainbridge W. (2020); Mygal V. P. and Mygal G. V. (b) 2022). Informativeness of heuristic models of the structure of interconnections of nano-, bio-, information-, cognitive technologies and components of cyber-physical systems is due to the use of a fractal triangle and fractal logic. In (Mygal V. P., Mygal G. V. and Balabanova L. M. (a) 2019; Mygal V. P., Mygal G. V. (b) 2020), new ideas are being developed, based on:

- inversion of the structure of information sources and the medium of its transmission;
- principle of detailed balance;
- similarity (kinematic, dynamic, geometric, etc.).

Their complementarity made it possible to identify the transition states of CDS elements of different nature.

Ways out of logical impasses. They were found by representatives of the most formal and exact science - mathematics. Thus, B. Russell in his Foundations of Mathematics (1903), showed that a class cannot include itself as an element of a class, and a type cannot be a subtype of itself. Similarly, a set that includes itself as a subset has special properties and cannot be considered in a series of ordinary sets without leading to logical errors of the indicated type. Kurt Gödel dealt with this problem most fully when he published his famous incompleteness theorems in 1931: “Any formal system of axioms contains unresolved assumptions” and “The logical completeness (or incompleteness) of any system of axioms cannot be proved within this system. To prove or disprove it, additional axioms are required (Gedel 1930). They are at the heart of metamathematics. Gödel’s work had a major impact on all exact sciences, not just mathematics. His ideas were continued in physics by Albert Einstein, who argued that “... it is impossible to solve a problem at the same level at which it arose. One must rise above this problem by rising to the next level” (Ainstain 2011). In fact, this is the same incompleteness theorem, expressed in a more abstract form.

Complementarity of heuristic and cognitive metamodels. In them, the structure of relationships is transformed into conjugated triads, the perception of harmony of which simplifies their system analysis through:

- establishing a balance of conjugated triads, the coloring of which with natural colors simplifies cognitive perception;
- inversion of conjugate triads, the effectiveness of which was manifested in physics, mathematics, software algorithms, etc.;
- synthesis of complementary dynamic, static and statistical metamodels.

Their spatial and temporal configurations showed that the perception of harmony depends on psychophysiological factors (fatigue, stress, etc.). The important role of external and internal factors is due to the manifestation of the Le Chatelier principle (Passino, 2005).

Determining the causes of key problems in the functioning of objects of various nature in extreme conditions makes it possible to predict the consequences of problems and find possible ways to solve them. Thus, the heuristic model of the cyber-physical system showed the importance of the NOT triad (non-linearity, uncertainty and instability) (Mygal V. P., Mygal G. V. and Mygal S. P. (c) 2021).

The secure functioning of cyber-sociotechnical systems (CSTS) requires specific integration with human and social factors (Patriarca R. et al. 2021). Technological progress requires the expansion of human capabilities (functional, physical and cognitive), and heuristic metamodeling is an effective method for solving new problems (Mygal, V. P., Mygal G. V. and Mygal S. P. (a) 2022).

Complementarity of principles as a universal. For modern metaphysics, the statistical diversity of natural fractals and multifractals, as well as structure-forming principles, are important:

- principles of duality and trinity, the hierarchy of which turns metaphysics into a single system of paradigms;
- the principle of fractality (self-similarity), reflecting the unity of the whole and the particular;
- the principle of double cyclicity, which manifests itself in the orderliness of the spatio-temporal structure of information flows of various nature.

The complementarity of these principles is manifested in natural dynamic fractals and multifractals (Mandelbrot 1988), as well as in structural functionalism (experimental psychology). Therefore, it is necessary to expand the worldview of the researcher on the basis of modern metaphysics, which is associated with metaphilosophy and metamathematics. To unlock the creative potential of an individual, a triad of principles is important, namely:

- the principle of personal vision of the ultimate goal;
- the principle of self-government based on empathic communication;
- the principle of creative cooperation and synergy.

The complementarity of these principles is universal and allows for a balanced self-renewal of various types of creative activity.

Complementary outlook and perception of the harmony of nature.Their connection unites science, art and ethical attitudes. Many natural connections are considered by modern metaphysics when studying the functioning of self-organizing objects. Metaphysicians creatively activate the statistical diversity of natural fractals and multifractals (Bird Alexander, Nature’s Metaphysics, 2007). For their worldview and perception of the harmony of nature, three key principles are important, namely:

- principles of duality and trinity, the hierarchy of which turns metaphysics into a single system of paradigms;
- the principle of fractality (self-similarity), reflecting the unity of the whole and the particular;
- the principle of double cyclicity, which manifests itself in the orderliness of the spatio-temporal structure of information flows of different nature.

The complementarity of these principles is better seen in natural dynamic fractals and multifractals (Mandelbrot, 1988). Therefore, it is necessary to expand the worldview of the researcher on the basis of modern metaphysics, closely related to metaphilosophy and metamathematics.

Cognitive value of interconnections between sciences and their metasciences. Coloring the interrelationship structure of the triad of key sciences in the form of the Star of David with natural colors according to I. Goethe made it possible to identify six conjugated triangles and six induced states that display the triangles highlighted by the dotted line (See Fig. 4).

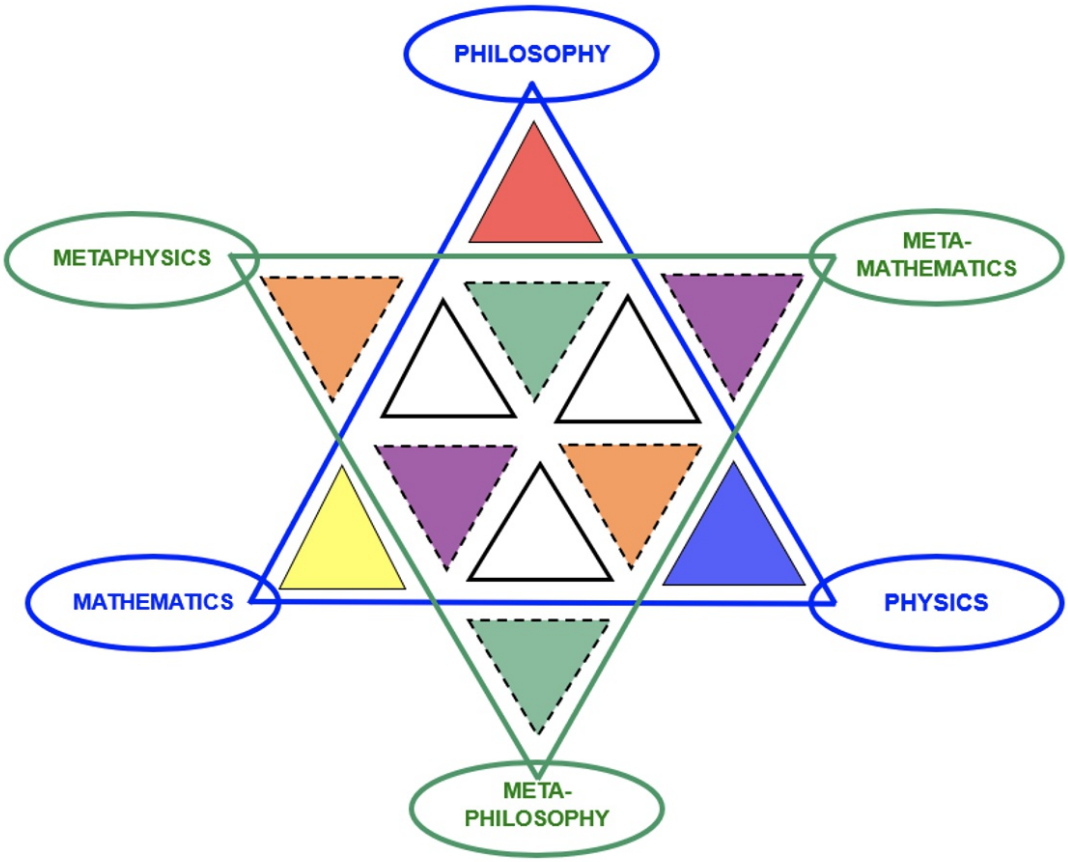

Fig. 4. Cognitive metamodel of the structure of interrelations of physics, mathematics and philosophy and their metasciences

From a systematic analysis of the relationships between key sciences (physics, mathematics and philosophy) and their metasciences, it follows this is choice of 6 natural colors in Fig. 4 is the only possible one. It is important to emphasize that:

- the triangle of key sciences has a triad of conjugated metasciences;
- the triangle of metasciences (metaphysics, metamathematics and metaphilosophy) has one state, the uncertainty of which is manifested in the balance of gray, not white;
- the choice of conjugate triangles (triads of colors) is individual and depends on heredity, education and successful

experience, as well as on psychophysiological factors (fatigue, stress, the influence of external natural factors).

Visualization of the structure of relationships between key sciences and their metasciences in the form of a Star of David allowed:

- establish the complementarity of the metasciences,
- expand the number of interpretations of the Star of David,
- transform the complementarity of interpretations into cognitive value (Mygal V. P., Mygal G. V. and Mygal S. P. (a) 2022; Mygal V. P., Mygal G. V. (b) 2022).

In the Eastern and Western perceptions of nature, the aspiration and need for harmony has been and is a global vital landmark. Obviously, therefore, the complementarity of the authors' worldview with the harmony of their worldview made it possible to overcome interdisciplinary barriers and synthesize heuristic metamodels of complex dynamic systems of various nature, which look like the Star of David (Mygal V. P., Mygal G. V., Mygal S. P. (a) 2022, Mygal V. P., Mygal G. V. and Mygal S. P. (c) 2021, (b) 2022).

5. Cybernetics of the second order - a transdisciplinary approach

Neurophysiological foundations of second-order cybernetics. The main ideas of second-order cybernetics are developed in the works (Foerster 1974; Glasersfeld 1987). Neurophysiological experiments have shown that:

- knowledge is a biological phenomenon;
- each individual constructs his own "reality";
- knowledge is "consistent" with the world of sensory experience, but not "identical" to it.

Therefore, second-order cybernetics is useful for studying social, biological systems, both autonomous and closed. It is based on the identification of cycles in a complex system consisting of interacting elements, as well as the evaluation of the quantitative characteristics of these interactions. This approach opens up prospects for modeling the dynamics and analyzing the viability of the system.

Therefore, Darwin's triad (variability, heredity, selection) can be used to analyze synergetic systems of any nature and evolution algorithms, including in the educational process. In particular, (Sviting 2016) considers design research as a kind of second-order cybernetic practice.

A bridge between natural science and humanitarian cultures. The introduction of the concept of complex systems thinking (Mainzer 1994) made it possible to build a bridge between cultures. At the heart of modern research – nanotechnology, chaos, artificial intelligence, neurosciences, humanitarian technologies – is internal unity, which is associated with the use of the theory of self-organization and synergetics (Haken 2003). This allows you to cover deep and important scientific ideas, including artificial life, cellular neural networks.

The cognitive space of dynamic events makes it possible to apply new ideas and technologies to analyze the statics and

dynamics of fractal information flows of any nature (Mygal V. P., Mygal G. V. and Mygal S. P. (c) 2021; (a, b) 2022; 2023). This confirms the modeling of the evolution of solar activity in the cognitive space of dynamic events, which made it possible to establish that this structure is multifractal (Mygal V. P., Klymenko I. A. and Mygal G. V. (d, e) 2020). A graphical representation of the structure of technological processes over time, as well as information and energy flows in a unified cognitive space opens up new avenues for creative activity in the digital world.

Individuality of signatures of the second order. A self-organized quasi-cyclic process of any nature in the space of dynamic events (state – speed – acceleration) is displayed by cognitive graphic images – signatures of the first and second orders (Mygal V. P., But A. V., Mygal G. V. and Klimenko I. A. (a) 2016). The phase portrait as a sequence of dynamic states is a simplified model of the first-order signature. The most important information is contained in the space-time signatures of the second order, the configurations of which reflect the space-time relationships of the energy and information (structural) components of the CDS functioning cycle. Cognitive visualization of the dynamics of signals of different nature and scale in one space gives the perception of dynamic complexity in its versatility, and the informativeness of the simultaneous perception of the whole and the particular (the area, as the power of a set of microstates) and the number of components of the natural decomposition is due to the fact that:

- morphologically different dynamic systems are functionally subject to the same principles of physics and biomimicry;
- different dynamic systems operate according to the same principles (laws);
- dynamic processes of different nature obey the principle of detailed balance.

It is important to emphasize that the indicators of dynamic and statistical complexity of second-order signatures are interrelated and provide complementary information online.

Thinking about your thinking – new possibilities. The increasing complexity of technology and the digital world creates new problems in the formation of a worldview in the learning process. This hinders overcoming interdisciplinary barriers in the digitized world and adaptation to extreme environmental conditions (pandemic, war, environmental and man-made disasters). Therefore, for philosophical reflection, it is necessary:

- humanization of technologies and scientific and technical development;
- understanding of actions, cycles and phenomena of reality;
- knowledge of extreme principles of natural science and their methodological significance.

Bacon believed that “the sciences that study thinking are certainly the key to all others. And just as the hand is the instrument of instruments, and the soul is the form of forms.” V. Vernadsky considered art to be another way through which it is possible to get to know nature, man and the cosmos more deeply. He is the creator of the theory of the birth and evolution of the Universe based on the biosphere and noosphere.

We presented the structure of links between physics and neurophysics, ergonomics and neuroergonomics, design and neurodesign in the form of the Star of David. This made it possible to use the natural circle of colors of I. Goethe and highlight:

- natural colors triad of links between physics, ergonomics and design;
- colors of the first order of the triad of connections between neurophysics, neuroergonomics and neurodesign;
- contrasting colors of opposites of conjugate triads.

As a result, a cognitive metamodel of the structure of conjugated triads was synthesized, the system analysis of which contributes to the formation of metathinking. It is based on the ability of a person to learn, analyze and change his own way of thinking, which opens up new opportunities for fruitful activity.

Metathinking and the structure of hidden connections. In The Hidden Connections, the author seeks to extend system dynamics and complexity theory to the social realm and provides a "conceptual framework that integrates the biological, psychological and social aspects of life (Frittjof Kapry 2002). Therefore, thinking about one's thinking (metathinking) opens up new opportunities for creative activity, the universal tools of which are recursion, balance and inversion (see Fig. 5).

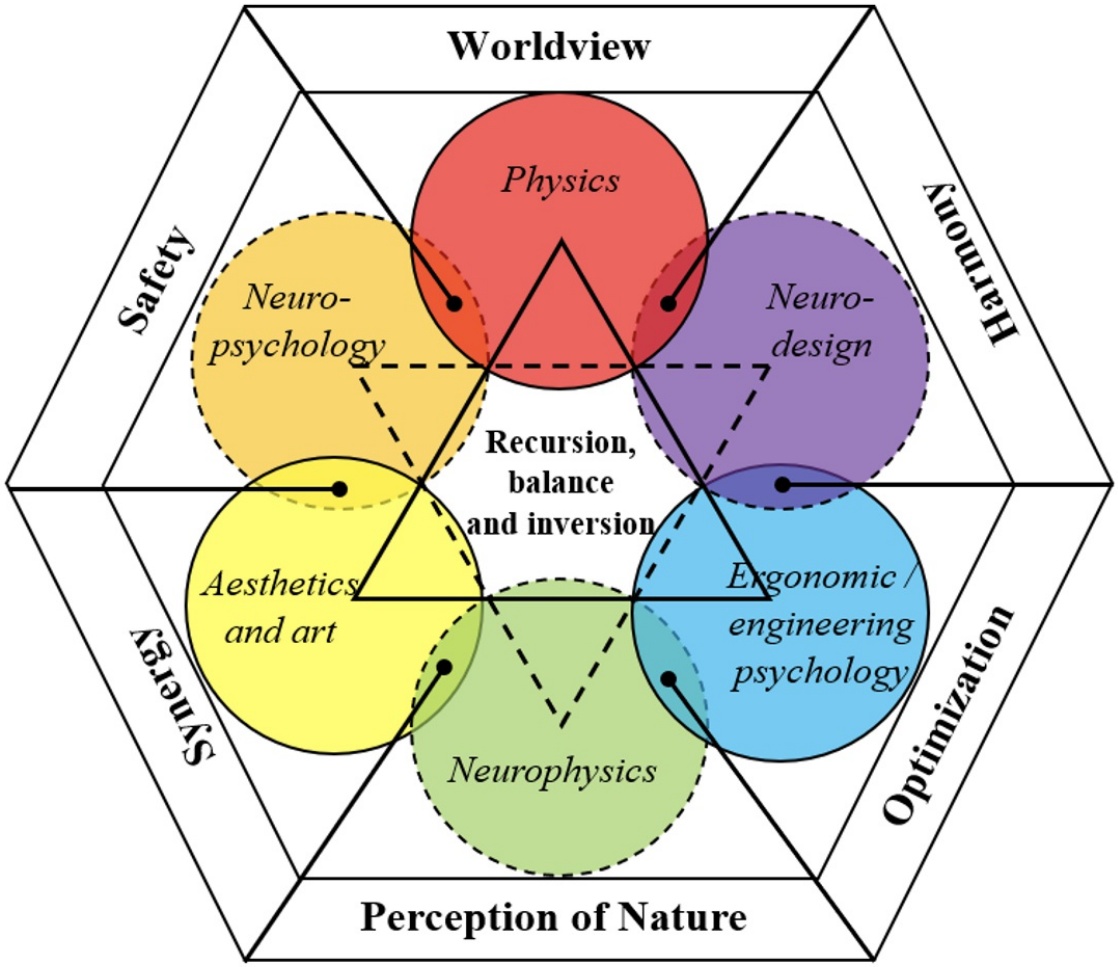

Fig. 5. The author's cognitive metamodel of the structure of conjugated triads of relationships that form the cycles of hybrid thinking

The coloring of the metamodel made it possible to systematically analyze the transition from dualism to triads, the

analysis of conjugation of which contributes to the development of cognitive thinking. The figure also shows that the harmonization of relationships and the inversion of opposites made it possible to establish that the triad of disciplines (physics, ergonomics and design) is associated with the triad of their neurosciences (neurophysics, neuroergonomics and neurodesign). The goals of these sciences are worldview, perception of nature, optimization, harmonization, synergy and security. Visualization of explicit connections allows you to identify hidden functional relationships of the second order, namely:

- physics forms the worldview, and neurophysics studies the perception of nature, which is based on the connection between neurophysics and neurophysiology;
- ergonomics optimizes activity, and neuroergonomics studies the human factor, which is based on neurophysical and neurobiological research methods;
- aesthetics and culture contribute to harmony, and neurodesign studies it and is the key to the consumer.

Triads of hidden connections. At the heart of consciousness and harmonic activity are recursion, balance and inversion, which are due to the duality of the hidden second-order relationships between the triad of disciplines (physics, ergonomics and design) and their neurosciences associated with the triad (neurophysics, neuroergonomics and neurodesign). The cognitive metamodel contains hidden triads that reflect the internal unity of opposites. This also confirms the cognitive value of the relationship between key sciences and metasciences (see Fig. 4).

From the system analysis of intersections depicted in Fig. 5 a triad of hidden connections can be deduced as follows:

- worldview promotes optimization and synergy;
- synergy promotes worldview and security;
- optimization contributes to the perception of nature and harmony.

A triad of induced connections also follows from the system analysis of intersections, namely:

- harmony promotes outlook and optimization;
- perception of nature promotes synergy and optimization;
- security promotes mindset and synergy.

All intersections are highlighted in non-natural colors and display hidden relationships that form forward and reverse cycles. Their asymmetry can reveal the individual's hybrid thinking, which is based on the recursion of thinking, the search for a balance of opposites and the inversion of patterns. Therefore, the universal tools of creative activity are – recursion, balance and inversion.

Hybrid processing of time series (signals). Features of hybrid processing of fractal signals of various nature are considered in the article (Illiashenko O., Mygal V., Mygal G., Protasenko O. 2021). The work (Mygal V. P., Mygal G. V. and Mygal S. P. (a) 2022) shows that the hybrid processing of information flows of various nature in a single cognitive space of dynamic events allows not only to "restore" information lost during digitization, but also to use fluctuations and heterogeneity of temporal series (signals) as universal sources of information. Uncertainties, instabilities and nonlinearities

affect interdisciplinary exchange, and taking them into account allowed the authors to generate “fresh” ideas. They contributed to the synthesis of heuristic metamodels in the form of the Star of David, which are of interest for cyber-physical systems, cognitive computing and artificial intelligence (Mygal V. P., Mygal G. V., Mygal S. P., (a) 2022; Mygal V. P., Mygal G. V. (b) 2022).

An analysis of the successful activities of the authors showed that the development of ideas occurs in a spiral and indicates the importance of the evolution of thinking. The individuality of functioning is most manifested in the cognitive space of dynamic events (Mygal V. P., But A. V., Mygal G. V. and Klimenko I. A. (a) 2016), which contributed to the further fruitful activity of each of us.

The role of extreme principles and paradoxes of technology.The unique heuristic role of the principle of least action in describing the behavior of physical systems was noted by M. Planck, L. De Broglie, E. Schrödinger, D. Bohm, M. Born. A number of philosophical generalizations related to this principle were made by R. Feynman.

There is a set of particular forms of extreme principles of motion of systems studied in specific areas of natural science, which are directly or indirectly related to the principle of least action. This connection is founded on the mutual derivability of equations, as well as on several analogies (geometric, mathematical, optical-mechanical, etc.). The overall dimension of these functionals corresponds to the concept of “action” (time x energy).

Other extremal principles, close in form to the principle of least action, play an important role in biology, in information theory, in optimal control problems that are not related to mechanical motion, geometry, or the concept of “action”.

All rational activity takes place in the world that is created by this activity. Therefore, in heuristic modeling, it is necessary to proceed from the reality of the technological world. Most of the new ideas about technology, based on common sense, turned out to be paradoxical. Among the ten paradoxes of technology highlighted, which are given in the work (Feenberg 2010), we have identified three key ones:

- the paradox of the obvious – the most obvious is the most hidden,
- paradox of action – by acting, we become the object of action.
- paradox of complexity – simplification complicates, i.e., simplicity of complexity and complexity of simplicity,

Behind everything rational is a forgotten history of the development of an idea (method, technology, etc.), the creative development of which requires the search for fresh ideas and universal tools.

6. Heuristic thinking in science, technology and art

Worldview, metathinking and semiotics.The worldview as a system of principles, values and ideals has a complex structure and includes a contradictory unity of knowledge and values, intellectual and emotional, beliefs and doubts. Metathinking as thinking about one’s own thinking is essential for fruitful creative activity. Semiotics uses signs to store and transmit information. However, in the process of digitalization of science and education, the logical basis for the

extraction of knowledge is increasingly moving away from reality. Researchers see many events that are not measured or modelled. Therefore, such events are expressed by signs, the ratios of which form something immeasurable and unimaginable.

The process of thinking is a process of pattern recognition (Haken 1995). The digitalization of science has increased the complexity of the tasks being solved, the increase of which limits the unique possibilities of digital modeling. Today, cognitive perception means organizing images (impressions) in such a way that common ideas gain new knowledge. The pragmatic understanding of information, communication and language is associated with second-order cybernetics, the essence of which is that information is a difference that creates a difference.

Section 5 synthesizes a cognitive metamodel of the structure and interrelations of conjugated triads that form metathinking, which is based on the ability of a person to cognize, analyze and change his own way of thinking. The universal tools of metathinking are recursion, balance and inversion. In our opinion, semiotics also unites sciences, technologies and art. In particular, the Star of David as a universal sign-symbol, many interpretations of which and their complementarity have heuristic value and innovative potential.

Complementarity of heuristic metamodels. The space-time structure of conjugate cyclic processes is considered in (Mygal V., Mygal G., Mygal S. (b) 2021; Mygal V., Mygal G. (b) 2022). It shows that the local dynamic equilibrium model can be synthesized by different methods. In particular, through the superposition of two Sierpinski fractals, the Koch Snowflake fractal and the antifractal, as well as conjugated fractal triangles (Mandelbrot 1988). It is important that it has the appearance of the Star of David, various interpretations, both traditional and those proposed in the late 20th and early 21st centuries. These are: a) fully connected graph, b) Goethe color circle, c) magic numbers, d) mathematical theorem, e) magic knots, f) da Vinci code, etc. Therefore, every nation, surviving in an environment with certain energy and information resources, interprets the Star of David in its own way. It can be assumed that the Star of David is a unique genetic algorithm for studying the processes of generation (self-organization) of a new phase (structure), its survival (stability) and development (adaptation) with certain energy and information resources. The application of such an algorithm turns the complementarity of heuristic metamodels in the form of hexagrams into a cognitive value that promotes creative activity. Thus, the use of natural colors, reduction and inversion in eristic meta-models in the form of the Star of David, increased their cognitive value. This made it possible to offer another interpretation of it – a person learns the dualism of nature and adapts to the environment through the dualism of thinking and mentality.

Semiotics and cognitive distortions. The composition of signs or symbols is a universal means of transmitting information in:

- physics (symbolic dynamics, spiral dynamics);
- ergonomics and engineering psychology;
- different types of design (ethnodesign, biodesign, object environment design).

This approach simplifies interdisciplinary interaction in the digital world. In fact, semiotics is associated with a wide range of scientific research from the humanities and natural sciences. As a research methodology, semiotics allows you to

analyze the main types of cognitive activity (ordinary, scientific, philosophical), stimulating the unification of the humanities and natural sciences.

To solve the actual problems of science, education and mental health, it is important to take into account the variety of systematic errors that are common to everyone. The most significant of them are due to:

- complexity of understanding;
- the need for rapid response;
- excess or lack of information.

The dependence of activity errors on the functional state (stress, fatigue, etc.) of a person is considered in the works (Mygal V. P. and Mygal G. V. (b) 2018; (a) 2021; Mygal V. P., Mygal G. V. and Mygal S. P. (c) 2021). These papers draw attention to genetically inherited cognitive distortions, the individuality of which is actively studied by neurosciences and cognitive sciences (Lee J. D., Wickens C. D., Liu Y., Boyle L. N. 2017; Parasuraman R., Mehta R. 2013). Genetically inherited cognitive distortions are the main cause of the manifestation of the human factor phenomenon in science, education and technology. It is necessary to search for new ideas to solve urgent problems:

- security (physical, functional and informational);
- stimulation of creative activity;
- mental health.

Therefore, the Star of David as a sign-symbol has a cognitive value for fruitful, creative and innovative activity.

The key problems are an objective assessment of ideas, methods and technologies.The criteria for the quality of scientific research developed on the basis of a metascientific approach are not objective enough. Science can benefit if “intellectual exchange, especially with regard to the social implications and applications of science and technology, is better valued and encouraged (Fortunato 2018). The development of science education, for example, teaching selected scientific disputes (Dunlop, Veneu 2019) and the historical process of discovering main scientific findings (Norsen 2016) and analyzing scientific fallacies improves the quality of scientific research, but does not solve key problems of creativity. Activities:

- objective evaluation criteria;
- the impact of cognitive distortions (editors, reviewers, etc.);
- worthy remuneration for new ideas (technologies).

In our opinion, the key to the integration of interdisciplinary research are the criteria for evaluation and remuneration, which are in the area of interest of the metasciences (Ioannidis, John P. A. 2019). On their basis, they began to structure the system of incentives through:

- descriptive peer reviews (“rather than [only or mostly] indexes”);
- institutional evaluation criteria;
- guarantees of transparency and professional standards (Chapman 2019).

However, this incentive system is almost entirely focused on publishing research rather than doing it right (Brookshire 2016). As a consequence, “the number of publications has ceased to be a good indicator as a result of:

- long lists of authors;
- short articles;
- systematic errors in measurements.

As a result, the number of publications is growing (Fire, Guestrin 2019).

On the one hand, digitalization allows you to create amazing (startups, patterns, etc.), which contributes to the development of creative thinking. On the other hand, the increasing complexity of algorithms creates new risks (health of a new generation, transport security, falsification, etc.).

Universal criteria and integrative indicators of creative activity.Business actively uses IT to create and promote in the market. Some magazines also use view and download statistics to solve their problems. In our opinion, the results of statistical processing are important not only for the researcher, but also for state institutions for:

- planning and financing of science and education;
- stimulation of innovative activity;
- encouragement of scientific activity.

In particular, the criteria for the significance of intellectual activity (idea, technology, program, model, article, etc.) are:

- number of views and downloads and their dynamics;
- the ratio of the number of views to the number of downloads and its dynamics;
- connection between dynamics and statistics.

The presentation of this data in the cognitive space of probable events in real time provides new opportunities for search (forecasting) and is an objective “compass” for creativity. In particular, the qualitative impact of the unique capabilities of AI requires the formation of hybrid thinking. To do this, it is necessary to discuss “fresh” ideas on a transdisciplinary basis and legally stimulate creative activity, because its results are the intellectual component of the state budget.

The war and the pandemic have sharpened our perception of reality, which allowed each author to overcome interdisciplinary barriers and create:

- cognitive space of dynamic events on a transdisciplinary basis;
- integrative means of predicting the viability of the CDS;
- systems design based on the development of design thinking and the evolution of a systems approach to design.

The need for market relations in science, art and design In musical culture and art, the problem of remuneration for intellectual activity is legally resolved through royalties. In the scientific environment, the results of intellectual activity (articles, patents and models) are promoted by the researcher himself, paying for numerous services (translation, editing,

presentations, etc.). Their consequence was crises in the sciences (metasciences are not a panacea), medical diagnostics, online learning, business (finance, etc.), ecology, etc. Before it is too late, it is necessary to stimulate innovation at the state level. We offer copyrights for published ideas, cognitive fractal graphics, spatio-temporal structures (patterns) to be guaranteed by law and create a kind of “market” of ideas (innovations). This is a kind of analogue of American venture capital companies.

We have proposed new universals, the complementarity of which opens up qualitatively new opportunities for:

- formation of balanced creative-critical thinking in the process of intellectual activity;
- revealing the peculiarities of an individual’s thinking and constructing his learning path;
- forecasting the risk of catastrophes.

7. Conclusions – suggestions

To survive in extreme conditions, a person learns the environment and survives in it through mutual adaptation and transformation. New problems that are generated by digitalization contribute to:

- development of predominantly abstract thinking;
- formation of fragmented knowledge;
- global challenges of the 21st century (epidemics, man-made and environmental disasters).

Their consequence is the manifestation of the phenomenon of the human factor in education, science and technology, which are caused by systematic errors and hidden cognitive distortions. It is shown that they depend on the functional state of a person (fatigue, stress and breakdown). The consequence of the conflicting nature of the educational environment is the deterioration of the mental health of the new generation (loss of empathy, psychosis, etc.).

For the development of a balanced creative-critical thinking of an individual, means are offered based on:

- identifying the characteristics of an individual’s thinking and using them to unlock creative potential;
- hybrid learning, when offline complements the intellectual dialogue with artificial intelligence online;
- deep interaction in the digital world through metaheuristic modeling.

The use of recursion, the search for a balance of opposites and the analysis of the results of inversion make metaheuristic models in the form of the Star of David complementary.

The development of interrelated natural sciences and the humanities makes it possible to reduce the risks associated with the increasing complexity of information (statistical, dynamic and structural), the excess or lack of which affects the safety and / or viability of a person (STS, university and state). The universality of semiotics makes it possible to take into account the influence of systematic errors (cognitive distortions) in solving key problems of creative activity and to propose:

- new universals that stimulate creativity;
- universal integrative indicators for various types of activities;
- objective criteria for evaluating ideas, methods and technologies,

Their complementarity opens up qualitatively new opportunities for the formation of balanced creative-critical thinking in the process of creative activity. On this basis, it is possible to create a kind of “market” of ideas, technologies and innovations, the self-regulation of which will contribute to a worthy reward.

References

- Ashby, W. (1947). Principles of the Self-Organizing Dynamic System. Journal of General Psychology, 37.
- Bird, A. (2007). Nature’s Metaphysics: Laws and Properties. Oxford University Press, New York: https://doi.org/10.1093/acprof:oso/9780199227013.001.0001
- Bogdanov, A. A. (1989). Tectology: a general organizational science. Book 1. M: Economics, 213-215.
- Cross, N. (2006). Designerly Ways of Knowing. ISBN: 978-1-84628-300-0.
- Einstein, A. (1916). The Foundation of the General Theory of Relativity. Annalen der Physik, 49, 769-822.
- Einstein, A. (2011). The Ultimate Quotable Einstein. In A. Calaprice (Ed.).
- Fedota, J., & Parasuraman, R. (2010). Neuroergonomics and human error. Theoretical Issues in Ergonomics Science, 11(5), 402-421. https://doi.org/10.1080/14639220902853104
- Feenberg, A. (2010). Ten Paradoxes of Technology. Research in Philosophy and Technology Special Anniversary Issue, 14(1), 3-15.
- Foerster, H. (1974). Cybernetics of Cybernetics. Future Systems, Minneapolis, MN.
- French, S. (2014). The Structure of the World: Metaphysics and Representation. Oxford University Press.
- Kapryi, F. (2004). Skryityie svyazi [Hidden connections]. Moscow: OOO Izdatelskiy dom «Sofiya» [LLC Publishing House “Sofia”]. ISBN 5-9550-0484-X.
- Gavrikova, I. G., Migal, V. P., & Rvachev, A. L. (1975). Photocarrier Sing Inversion under the Influence of Thermal Treatment. Physica Status Solidi (a), 30, K95-K99.
- Gavrikova, I. G., Migal, V. P., & Rvachev, A. L. (1976). Optical Sensitization of the Photoconductivity Bands. Physica Status Solidi (a), 37, K21-K24.
- Gedel, K. (1930). Die Vollständigkeit der Axiome des logischen Funktionenkalküls. Monatshefte für Mathematik und Physik, 37, part 2.
- Glasersfeld, E. v. (1987). The Construction of Knowledge. Intersystems, Salinas, CA.
- Haken, G. (2003). Secrets of nature. Synergetics: the doctrine of interaction. Izhevsk: IKI.
- Haken, H. (1995). Principles of Brain Functioning:A Synergetic Approach to Brain Activity, Behavior and Cognition. Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-79570-1.
- Haken, H. & Portugal, J. (2016). Information and self-organization: a unifying approach and applications. Entropy, 18(6), 197. https://doi.org/10.3390/e18060197.

- Illiashenko, O., Mygal, V., Mygal, G., & Protasenko, O. (2021). A convergent approach to the viability of the dynamical systems: The cognitive value of complexity. International Journal of Safety and Security Engineering, 11(6), 713-719. https://doi.org/10.18280/ijsse.110612.
- Goethe, J. W. v., & Eastlake, D. (1840). Theory of Colours.
- Komar, V.K., Migal V.P., & Chugay O.N. (1993). Anomalii teploprovodnosti kristallov selenida tsinka, soderzhaschih dvumernyie defektyi strukturyi, [Thermal conductivity anomalies of zinc selenide crystals containing two-dimensional structural defects. Letters to JTF]. Pisma v ZhTF, 19(1), 47-51.
- Lee, J. D., Wickens, C. D., Liu, Y., & Boyle, L. N. (2017). Designing for People: An introduction to human factors engineering. CreateSpace.
- Loshak, Zh. (2005). Geometrization of physics. M.-Izhevsk: SIC. Regular and chaotic dynamics [In Russian].
- Mainzer, K. (1994). Thinking in Complexity: The Complex Dynamics of Matter, Mind, and Mankind. Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-662-03014-1.
- Mandelbrot, B. B. (1988). Self-affine fractal sets. Fractals in physics. M, Mir.
- Migal', S. & Vvedenskij, I. (1974). [On the issue of a systematic approach to furniture design. Forestry, paper and wood processing industry], 4, 37–39.
- Migal', S., Vvedenskij, I. & Vasil'eva, V. (1974). Sistemnyj podhod k proektirovaniju i organizacii sovremennoj aptechnoj sredi, [A systematic approach to the design and organization of a modern pharmacy environment]. Farmacija, 6, 3–7.
- Migal, S.P. (1989). Osnovyi proektirovaniya mebeli [Basics of turniture design]: ucheb. posobie. Lvov.
- Migal, V.P. (2002). Technologically inherited states of AIIBVI crystals. Manuscript. Doctoral degree dissertation in applied material science. «Institute for Single Crystals of STC «Institute for Single Crystals» National Academy of Sciences of Ukraine, Kharkiv.
- Migal, V.P. (1998). Study of macroscopic ordering of polycrystalline ZnSe by natural elastic vibrations method. Functional Materials, 5(2), 188 – 190.
- Mygal, G. & Protasenko, O. (2020). Human resources are a factor in applying of man-machine systems safety. Municipal Economy of Cities, 6(159), 139-146. https://doi.org/10.33042/2522-1809-2020-6-159-139-146.
- Mygal, G., & Protasenko, O. (2021a). Human Factors: The Problem of Man-machine Interaction in the Digitalization Conditions. Periodyk naukowy akademii polonijnej (PNAP), 48 (5), 198- 210. https://doi.org/10.23856/4825.
- Mygal, G., & Protasenko, O. (2021b). The viability as an emergent property of self-organizing systems. Municipal economy of cities, 1(161), 307-314. https://doi.org/10.33042/2522-1809-2021-1-161-307-314.
- Mygal, G., & Protasenko, O. (2022). The human factor issues in biomedical systems. Scientific Journal of Polonia University, 54(5), 150-158. https://doi.org/10.23856/5420
- Mygal, G., & Protasenko, O. (2023). Ergonomics 4.0: digitalization problems and overcoming them. Municipal economy of cities. Kharkiv: XNUMX named after Beketova, 3, Issue 177, 182-188. http://repository.hneu.edu.ua/handle/123456789/29551.
- Mygal, S. P. (1999). Furniture design. Lviv, Svyt. [In Ukrainian].
- Mygal, S. P. (2017). Environment design. Lviv, Prostyr-M. [In Ukrainian].
- Mygal, S. P., Dyda, I. A., & Kazantseva, T. S. (2014). Bionics in the design of spatial-subject environment. Lviv, Lviv.

Polytechnic. [In Ukrainian].

- Mygal, S. P., et al. (2012). Design and engineering. [In Ukrainian].
- Mygal, V. P., But, A. V., Mygal, G. V., & Klimenko, I. A. (2016a). An interdisciplinary approach to study individuality in biological and physical systems functioning. Nature, Scientific Reports, 6, 387-391. DOI: 10.1038/srep29512.
- Mygal, V. P., & Mygal, G. V. (2016b). Cyber physical approach to study the functioning of dynamic systems. Electrical and computer systems, 22(98), 354-358. http://dx.doi.org/10.15276/eltecs.22.98.2016.65.
- Mygal, V. P., Klymenko, I. A., & Mygal, G. V. (2017). Individuality of photoresponse dynamics of semiconductor sensors. Functional Materials, 24(2), 212-218. DOI: https://doi.org/10.15407/fm24.02.212.
- Mygal, V., & Mygal, G. (2018a). Interdisciplinary approach to informational teaching environment formation. Proceedings of Odessa Polytechnic University, Issue 1(54), 92-98. DOI: 10.15276/opu.1.54.2018.13.
- Mygal, V. P., Klymenko, I. A., & Mygal, G. V. (2018b). Influence of radiation heat transfer dynamics on crystal growth. Functional Materials, 25 (3), 574-580. DOI: 10.15407/fm25.03.574.
- Mygal, V. P., & Mygal, G. V. (2018c). Analysis of the university's viability as a complex dynamic system. Electrotechnic and computer systems, 27(103).
- Mygal, V. P., Mygal, G. V., & Balabanova, L. M. (2019a). Visualization of Signal Structure Showing Element Functioning in Complex Dynamic Systems – Cognitive Aspects. Journal of Nano- and Electronic Physics, 11, (2), article number: 02013. DOI: 10.21272/jnep.11(2).02013.
- Mygal, V., & Mygal, G. (2019b). Problems of Digitized Information Flow Analysis: Cognitive Aspects. Information & Security: An International Journal, 43(2), 134-144. DOI: 10.11610/isij.4312.
- Mygal, V., & Mygal, G. (2020a). Interdisciplinary approach to the human factor problem. Municipal Economy of Cities, 3(156), 149-157. Retrieved from https://khg.kname.edu.ua/index.php/khg/article/view/5613. DOI: 10.33042/2522-1809-2020-3-156-149-157.
- Mygal, V. P., & Mygal, G. V. (2020b). Cognitive and ergonomics aspects human interactions with a computer. Radioelectronic and computer systems, #1(93), 90-102. https://doi.org/10.32620/reks.2020.1.09.
- Mygal, V. P., & Mygal, G. V. (2020c). Convergent Approach to Identification of Transient States of a Dynamic System. Journal of Nano-Electron. Phys., 12(6). https://doi.org/10.21272/jnep.12(6).06018.
- Mygal, V., Klymenko, I., & Mygal, G. (2020d). 3D-Modeling of the Dynamics of Real Processes of Different Nature. In Integrated Computer Technologies in Mechanical Engineering. Lecture Notes in Networks and Systems. Springer, Cham., 188. https://doi.org/10.1007/978-3-030-66717-7_54.
- Mygal, V. P., & Mygal, G. V. (2020e). The dynamic systems viability in complex conditions – cognitive aspects. In Proc. 11th International IEEE Conference Dependable Systems, Services and Technologies DESSERT'2020, 224-229. DOI: 10.1109/DESSERT50317.2020.9125063.
- Mygal, V., Mygal, G., Chukhray, A., & Havrylenko, O. (2020f). Application of space-time patterns in tutoring. In 16th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Kharkiv, 1, 430-437. DOI: http://ceur-ws.org/Vol-2740/20200430.pdf.
- Mygal, V., & Mygal, G. (2021a). Topological 3D model of the functioning of a dynamic system - cognitive estimation of complexity. Journal of Nano- and Electronic Physics, 13(4). https://doi.org/10.21272/jnep.13(4).04023.

- Mygal, V., Mygal, G., & Illiashenko, O. (2021b). Intelligent Decision Support - Cognitive Aspects. Digital Transformation, Cyber Security and Resilience of Modern Societies. Cham: Springer, 84, 395-411. https://doi.org/10.1007/978-3-030-65722-2_25.
- Mygal, V. P., Mygal, G. V., & Mygal, S. P. (2021c). Transdisciplinary convergent approach – human factor. Radioelectronic and Computer Systems, Modelling and digitalization, 4(100), 7-21. https://doi.org/10.32620/reks.2021.4.01.
- Mygal, V., Mygal, G., & Mygal, S. (2022a). Cognitive Space for Online and Offline Learning: A Convergent Approach. The Educational Review, USA, 6(4), 109-123. https://doi.org/10.26855/er.2022.04.001.
- Mygal, V. P., & Mygal, G. V. (2022b). Heuristic Modeling of NBIT Capabilities: Cognitive Aspects. Journal of Nano-Electron. Phys., 14(4), 04007(5pp). https://doi.org/10.21272/jnep.14(4).04007.
- Mygal, V. P., Mygal, S. P., & Mygal, G. V. (2023). Ergo-design of cognitive space – a transdisciplinary approach. In 1st International Scientific and Practical Conference of the Tavri National University to the 160th anniversary of the birth of V. I. Vernadskyi: materials of the International Scientific and Practical Conference, March 16–17, 2023, Kyiv. Part 1.
- Myhal, S., & Kazantseva, T. (2014). Aesthetic tendencies in the architectural and land-scape design driven by natural shapes. Czasopismo naukowe: space and przestrzen I forma [Scientific journal: space and form], 22/1, 92-104.
- Nay, Dzh. (1967). Fizicheskie svoystva kristallov i ih opisanie pri pomoschi tenzorov i matrits [Physical properties of crystals and their description using tensors and matrices], M. Mir, s.385.
- Parasuraman, R., & Mehta, R. (2013). Neuroergonomics: a review of applications to physical and cognitive work. Front Hum Neurosci, 7, 889. https://doi.org/10.3389/fnhum.2013.00889.
- Patriarca, R., Falegnami, A., Costantino, F., Di Gravio, G., De Nicola, A., & Villani, M. L. (2021). An integrated conceptual framework for the analysis of cyber-socio-technical systems. Safety Science, 136, 105142. https://doi.org/10.1016/j.ssci.2020.105142.
- Passino, K. M. (2005). Biomimicry for Optimization, Control, and Automation Springer-Verlag London. https://doi.org/10.1007/b138169.
- Prigogine, I. (1993). Chaotic Dynamics and Transport in Fluids and Plasmas: Research Trends in Physics Series. New York: American Institute of Physics.
- Protasenko, O., & Mygal, G. (2021a). Human Factors: The Problem of Man-machine Interaction in the Digitalization Conditions. Scientific journal of Polonia university. Periodyk naukowy akademii polonijnej (PNAP) [Scientific journal of Polonia University. Scientific periodical of the Polonia Academy], https://doi.org/10.23856/4825.
- Protasenko, O. & Mygal, G. (2021b). Human Factors: The Problem of Man-machine Interaction in the Digitalization Conditions. Scientific journal of Polonia University. Periodyk naukowy akademii polonijnej (PNAP) [Scientific journal of Polonia University. Scientific periodical of the Polonia Academy],48(5), 198-210. https://doi.org/10.23856/4825.
- Poincaré, A. (1990). On Science. M.: Nauka, [Science]. 736 p.
- Roco, M. & Bainbridge, W. (2020). Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science
- Sviting, B. (2016). Dizayn-issledovaniya kak raznovidnost kiberneticheskoy praktiki vtorogo poryadka [Design research as a kind of second-order cybernetic practice] Osnovyi konstruktivizma [Foundations of Constructivism], 11(3), 572-

579.

- Venda, V. F., & Venda, Y. V. (1995). Dynamics in Ergonomics, Psychology, and Decisions: Introduction to Ergodynamics. Norwood, NJ: Ablex.
- Wikipedia. https://en.wikipedia.org/
- Zagoruiko, J.A., Komar, V.K., & Migal, V.P. (1995). Lazer radiation power and modulator bused on zinc selenide single crystal. Proceedings SPIE, 2257, 228-229.